Annex 2

Feasibility Study

Enhancing Early Warning Systems to build greater resilience to hydro-meteorological hazards in Timor-Leste

FEASIBILITY STUDY

(Source: Wikimedia Commons)

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1 – INTRODUCTION

This Feasibility Study supports the Funding Proposal for "Enhancing Early Warning Systems to build greater resilience to hydro-meteorological hazards in Timor-Leste" Project prepared by the United Nations Environment Programme (UNEP) and submitted to the Green Climate Fund (GCF) at the request of the Nationally Designated Authority (NDA) of the Government of Timor-Leste.

The transformative goal of the Project is to enhance livelihoods and increase resilience to climate change and climate-related hazards of sectors – including health, agriculture, disaster risk reduction and environmental management – and communities in Timor-Leste.

Timor-Leste is a Least Developed Country (LDC), a Small Island Developing State (SIDS) and a post-conflict country whose infrastructure and governmental systems have been devastated by a 25-year war of independence between 1975 and 1999, during which about one-third of the population was killed. Most of Timor-Leste's essential infrastructure was destroyed in the last months of the war and uncontrolled logging left previously forested areas with reduced biodiversity and vulnerable to landslides.

It is ranked 131 out of 189 countries on the Human Development Index (HDI)[1] and as one of the world's lowest in gender equality measures.[2] Over 70% of its population is classified as living in or vulnerable to multidimensional poverty, which considers deprivation based on health, education and standard of living.[3] Half of Timor-Leste's children suffer from stunting caused by malnutrition, and most women and girls are anaemic.[4]

Climate change presents serious challenges to Timor-Leste's development, including increased climate-related risks to lives, livelihoods, biodiversity, food security, water supply and economic growth. The country is increasingly under threat from climate change impacts common to tropical SIDS – rising mean temperatures, warming and rising seas, ocean acidification[5] and deoxygenation, less predictable and more extreme rainfall, tropical cyclones, flooding, landslides and prolonged droughts. Climate variability and change has direct impacts on the health and well-being of Timor-Leste's population – for example, deaths from extreme weather events, wildfires and emerging infectious diseases[6] – with disproportionate impacts on women and girls.[7] Health and well-being are further affected by climate-related ecosystems degradation and associated biodiversity loss.[8] In 2019, the World Risk Index identified Timor-Leste as the 15th most at risk country in the world to natural disasters, as result of its location, geography and very limited capacity to prepare for and recover from climate impacts.[9]

Air pollution poses additional health risks. The annual mean concentration of PM2.5 is 19 µg/m^3, which exceeds the "safe" maximum of 10 µg/m^3 recommend by the World Health Organization.[10]

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[1] UNDP, 2019. Human Development Report 2019

[2] UNDP, 2019. Briefing note for countries on the 2019 Human Development Report – Timor-Leste – Based on the Gender Development Index (GDI)

[3] UNDP, 2019. Human Development Report 2019 – Based on the Multidimensional Poverty Index, 45.8% of the population are classified as multidimensionally poor and an additional 26.1% are vulnerable to multidimensional poverty.

[4] https://insight.wfp.org/mothers-on-the-front-line-of-fighting-malnutrition-in-timor-leste-2e0c291a4a31

[5] Matear, R.J and Lenton, A. Biogeosciences, 2018. Carbon-climate feedbacks accelerate ocean acidification. "For the RCP4.5 scenario, by 2100 the carbon-climate feedbacks nearly double the area of surface water undersaturated with respect to aragonite and reduce by 50% the surface water suitable for coral reefs."

[6] McMichael A.J. *et al.*, 2006. The Lancet. Climate change and human health: present and future risks

[7] Carbon Brief, 2020. Mapped: How climate change disproportionately affects women's health. Available at: https://www.carbonbrief.org/mapped-how-climate-change-disproportionately-affects-womens-health

[8] Peel, G.T. *et al.*, 2017. Science. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being

[9] Bündnis Entwicklung Hilft, 2019. World Risk Report 2019

[10] IAMAT, 2021. Timor-Leste General Health Risks: Air Pollution

About 70% of the Timorese (880,000 people) live in rural areas[11] and the agricultural sector provides subsistence to an estimated four-fifths of the country's total population.[12] Coastal populations are affected by storm surges, river flooding, saltwater intrusion into agricultural land and drought. Villages at higher elevations are affected by changes to the intensity and timing of rainfall, landslides precipitated by heavy rain on over-cleared, deforested slopes, and increasing drought. Climate-related hazards—particularly drought, flooding and landslides—are affecting Timor-Leste's development by disrupting transport and services, destroying public and private infrastructure, degrading ecosystems and exacerbating already severe food insecurity.[13] The 2015/16 El Niño event caused one of the most severe droughts recorded in Timor-Leste, putting crops and animals under water stress and leading to tens of thousands of farmers losing their crops and livestock. Maize production fell by 40% and rice by 57%. It is estimated that 63,000 of 122,000 households affected by the 2015/16 El Niño drought suffered severe food insecurity.

Since independence in 2002, the social and economic policies of Timor-Leste have focused on alleviating poverty, consolidating security and stability, and providing an institutional foundation to build the nation. This process of peace building and state building has been necessary to address the immediate needs of the country. However, climate change presents serious environmental and political challenges for Timor-Leste. The Government of Timor-Leste acknowledges that "sustainable development and the imperative to consider the needs of future generations is particularly relevant to the climate change threat as it is the Government's responsibility to ensure that when we make decisions today, we are taking into consideration the impact of those decisions on future generations."[14]

Timor-Leste is rebuilding its public infrastructure—including roads, ports and airports, water and sanitation systems, power and communication grids, and government facilities—and institutional frameworks. It is vital that these investments are informed by high quality climate information and science-based advice on planning adaptation to longer term climate change impacts.

As the effects of climate change manifest and the frequency and intensity of climate-related hazards increases, Timor-Leste needs accurate, timely and actionable information and early warnings on local weather, climate and ocean conditions and related risks to human and environmental health. Investments in infrastructure and institutional frameworks must be informed by high quality climate information and science-based advice on planning adaptation to longer term climate impacts. Disaster risk and public health management must integrate impact-based forecasts and warnings and be tailored to location- and sector-specific needs. Without a transformation at scale of Timor-Leste's climate information services, early warning systems and disaster risk reduction mechanisms, climate change will further exacerbate existing vulnerabilities and hamper the country's recovery and future development.

The vulnerability of Timor-Leste is evident from the devastating impacts of the recent tropical cyclone, heavy rains, flooding and landslides that occurred between 29th March and April 2021, and which

[11] World Bank, 2018. Rural Population – Timor-Leste. Estimates based on the United Nations Population Division's World Urbanization Prospects: 2018 Revision

[12] Democratic Republic of Timor-Leste, 2019. Timor-Leste Agricultural Census 2019

[13] Infant and maternal mortality rates are very high by global standards and more than half the children under 5 are stunted by malnutrition and under-nutrition: https://www.usaid.gov/sites/default/files/documents/1864/Timor-Leste -Nutrition-Profile-Mar2018-508.pdf

[14] Democratic Republic of Timor-Leste, 2019. GCF Country Programme. Available from: https://www.greenclimate.fund/document/timor-leste-country-programme

affected over 30,300 households and caused 48 fatalities.[15] In addition to causing considerable human and economic loss, the flooding and landslides significantly undermined COVID-19 response efforts as Timor-Leste struggled to contain the virus' second wave. Heavy flooding in the National Laboratory and medical storage facility led to the loss of vital medical supplies and a COVID-19 isolation facility had to be temporarily evacuated. Moreover, displaced people sheltered in improvised evacuation centres and in the homes of relatives, which likely exacerbated the spread of the virus. [16,17] The compounding impacts of weather hazard-induced disasters and the COVID-19 pandemic provide demonstrable evidence of the potential for a repeat of the "unprecedented double disaster" warned of by the UNDRR Asia Pacific COVID-19 Brief in April 2020, following the devastation of large areas of Vanuatu by Tropical Cyclone Harold.[18] In addition, the Brief emphasises "the need for countries to focus on a multi-hazard integrated disaster risk management approach that includes high levels of disaster preparedness and accelerated disaster risk reduction across sectors".[19] The dual challenge of climate change and a global pandemic highlights the urgency required to prioritise disaster risk management efforts and enhance multi-hazard early warning systems. The Global Ocean Observing System (GOOS) asserts that "[d]espite its significant impacts on the ocean observing system, the COVID-19 crisis can also be an opportunity for us to look at how to build greater resilience into the system." [20] The World Bank emphasises strengthening health preparedness as an important precondition for a robust and sustained recovery.[21] Enhancing climate observations in concurrence with health and disaster preparedness capacity building will be a major focus of the Project.

Timor-Leste starts from a low institutional base and lacks climate observation infrastructure and human resources required to generate robust climate data and information and impact-based multi-hazard early warning services (MHEWS) covering the whole country. The main barriers to delivering effective climate and ocean information services and MHEWS include: i) lack of legislative, regulatory and policy frameworks for climate services and disaster risk management; ii) inadequate observation networks and limited sector-specific climate information; iii) limited communication and use of climate hazard and risk information; and iv) limited capacity and funding to prepare for and manage climate risks.

Therefore, this Project will address the urgent need for integrated climate information services, covering oceans, and proactive disaster risk management approaches founded on impact-based forecasting and end-to-end MHEWS. This will be achieved through four inter-related components – the Project Results:

1. Strengthened delivery model and legislation for climate information and multi-hazard early warning services;
2. Strengthened observations, monitoring, analysis and forecasting of climate and its impacts;
3. Improved dissemination and communication of risk information and early warning;

[15] UN Resident Coordinator's Office (RCO) Timor-Leste, 2021. Timor-Leste: Floods. Situation Report No. 10 (As of 18 June 2021). Available at: https://timorleste.un.org/sites/default/files/2021-06/TL%20April%20Flood%20Response%20Situation%20Report%2010%20%2821%20June%2021%29.pdf

[16]

[17] UN News, 2021. 5 April 2021. UN steps up response, as thousands impacted by Timor-Leste floods. Available at: https://news.un.org/en/story/2021/04/1089012

[18] UNDRR, 2020. UNDRR Asia Pacific COVID-19 Brief. Combating the Dual Challenge of COVID-19 and Climate-Related Disasters

[19] UNDRR, 2020. UNDRR Asia Pacific COVID-19 Brief. Combating the Dual Challenge of COVID-19 and Climate-Related Disasters

[20] Global Ocean Observing System, 2020. Briefing Note: Covid-19's impact on the ocean observing system and our ability to forecast weather and predict climate change

[21] World Bank, 2020. Timor-Leste Economic Report: Towards a Sustained Recovery

4. Enhanced climate risk management capacity.

The Project will enable a paradigm shift to evidence-based planning and early action for climate resilience through accurate, timely and actionable climate information, impact-based forecasting, people-centred multi-hazard early warning systems (MHEWS) and Forecast-based Financing (FbF). The Project will build the capacity of Timor-Leste to provide the essential high-resolution data and climate information needed to underpin science-based transformational planning and programming, de-risk investments, and facilitate long-term resilience to climate change, protecting both human lives as well as the diverse ecosystems that sustain them. The interventions are designed to demonstrate the value of climate data at all levels of Timor-Leste's economy – from government policies to the decision-making of subsistence farmers – and pay particular attention to establishing climate services for health. The Project will also ensure adequate funding for early action through Forecast-based Financing and Early Warning Early Action (EWEA) for agriculture and food security. This will facilitate that climate-resilient early actions from national to community level are identified and funded before a climate shock and become an integral component of disaster risk management and disaster risk reduction in Timor-Leste.

The Project Results will strengthen implementation of the WMO Global Framework for Climate Services (GFCS) in Timor-Leste and are designed to align with the four elements of the checklist for Multi-Hazard Early Warning Systems (MHEWS) prepared by the partners of the International Network for MHEWS: i) Disaster Risk Knowledge; ii) Detection, monitoring, analysis and forecasting of hazards and possible consequences; iii) Warning dissemination and communication; iv) Preparedness and response capabilities. Furthermore, the Project will directly contribute to the attainment of selected targets and indicators of the Paris Agreement, Sustainable Development Goal (SDG) 13 on Climate Action, SDG 3 on Good Health and Well-Being and the Sendai Framework for Disaster Risk Reduction.

The Project has been developed at the request of and with the support of the Nationally Designated Authority for Interaction with the GCF (the NDA). All proposed interventions are aligned with and will contribute to the achievement of goals identified in major national strategic and policy documents, including the Nationally Determined Contributions for adaptation and the National Adaptation Program of Action. Continued country ownership will be ensured through strong stakeholder and community engagement.

At the request of the NDA of Timor-Leste, the UN Environment Programme (UNEP) will serve as the Accredited Entity (AE) for the Project. The AE will work with the Secretary of State for the Environment (SSE) as the national Executing Entity (EE) alongside a range of technical partners and national service providers, including Timor-Leste Meteorological Service (National Directorate for Meteorology and Geophysics – DNMG), the National Disaster Management Directorate (NDMD), the Ministry of Agriculture and Fisheries (MAF), Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES), the Food and Agriculture Organization (FAO), International Federation and Red Cross and Red Crescent Societies (IFRC) – including its Climate Centre and national society (Cruz Vermelha de Timor-Leste – CVTL), Indonesian Meteorological, Climatological and Geophysical Agency (Badan Meteorologi, Klimatologi dan Geofisika – BMKG), International Centre for Theoretical Physics (ICTP) and the World Meteorological Organization (WMO).

1.1 – GEOGRAPHY

Timor-Leste occupies the eastern half of the island of Timor and is situated at the eastern end of the Lesser Sunda Islands of the Indonesian archipelago, about 500 km northwest of Australia. It lies between latitudes 8'15 and 10'30 south, and longitudes 124'50 and 127'30 east.

"Formed by continental uplift along a major fault line (and in the case of Atauro, submarine volcanic activity), Timor-Leste is rugged with a mountainous backbone rising to over 2,000 m. The highest peaks have marine fossils and the forested ranges are riddled with caves. Almost half of Timor-Leste's 15,000 km^2 land area has a slope of 40 degrees or more making it scenically beautiful but extremely difficult for road construction and cultivation. … The areas west of Baucau and around Lospalos and Maliana are rolling highland plains important for agriculture. On the south side of Timor-Leste, the coastal flats are 20–30 km wide, while to the north they are much narrower with many stretches where the mountains fall directly into the sea. Timor-Leste is surrounded by fringing reefs."[22]

Historical rainfall and temperature records show Timor-Leste has three different climatic zones:

- North coast region, characterised by average mean temperature of more than 24 °C, annual rainfall amount less than 1500 mm, with a dry season lasting for around five months;
- Mountainous region, characterized by average mean temperature less than 24 °C, annual rainfall amount more than 1500 mm and dry season lasting for four months; and
- South coast region, characterized by average mean temperature more than 24 °C, annual rainfall amount of about 2500 mm, and dry season lasting for only three months.[23]

The geology of Timor-Leste is mainly limestone and coral. Soils are shallow and rocky, alkaline, not particularly fertile, do not store water well, and are easily eroded. Very high temperatures cause soil nutrients to decompose faster than they accumulate, which further exacerbates the soils' erodibility. The steep terrain is dissected by short, fast-running rivers, which results in very high sediment loads in the rivers, and extensive, thick alluvial fans and flood plains along river courses and across the coastal plains. Micro-climates vary from dry, barren hill sides to thickly forested peaks and relatively fertile coastal lowlands—climate forecasts must use high-resolution localised data to be relevant to all inhabited areas of the country.

The percentage of Timor-Leste's land area suitable for farming is variously estimated: according to the World Bank collection of development indicators, compiled from officially recognized sources, arable land makes up 25.55% of the total area.[24] According to FAO,[25] forest remains the largest land use/cover category in the country, occupying about 50% of the total land area. The second largest is grassland and shrubs occupying about 27% of the total land area. The remaining are bare land, rice fields and dry farms covering approximately 3.3%, 2.8% and 1.5% of total land respectively, while settlement covers only 0.2% of the total land area.

"Rural populations of Timor-Leste are highly exposed to a number of hazards including flash floods, landslides, soil erosion, coastal flooding and drought, due to unfavorable terrain, socio-economic factors and intensification of these climate-induced hazards over time. In addition, anthropogenic factors such as poor, non-climate-resilient design and application of infrastructure construction standards and the limited investment in operation and maintenance are exacerbating exposure and resulting in the failure of small-scale rural infrastructure, which is essential to the development of rural communities. Impacts include isolation of communities when roads and bridges are damaged by localized extreme events, contamination of unprotected water sources, reduction in yield of water supply sources due to droughts, flooding of communities due to inadequate or failing flood defenses. In addition, the institutional and financial capacity of local administrations and communities to adapt

[22] https://www.timorleste.tl/east-timor/about/geography-climate/
[23] Kirono, Dewi. (2010). Climate change in Timor-Leste – a brief overview on future climate projections.
[24] https://tradingeconomics.com/timor-leste/agricultural-land-percent-of-land-area-wb-data.html
[25] The Food and Agriculture Organization of United Nations' Global Forest Resources Assessment (2005 & 2010) and the State of the World's Forests (2009, 2007, 2005, 2003, 2001)

to the situation is weak. This includes the ability of municipality planning officials, engineers and decision makers to identify areas that are critically vulnerable to climate hazards, to draw the links between ecosystems management and infrastructure development, and to identify, appraise, prioritize, design, cost and 'budget in' greater resilience measures."[26]

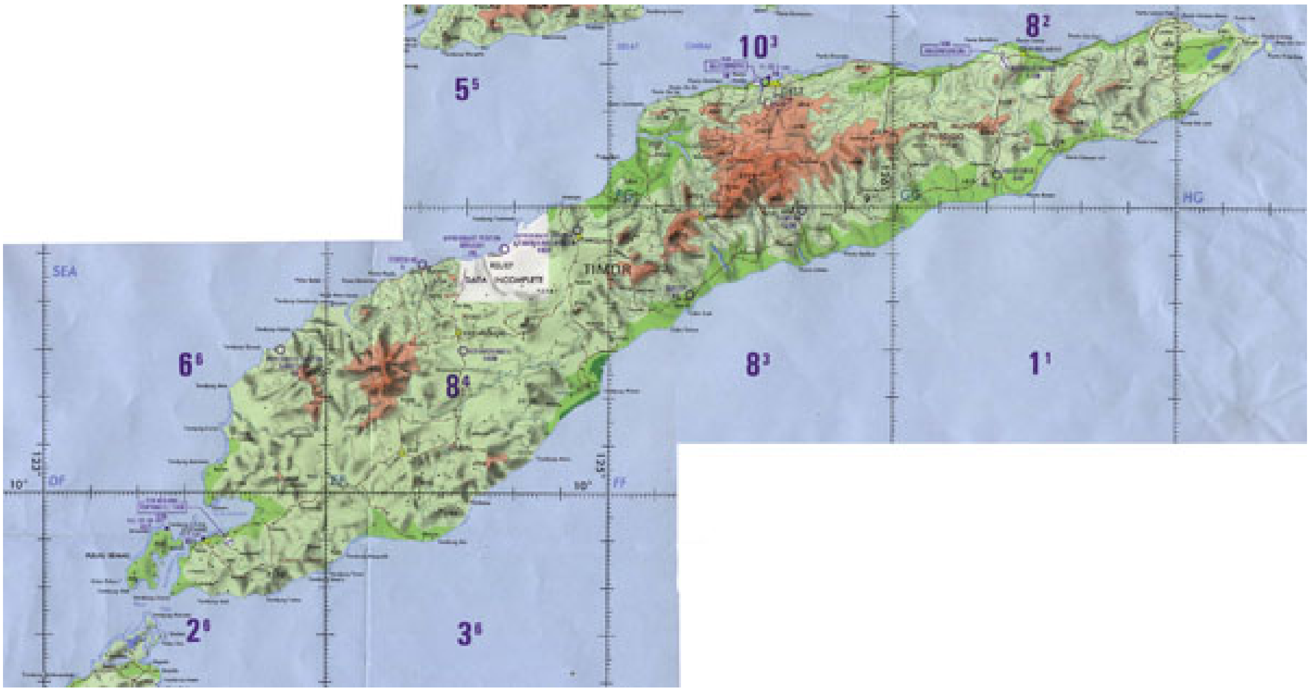

Figure 1: Topographical map of Timor-Leste[27]

1.2 – HISTORICAL CONTEXT

The island of Timor is divided into two parts: the West is part of the Republic of Indonesia; and the East had been a Portuguese territory since the 16th century, until its independence in 2002. The historical context of Timor-Leste, as detailed in the CIA World Factbook, is provided below:

"The Portuguese began to trade with the island of Timor in the early 16th century and colonized it in mid-century. Skirmishing with the Dutch in the region eventually resulted in an 1859 treaty in which Portugal ceded the western portion of the island. Imperial Japan occupied Portuguese Timor from 1942 to 1945, but Portugal resumed colonial authority after the Japanese defeat in World War II. East Timor declared itself independent from Portugal on 28 November 1975 and was invaded and occupied by Indonesian forces nine days later. It was incorporated into Indonesia in July 1976 as the province of Timor Timur (East Timor). An unsuccessful campaign of pacification followed over the next two decades, during which an estimated 100,000 to 250,000 people died. In an August 1999 UN-supervised popular referendum, an overwhelming majority of the people of Timor-Leste voted for independence from Indonesia. However, in the next three weeks, anti-independence Timorese militias - organized and supported by the Indonesian military - commenced a large-scale, scorched-earth campaign of retribution. The militias killed approximately 1,400 Timorese and forced 300,000 people into western Timor as refugees. Most of the country's infrastructure, including homes, irrigation systems, water supply systems, and schools, and nearly all of the country's electrical grid were destroyed. On 20

[26] UNDP, Safeguarding communities and their physical assets from climate induced disasters in Timor Leste - Feasibility Study
[27] www.vidiani.com/large-detailed-topographical-map-of-east-timor/

September 1999, Australian-led peacekeeping troops deployed to the country and brought the violence to an end. On 20 May 2002, Timor-Leste was internationally recognized as an independent state.

"In 2006, internal tensions threatened the new nation's security when a military strike led to violence and a breakdown of law and order. At Dili's request, an Australian-led International Stabilization Force (ISF) deployed to Timor-Leste, and the UN Security Council established the UN Integrated Mission in Timor-Leste (UNMIT), which included an authorized police presence of over 1,600 personnel. The ISF and UNMIT restored stability, allowing for presidential and parliamentary elections in 2007 in a largely peaceful atmosphere. In February 2008, a rebel group staged an unsuccessful attack against the president and prime minister. The ringleader was killed in the attack, and most of the rebels surrendered in April 2008. Since the attack, the government has enjoyed one of its longest periods of post-independence stability, including successful 2012 elections for both the parliament and president and a successful transition of power in February 2015. In late 2012, the UN Security Council ended its peacekeeping mission in Timor-Leste and both the ISF and UNMIT departed the country. Early parliamentary elections in the spring of 2017 finally produced a majority government after months of impasse. Currently, the government is a coalition of three parties and the president is a member of the opposition party. In 2018 and 2019, this configuration stymied nominations for key ministerial positions and slowed progress on certain policy issues."[28]

Legacies of colonialization and occupation

Timor-Leste's National Adaptation Plan (NAP) provides the following context on the legacies of colonialization and occupation in Timor-Leste:

"Timor-Leste gained its independence from Indonesia in 2002. During the quarter-century conflict for independence from Indonesia, there were at least 102,800 conflict related deaths.[29] During this period crop production fell by up to two-thirds as crops were burnt to starve out guerrillas.[30] The occupation ended violently, and after the referendum as the Indonesian forces retreated from Timor-Leste, they executed operation 'Clean Sweep' during which they reduced buildings and infrastructure to rubble and executed hundreds, if not thousands of Timorese.[31] During this time more than three-quarters of the population was displaced, and 70% of the infrastructure was destroyed. In addition, throughout the country educational infrastructure was targeted, and nearly 90% of schools nationwide, including the Universitas Timor-Timur,[32] the only higher education institution at the time, was damaged or destroyed.[33] While overall Timor-Leste has made tremendous progress in rebuilding the country, the inherent fragility that exists after decades of struggle and national trauma has given rise to some episodes of instability, including a period of violence in 2006 when deep-seated tensions emerged, and again in February of 2008 when the President and Prime Minister of Timor-Leste were nearly assassinated in a coup attempt."[34]

The NAP incorporates perspectives and insights concerning reducing the risks of climate change-driven social unrest and insecurity, and one of its key guiding principles is integrating climate change adaptation considerations into the nation-building and recovery process. Consideration of social conflict issues is very much aligned with one of the guiding principles applied for the National Climate

[28] https://www.cia.gov/library/publications/the-world-factbook/geos/tt.html
[29] Mercer, J. *et al.,* 2014. Nation-Building Policies in Timor-Leste: Disaster Risk Reduction, including Climate Change Adaptation
[30] Molyneux, N. *et al,* 2012. Climate change and population growth in Timor-Leste: Implications for food security
[31] Mercer, J. *et al.,* 2014. Nation-Building Policies in Timor-Leste: Disaster Risk Reduction, including Climate Change Adaptation
[32] After independence, the name of the university was changed to Universidade Nacional Timo Lorosa'e
[33] Timor-Leste, 2014. Timor-Leste's Initial National Communication to the UNFCCC
[34] Mercer, J. *et al.,* 2014. Nation-Building Policies in Timor-Leste: Disaster Risk Reduction, including Climate Change Adaptation

Change Policy of Timor-Leste which highlights that planning and implementation intervention of the Policy will embrace conflict sensitivity and promote long-term peace and prosperity.

1.3 – POLITICAL CONTEXT

Timor-Leste is the second youngest nation in the world and the newest country in Asia. Although notable progress has been made in addressing key areas – including poverty, unemployment, environmental degradation, peacebuilding and state building[35] – Timor-Leste remains fragile as it contends with legacies of past conflict. "This fragility is evidenced by weak institutional capacity and governance, poor social cohesion, lagging human capital indicators, corruption and inadequate infrastructure. Timor-Leste still struggles with insufficient technical and managerial capacity in the public service and the wider economy, policy ambiguity and inconsistency, weak public finance management and sectoral regulation, and lack of clear laws on the ownership and use of economic assets, such as land and financial credit. Tensions also arise from geographical imbalances and socio-economic grievances. However, significant progress has been made with regards to consolidating peace, effectively managing elections and transition of political power, strengthening of rule of law institutions, and rebuilding infrastructure and public services."[36]

Timor-Leste operates a multi-party democracy with a unitary semi-presidential system of government. The President is the Head of State, while the Prime Minister is the Head of Government. Timor-Leste has successfully organised four multi-party elections since independence, which were all "peaceful, free and fair" and led to smooth transitions in government. Two major political parties are dominant however, a total of eight parties have been represented in government coalitions.[37]

In May 2018, three political parties formed a majority coalition government – the current VIII Constitutional Government. The Government successfully obtained parliamentary approval of the budgets for 2018 and 2019, which the previous minority government had failed to achieve during the political stalemate of 2017. However, key ministerial positions – including those in finance, health and strategic investments – have remained vacant because the President has refused to swear-in the nominees on the grounds of corruption and the ruling coalition has refused to offer alternatives.[38]

In February 2020, the Prime Minister of Timor-Leste sent a letter of resignation to the President after the governing coalition repeatedly failed to pass its budget for 2020.[39] However, the Prime Minister has since withdrawn his resignation in order to oversee the country's efforts to deal with the COVID-19 pandemic.[40]

1.4 – ECONOMIC CONTEXT

Despite being an oil rich country, Timor-Leste is one of the poorest countries in the Asia-Pacific region. Its economic performance since gaining independence from Indonesia in 2002 has been fragile, and the investment of aid funds and oil revenues has been slow. The country is set to benefit from the commercial exploitation of its petroleum and natural gas reserves and in June 2005, the National Parliament of Timor-Leste unanimously approved the Petroleum Fund law following public

[35] Timor-Leste, 2016. Intended Nationally Determined Contributions (INDC)
[36] World Bank, 2020. Country Partnership Framework for the Democratic Republic of Timor-Leste for the period FY2020-FY2024
[37] World Bank, 2020. Country Partnership Framework for the Democratic Republic of Timor-Leste for the period FY2020-FY2024
[38] World Bank, 2020. Country Partnership Framework for the Democratic Republic of Timor-Leste for the period FY2020-FY2024
[39] Reported in the Guardian, 25 February 2020. Available at: https://www.theguardian.com/world/2020/feb/25/timor-leste-prime-minister-offers-resignation-after-political-coalition-collapses
[40] Reported in The Straits Times, 8 April 2020. Available at: https://www.straitstimes.com/asia/se-asia/timor-leste-pm-withdraws-resignation-to-tackle-coronavirus

consultation.[41] This law was aimed at effectively managing and investing oil revenue in the country's development after exploitation of these resources ends.

Petroleum revenues account for around 33% of GDP and finance 90% of the country's budget. As a result of exploitation of petroleum resources and creation of the Petroleum Fund, Timor-Leste has accumulated financial assets worth around 17.5 billion USD, which is equivalent to over 10 times the size of non-oil GDP or approximately 13,800 USD per capita.[42] "The accumulated assets in the Petroleum Fund have cushioned the macroeconomic impact of volatile oil and gas prices. Oil rents have also been central to maintaining the post-independence political settlement and ensuring peace and stability. The absorption of oil rents into the economy has occurred mainly through considerable increases in public spending, particularly on infrastructure, public sector wages, cash transfers (including pensions for resistance veterans). The public sector-driven expansion of output has been supported by significant growth in private consumption, fuelled by wages and transfers. Thus, as with natural resource-dependent economies, construction and services have driven growth at the expense of tradeable sectors."[43]

The development of offshore oil and gas resources has greatly supplemented government revenues but has done little to create jobs due to the lack of production facilities in Timor-Leste, with gas currently being piped to Australia for processing. Ratification of the Maritime Boundary Treaty between Australia and Timor-Leste presents an opportunity to develop the Greater Sunrise oil and gas field, which are estimated to hold reserves worth 40 – 60 billion USD. However, there is significant uncertainty about the financing modality to be used for this development.[44]

"Annual government budget expenditures increased markedly between 2009 and 2012 but dropped significantly through 2016. Historically, the government failed to spend as much as its budget allowed. The government has focused significant resources on basic infrastructure, including electricity and roads, but limited experience in procurement and infrastructure building has hampered these projects. The underlying economic policy challenge the country faces remains how best to use oil-and-gas wealth to lift the non-oil economy onto a higher growth path and to reduce poverty."[45]

"The recent political stalemate had a strong adverse effect on the economy. The political party that won the most seats in the parliamentary elections held in July 2017 was sworn-in as a minority government, thus forming the VII Constitutional Government. The then opposition-coalition controlled the majority of the parliamentary seats, hence, the ruling government could not secure parliamentary approval for its proposed program. This situation resulted in a year-long political stalemate which led to the fall of the VII Constitutional Government and a call by the President for early parliamentary elections. The political stalemate, and the political fractures that underpinned it, created an atmosphere of uncertainty. These events limited government spending and contributed to two consecutive years of economic contractions in 2017 and 2018."[46]

"Deficits in rural infrastructure are being addressed, albeit at a slow pace, not in keeping with the desire of Timorese people to be economically stable and self-sufficient. Furthermore, in addressing the infrastructure deficit, the Government is not systematically taking account of climate risks and therefore not building climate resilient infrastructure that will be sustainable in the long-term. A lack of capacity—financial and technical at both central government and local government level—is part

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[41] IMF, 2009. IMF Country Report No. 09/220. Democratic Republic of Timor-Leste: Selected Issues
[42] World Bank, 2020. Country Partnership Framework for the Democratic Republic of Timor-Leste for the period FY2020-FY2024
[43] World Bank, op cit.
[44] World Bank, 2019. Timor-Leste Economic Report October 2019
[45] https://www.cia.gov/library/publications/the-world-factbook/geos/tt.html
[46] World Bank, op cit.

of the reason. Lack of access to climate risk information is another, and lack of government funding for climate resilient rural infrastructure is also a factor. Coupled with this, there is a need for livelihood generation in rural areas which are characterised by limited participation of income generating economic activities, and environmentally risky land use activities such as slash and burn farming, deforestation for access to firewood, farming on inappropriate slopes and over-exploiting soils with poor fertility."[47]

The World Bank's assessment of Timor-Leste's October 2019 budget report found that despite the late approval of the 2019 budget, public expenditure in the first half of 2019 was 16% higher than in the same period in 2018. Private investment was also expected to benefit from greater political and economic stability and GDP was expected to grow by 4.1 percent in 2019. "GDP growth is expected to accelerate to 4.9 percent by 2021, driven by larger public spending and household consumption. Medium-term growth prospects are hampered by a weak private sector. Developing productive capabilities will require continued political and macroeconomic stability, strong investments in high-return connective infrastructure and relevant skills, as well as policy and regulatory reforms that improve the business environment.[48] This assessment was made before the emergence of the COVID-19 virus.

1.5 – SOCIO-ECONOMIC INDICATORS

Timor-Leste has a population of around 1.3 million, with almost 70% of the population living in rural areas.[49] The growth rate of the population is estimated to be 2.27%,[50] which is high by world standards and applies significant pressure on the provision of food, water, sanitation, and public services. Furthermore, there is a significant geographical divide, with rural women and men having lower education, less employment, higher poverty levels and worse living standards.[51]

The Human Development Index (HDI) value for Timor-Leste is 0.626, which ranks it at 131 out of 189 countries. This is lower than the average HDI for the East Asia and Pacific region (0.741) and for SIDS (0.723). The inequality-adjusted HDI adjusts the HDI value according to inequalities relating to health, education and income, with the 'loss' in human development due to inequality expressed as a percentage. In 2018, the overall loss for Timor-Leste was calculated at 28.0%, which is much greater than the global average loss of 20.2%.[52]

Between 1990 and 2018, Timor-Leste has made considerable progress in each of the HDI indicators: life expectancy at birth increased by 20.8 years; mean years of schooling increased by 1.8 years; and GNI per capita increased by around 85.0%. The overall HDI value of Timor-Leste increased from 0.505 to 0.626 between 2000 and 2018, which is an increase of 23.8%.[53]

Poverty

In 2018, GNI per capita was reported as 2,656 USD[54] and GDP was 2.581 billion USD, with annual growth rate at 2.8%.[55] Income poverty has fallen substantially since 2007, with the percentage of the population living below the national poverty line declining from 50.4% to 41.8% (in 2014). Measured

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[47] Safeguarding communities and their physical assets from climate induced disasters in Timor Leste, UNDP, 2018
[48] https://www.worldbank.org/en/country/timor-leste/publication/timor-leste-economic-report
[49] UN Department of Economic and Social Affairs: Population Division, 2018. World Urbanisation Prospects: The 2018 Revision
[50] CIA, 2020. The World Factbook. Timor-Leste. Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/print_tt.html
[51] Asian Development Bank, 2014. Timor-Lest Country Gender Assessment
[52] UNDP, 2019. Human Development Report 2019
[53] UNDP, 2019. Human Development Report 2019
[54] UN Department of Economic and Social Affairs, 2018. Economic Analysis – 2018 Triennial Review
[55] World Bank, 2018. Country Profile – Timor-Leste

by the internationally comparable poverty line of 1.90 USD per day, poverty declined from 47.2% to 30.3% between 2007 and 2014. However, poverty reduction in Timor-Leste has progressed with considerable geographical disparities. Around 80% of the poor are concentrated in rural areas, with the incidence of poverty at 47% in rural areas compared to 28% in cities. "Poverty has been a key driver of migration to cities and overseas, especially among the youth. These regional and urban-rural disparities in living conditions act as a source of social tension."[56]

The World Bank Country Partnership Framework for Timor-Leste (FY2020-FY2024) reported that: "There is strong correlation between poverty rates and access to basic services and amenities. As of 2014, about 90 percent of the population used dung, wood, or charcoal for their cooking fuels, which pose health dangers. While around 65 percent of non-poor households have access to improved sanitation facilities, nearly half of the poor have not. Similarly, even though access to electricity has doubled between 2007 and 2014, around 40 percent of poor households still live without access to electricity. Moreover, one-quarter of households still do not have access to safe drinking water. There is also significant inequality in access to education and health, and access is particularly lacking for poor households in rural areas. Households headed by those with a senior secondary level of education are considerably less likely to be poor, however more than 50 percent of household heads have no more than primary education. Development and income disparities between and within regions can worsen social risks where these overlap with uneven and poor quality of service delivery."[57]

The UNHDR's Multi-dimensional Poverty Index (MPI) identifies multiple overlapping deprivations suffered by individuals in three dimensions: health, education and standard of living. The MPI is calculated for 101 developing countries in the 2019 HDR, which provides definitions of deprivations in each indicator, as well as the methodology of the MPI in its Technical Note 5. The most recent survey data that were publicly available for Timor-Leste's MPI estimation refer to 2016. In Timor-Leste, 45.8 percent of the population (594,000 people) are multidimensionally poor while an additional 26.1 percent are classified as vulnerable to multidimensional poverty (338,000 people). The breadth of deprivation (intensity) in Timor-Leste, which is the average deprivation score experienced by people in multidimensional poverty, is 45.7 percent.[58]

Education

As identified in Timor-Leste's Second National Communication:[59]

"Timor-Leste is facing enormous challenges in secondary and higher education institutions. Following the referendum in 1999 there was widespread burning and destruction of property all over the country, and nearly 90% of the schools including Universitas Timor-Timur, which was the only higher education institution at the time, were damaged and destroyed. In 2015, there were 1,264 schools including basic education, general and technical schools registered as public and private, with total student and teacher numbers of 321,451 and 10,884 respectively.

Due to pressing demand from young people to enter university after the country separated from Indonesia, in 2000 the Universidade Naçional de Timor-Lorosa'e/National University of Timor-Leste (UNTL) was established. Since then, some other higher education institutions have been established mainly concentrated in the capital city of Dili including eleven private tertiary education institutions.

[56] World Bank, 2020. Country Partnership Framework for the Democratic Republic of Timor-Leste for the period FY2020-FY2024
[57] World Bank, op cit.
[58] hdr.undp.org/sites/all/themes/hdr_theme/country-notes/TLS.pdf
[59] Timor-Leste, 2020. Second National Communication under the UNFCCC

Although there has been rapid growth in the establishment of the higher education institutions and the number of student enrolments in the country, the quality of these institutions remains an issue. Inadequacy of facilities, lack of human resources, weaknesses in policies as well as the capacity to regulate and control these institutions are considered as obstacles to their development. At present, there is only one public university fully financed by the government – the UNTL. Within the UNTL, there is a National Centre for Scientific Research (CNIC) and through its collaboration with other research institutions both locally and internationally, it is expected that these research institutions will play a vital role in contributing to the development of climate change adaptation and mitigation actions for the country in the near future.[60]"

Employment

According to the Human Development Report 2019 (UNHDR)[61] Statistical Annex, Timor-Leste is 1.7 times below the average employment rate for developing countries and 1.9 times below the rate for the region. This trend is magnified when the gender disaggregate data is examined: the rate of employment among Timor-Leste's women is 2.5 times lower than the regional average while males are 1.6 times below the regional average. Working poor are 66.9% of the population, compared to the regional average of 23.8%. Youth unemployment is in line with the average for developing countries at 14.8%, but below the regional average of 18.6%, but this may mask the fact that a larger than average percentage of the potential Timor-Leste work force is comprised of the youth (population median age of 16.9 years). 50% of employment is in agriculture and 40% is in services.[62] The child dependency ratio—the ratio of people below working age (under 15) to the workforce—is 54.1% and the unemployment rate for young people is consequently very high.[63]

Gender inequality

The World Bank Country Partnership Framework for Timor-Leste (FY2020-FY2024) reported on the relationship between poverty and gender in the country as follows:

"Timor-Leste was ranked the lowest of all the countries in East Asia and Pacific Region in the 2017 Global Gender Gap Index. World-wide, it was ranked 128 out of 144 countries. Despite improvements in school enrolment, relatively lower risk of poverty among female headed households in recent years, and high political representation of women in the national parliament, gender disparities remain a significant issue. The society is still highly patriarchal. Customary laws and local leaders privilege male property rights, inheritance practices, and succession in traditional offices and local government positions. Women earn less than men for similar work and are more likely to work as unpaid family labour or in the informal sector. Women also tend to own less land and often have more difficulty accessing legal or other government services.

"These gender gaps have far-reaching social and economic implications. These are evident in constraints to employment and self-employment, access to information, productive inputs and resources, and in some health outcomes such as reproductive health, maternal mortality (195 maternal deaths per 100,000 live births)[64] and nutrition. Men still outnumber women at the tertiary education level, despite the achievement of gender parity in education and the superior performance of girls up to the secondary level. The gender-disaggregated poverty small area estimates reveal two

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[60] Timor-Leste, 2010. Timor-Leste Strategic Development Plan 2011 – 2030
[61] hdr.undp.org/sites/all/themes/hdr_theme/country-notes/TLS.pdf
[62] hdr.undp.org/sites/all/themes/hdr_theme/country-notes/TLS.pdf.
[63] https://countrymeters.info/en/Timor-Leste#population_forecast
[64] For comparison, maternal mortality in Japan is 5 /100,000 live births; Indonesia, 177/100,000 (https://www.cia.gov/library/publications/the-world-factbook/rankorder/2223rank.html)

major patterns. First, in poorer areas of Timor-Leste there is higher education-related female disadvantage and greater levels of abuse and domestic violence against women. Second, there is an inverse pattern between gender-related labour force gaps and poverty rates: the prevalence of a female labour force disadvantage is highest in the more economically developed areas.

"The incidence of gender-based violence (GBV) is rising in Timor-Leste. About 38 percent of ever-partnered women aged 15-49 years have been victims of either physical or sexual violence. Domestic Violence Law has recognized domestic violence as a public crime and encouraged reporting of cases. The formal justice system is beginning to pay more attention to the increasing number of reported domestic and sexual abuse cases, reflecting greater knowledge by community leaders and police officers. However, the access of women to legal remedies in cases of abuse and gender-based violence and counselling of victims is limited. The government-led National Action Plan against Gender-based Violence (2017) identifies responsibilities within government, indicators, budgets and specific actions to be undertaken in prevention, coordination, monitoring and evaluation, and provision of services to victims."[65]

The Gender Assessment and Action Plan (Annex 8) provides a more detailed analysis of gender context, issues and vulnerabilities in Timor-Leste, including those specific to climate change and access to climate services and early warning.

Malnutrition

Timor-Leste is highly vulnerable to economic shocks – in particular, food price shocks that exacerbate existing problems of malnutrition and stunting.[66] Timor-Leste has one of the highest rates of malnutrition in the world, with 46% of children under-five suffering from chronic malnutrition – affecting both physical and cognitive development.[67] Malnutrition is the single greatest contributor to premature death and disability in Timor-Leste. Lower workforce participation resulting from malnutrition-induced health and capacity limitations lead to losses of around 41 million USD annually in Timor-Leste, which is equivalent to the entire budget of the Ministry of Health. "The causes of maternal and child undernutrition span multiple sectors and thus require multi-sectoral solutions under a strong and coordinated national management system. These include childcare and feeding practices, women's reproductive health, paediatric and neonatal health care, dietary diversity, water, and sanitation, and early childhood education."[68] Low and unreliable agricultural productivity is a very significant factor in rural areas, exacerbated by poor prediction of seasonal variability and long-term climate change impacts.

2 – PROJECT BACKGROUND

This proposal is the outcome of a consultative process among the GCF, WMO and Timor-Leste, and more recently the United Nations Environment Programme (UNEP). At a GCF Regional Dialogue in August 2016 in Suva, Fiji, WMO began consultations with SIDS representatives on opportunities for partnering on the design and development of proposals for GCF funded climate resilience programs. These preliminary discussions culminated in the Concept Note for a proposal to strengthen resilience to hydrometeorological events in Fiji, Papua New Guinea, the Solomon Islands, Timor-Leste and Vanuatu. The Concept Note focused on the development of early warning systems in each country,

[65] World Bank, op cit.
[66] World Bank, 2020. Country Partnership Framework for the Democratic Republic of Timor-Leste for the period FY2020-FY2024
[67] Gorton, C. Future Directions International, 2018. Food and Nutrition Security in Timor-Leste: Challenges and Prospects
[68] World Bank, 2020. Country Partnership Framework for the Democratic Republic of Timor-Leste for the period FY2020-FY2024

addressing all components of the value chain from the observation network to the delivery of practical, early advice to communities on reducing the impact of extreme events.

The GCF has encouraged the development of early warning systems in developing countries as a means of quickly reducing the impacts of climate variability and change on vulnerable populations. The GCF recognises that WMO holds expertise in and has long experience of designing, establishing and supporting early warning systems.

In 2018, finding itself "confronted with a situation where some early warning system project proposals lack technical quality and engagement with WMO", the GCF created a new partnership with WMO through which WMO provides the climate science basis for the Fund's climate rationale design. WMO will support, in collaboration with National Meteorological and Hydrological Services (NMHSs) and Nationally Designated Authorities (NDAs), implementation of this climate rationale for all GCF funded activities. This scientific and technical expert partnership ensures that GCF funded hydrometeorology projects are based on WMO standards and practices.

In order to avoid potential conflicts of interest, WMO's role in project development changed from implementer to expert adviser to other GCF Accredited Entities (AEs) preparing and implementing projects. The GCF Secretariat invited Timor-Leste's NDA and the Director of the National Directorate for Meteorology and Geophysics (DNMG) to discuss ways of progressing the project's development with other agencies working on EWSs in the Pacific, including SPREP and UNEP at the GCF Pacific Structured Dialogue (30 July–3 August 2018) in Pohnpei, Federated States of Micronesia. The Timor-Leste delegates agreed to continue development of their proposed project with UNEP, separately from the four Pacific countries, and in April 2019 the NDA formally advised the GCF that UNEP was now its AE for the project.

3 – CLIMATE RATIONALE

3.1 – OVERVIEW

The Climate Rationale is based primarily on Timor-Leste's Initial National Communication (INC) to the United Nations Framework Convention on Climate Change (UNFCCC), submitted in 2014. It includes supplemental research from the Australian Bureau of Meteorology (BoM) and the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) conducted under the Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program. It also includes a new historical analysis of key hazards, undertaken by the World Meteorological Organization's (WMO) Expert Team on Sector-specific Climate Indices (ET-SCI) using Climpact.[69]

The climate analysis was prepared with support from Lisa Alexander (Australia) Chair of the World Meteorological Organization's (WMO) Expert Team on Sector-specific Climate Indices (ET-SCI) and collaborators Ardhasena Sopaheluwakan (Indonesia), Deputy Director for Climate and Air Quality Research, Center for Research and Development, Agency for Meteorology Climatology and Geophysics (BMKG), Jorge L. Vazquez (Mexico), ET-SCI member and Atmospheric Science Lecturer - researcher on data, prediction and climate services (DAPSCLIM), Universidad Veracruzana (Mexico);

[69] Climpact is a software package developed by the World Meteorological Organization's Expert Team on Sector-Specific Climate Indices (ET-SCI) and used to calculate climate indices relevant to the health, agriculture and water sectors. The indices calculated by Climpact are derived from daily temperature and rainfall data and allow researchers to deliver useful and relevant climate information to sector users. Climpact allows users to calculate these indices from their own daily weather data—either plain-text point data (from a weather station, for example) or across an entire gridded file (like climate model output).

Citlali Villa-Falfán and Martín Guillén-Cadena, DAPSCLIM Associates, UV (Mexico); and Nicholas Herold, Senior Scientist, Department of Planning, Industry and Environment, NSW (Australia).

3.1.1 Data and methodology

Reanalysis and grid point data

In this climate analysis for Timor-Leste, wherever the historical observed data has been missing, the fifth generation of the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis model (ERA5) is used to fill the gap. The ERA5 provides hourly estimates of a large number of atmospheric, land and oceanic climate variables. The data cover the Earth on a 30 km grid and resolve the atmosphere using 137 levels from the surface up to a height of 80 km. ERA5 includes information about uncertainties for all variables at reduced spatial and temporal resolutions.[70]

Approaches for addressing limited or absent data

Two main approaches were considered to still provide a scientifically robust analysis:

1. Remote sensing observations combined with gridded data or extrapolated information from neighbouring areas with similar climate conditions;[71] and
2. Use of high-quality, peer-reviewed reanalysis products.

In this climate analysis, a combination of remote sensing data from CHIRPS was used on a case-by-case decision depending on the local context and area of focus. Furthermore, consultation was made with a senior climate specialist from the Indonesian Meteorological, Climatological and Geophysical Agency (BMKG). The climate expert involved in the process who is closely affiliated to WMO's climate data and monitoring activities helped choose the appropriate approach(es) – and corresponding datasets – and was able to demonstrate how reliable the products could be for any given application and context, and whether the outputs from applying the approach(es) were suitable for further analysis and use.

Remote sensing observations and extrapolation

Remote sensing products from Climate Hazards Group Infrared Precipitation With Station-Global Ensemble Forecasting System (CHIRPS-GEFS) were found adequate for this climate analysis Timor-Leste because they were biased corrected.

Climate projections

The Swedish Meteorological and Hydrological Institute (SMHI) has produced bias-adjusted data in Climate Information Platform (CIP)[72] – with respect to the station data availability of countries – and these are made available to the users. For the data in the CIP, a global reference data set is used – HydroGFD, a global product of corrected reanalysis. As quality check when producing the indicators (both bias and non-bias adjusted) in the reference period, SMHI compares them to this reference dataset. There are also additional checks when doing the bias adjustment. The user of the CIP and the Data Access Platform can access both non and bias-adjusted indicators of model data so this open to the user.

[70] ECMWF, 2021. Reanalysis datasets – ERA5. Available at: https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5
[71] Biased correction uses available station data to correct systematic over/under-estimation of values of the variable of interest by the satellite sensor. When in-situ observations are not available, the bias adjustment is extrapolated based on data from other regions.
[72] Climate Information, 2021. Available at: https://climateinformation.org/

The methodology and the references for the bias adjustment and the global reference dataset used for the CIP are provided below:

Bias adjustment method

CORDEX and CMIP5 variables are bias-adjusted using the Distribution Based Scaling method (DBS; Yang et al., 2010) versus the global reference dataset Global Forcing Data for Hydrology (HydroGFD) 2.0.[73] Both bias adjustment method and global reference dataset are developed by SMHI.

The DBS method is a parametric quantile-mapping variant. This type of method fits a statistical distribution to the cumulative distribution function and uses those fitted distributions to conduct the quantile mapping. For precipitation, the number of wet days is first corrected by applying a wet-day threshold. Then, the single (double) gamma distribution[74] is fitted to the daily rain data in case there are more than 25 (500) rain days. Below 25 rain days, the mean precipitation intensity is corrected instead of a distributional correction. For temperature, the normal distribution is fitted to the data. Temperature corrections were done conditional on the wet/dry state of the corresponding precipitation time series. The seasonal variations in the biases were represented by monthly parameter windows for precipitation and a moving window of 31 days width for temperature.

There is some post-processing in place for the data to be suitable for hydrological impact modelling. Bias adjustment of daily mean/maximum/minimum temperature using quantile mapping can in some cases lead to inconsistencies. For e.g., the daily maximum (minimum) temperature could be lower (higher) than the daily mean temperature. If such inconsistencies occur, daily minimum and maximum temperatures are adjusted in such a way that the anomalies with respect to the daily mean temperature are in line with the climatological anomalies for the particular day in the seasonal cycle. This means, for e.g., that an inconsistency occurring on June 25 will be adjusted using the climatological anomalies for June 25, estimated by a moving window. Also, the adjustment is done conditional on the wet/dry state of the corresponding precipitation series. The climatology of the anomalies was derived from the HydroGFD2.0 global reference data set.

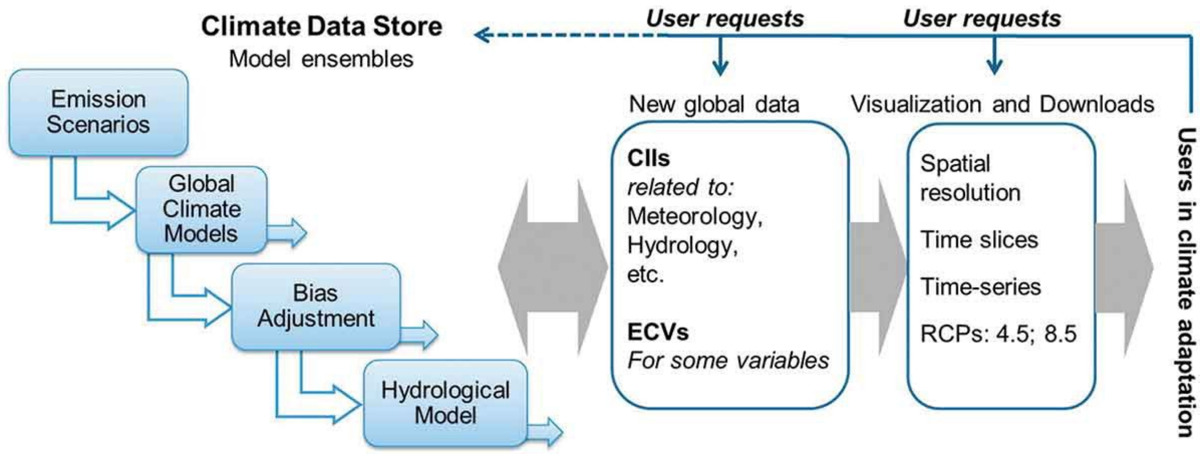

Figure 2: Production chain of climate impact indicators (CIIs) for global users of the Copernicus Climate Change Services (C3S)

Quality control checks

[73] Berg, P. *et al.,* 2018. Hydrology and Earth System Sciences. Near-real-time adjusted reanalysis forcing data for hydrology

[74] Yang, W. *et al.,* 2010. Hydrology Research. Distribution-based scaling to improve usability of regional climate model projections for hydrological climate change impacts studies

There is a detailed workflow to calculate the Climate and water Indicators (CI) provided in the two tools of ClimateInformation.org: the Site-specific report and the Data Access Platform. Many checks are completed throughout the production to ensure that the indicators are of reliable quality.

The figure below describes the different steps in the workflow and highlights (in orange) when quality control procedures happen. Each procedure is adapted to the dataset it is applied to (to account for different variables, ranges and more), and can be repeated throughout the workflow. Essential Climate Variables (ECV) from Global and Regional Climate Models (GCM/RCM) are downloaded from the Earth System Grid Federation (ESGF), the largest archive of climate data worldwide. ESGF has already some standards which the climate community follows in order for the output of the climate models to be available to the scientific community.

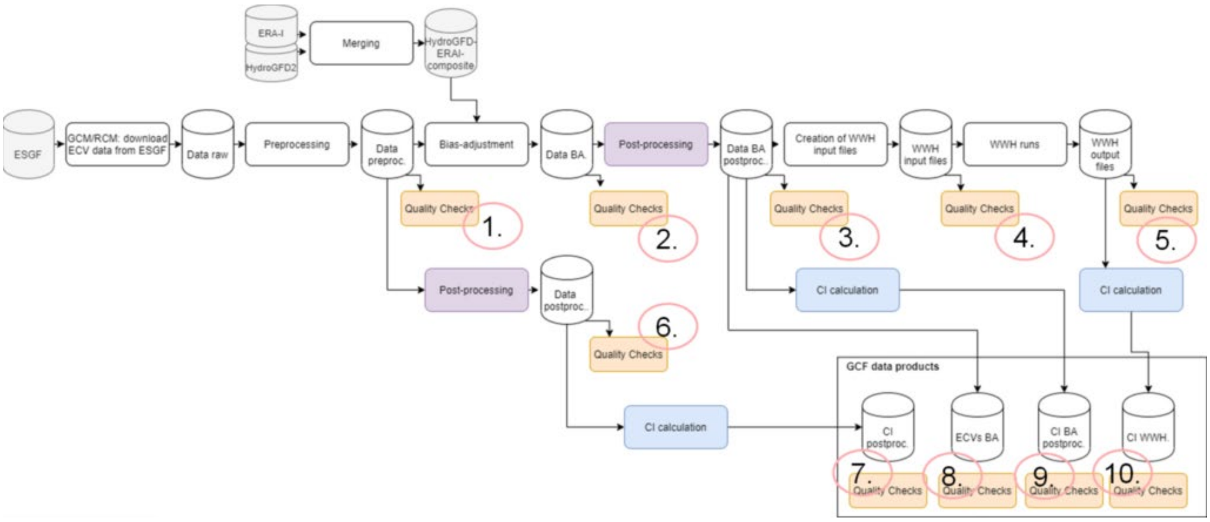

Figure 3: Workflow describing the quality checks taking place during the production of climate and water indicators (Source: Climate Information, 2021)

The various types of quality control procedures that are included in the orange boxes in the figure above are outlined below.

File format checks/pre- and post-processing (Procedures 1 – 10)

The file format checking procedure is used in all steps of data processing. It ensures that the files are in the right format. The following points are checked and corrected if necessary (how it is corrected is described in the brackets):

- Data gaps/overlapping periods or missing values: If a single time step is missing in climate scenario data, a time step before or after the missing one is copied and added. Sometimes scenarios have overlapping periods between the historical period and the RCP period. RCP data begins in 2006 and data sets are cut to follow this standard.
- Units appropriate for each indicator; for e.g. the climate model temperature unit is in general Kelvin (ºK), values and are then converted to Celsius (ºC).
- Data dimensions and domain dimension are correct: Data should cover the full CORDEX domain. If not, the data is excluded from the production. Data must also have a daily time series from 1971 to 2100 to be used for the calculation of the indicators. Some scenarios end in 2098 or 2099, and if so, the last year is copied and added to fill out the time series to 2100.

- Metadata is complete and correct: Metadata should follow the Climate and Forecast metadata standards.[75] All files are edited to make metadata homogeneous.

Data pre-processing

Data pre-processing quality procedures are completed in Step 1. This step is needed to make sure all datasets are in a format that can be treated within the production of the indicators. All files must be in the same format to be comparable. The following points are the main steps in this quality control procedure:

- Convert calendar to standard, standard time reference
- Remap data to HydroGFD 0.5 degrees for the bias adjustment
- Sea masking by data points used in HydroGFD, plus data points needed by World-Wide HYPE for the hydrological assessment.

Range check on Essential Climate Variable (ECV) data

All ECV climate scenario data (time series of both raw and bias-adjusted data) are tested against the constant minimum and maximum values of a Global Climate Model (GCM) ensemble in Steps 1, 3 and 6. It ensures that the data do not have unrealistic values. Scenarios with data outside the GCM range are flagged for further investigation. If a dataset has too many values outside the expected range, it can be excluded from the workflow based on expert judgement.

Range check vs HydroGFD climatology

HydroGFD[76] is a global forcing data set used for evaluation and bias adjustment of climate scenario data. The HydroGFD data set is used to define ranges with min/max diurnal values from a 30-day moving window, using daily data from the full reference period 1981-2010. The procedure is used in step 1, 2, 3, and 6. This results in the grid-point specific annual cycle of min/max value range in the GFD data set and constitutes the reference in the range checks. All climate ECV data (non-adjusted and bias-adjusted) are compared to the ranges during the reference period. The same ranges are also used to evaluate the full climate scenario period, with expected change for the respective variable considered. This procedure gives a more detailed check of data, compared to the GCM range used for ECV data. Here, ranges are calculated for each grid box which take into account spatial differences in data. If a scenario has values outside the range, manual inspection is made to assure the quality. If the scenario has too poor quality, it is excluded from the project.

Range check vs hydro-GFD climate indicators

To evaluate the ranges of the calculated CI from CORDEX, a manual comparison of Climate Indicators calculated from the HydroGFD CI's historical period 1981-2010 to the calculated CORDEX CIs are performed. Experts check if the patterns are within a reasonable range. This test is made in Steps 7 and 9.

This test gives information on outliers and possible extreme values in need of further investigation. This test is also made in Steps 7, 9 and 10.

Evaluation of bias adjustment

Statistics for climatological periods such as mean, median, minimum, maximum values over the full ensemble are calculated for every grid point. Experts inspect the bias adjustment performance.

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[75] CF Metadata, 2021. CF Conventions and Metadata. Available at: http://cfconventions.org/

[76] Berg, P. *et al.,* 2018. Hydrology and Earth System Sciences. Near-real-time adjusted reanalysis forcing data for hydrology

Statistics on missing values are used to identify scenarios where the bias adjustment did not work properly. Bias adjustment with Distribution Based Scaling method[77] requires post-processing for temperature, where possible shifts between maximum and minimum temperature are corrected. This procedure is made in Step 2.

Mapping of climate scenarios to HYPE catchments

The global hydrological assessment is performed with WW-HYPE.[78] Manual inspections are made to confirm height correction created from HydroGFD weights.

Reference period mean statistics are calculated for each scenario and plotted and diff plots are created to compare with HydroGFD. The plots confirm correct calculations of weights and height correction for each sub-basin in the hydrological model. This procedure is made in Step 4.

WW-HYPE output files

Qualitative assessment of the validity of HYPE output data is performed through diagnostic map plots. The validity of spatial patterns in hydrological variables is assessed through visual inspection of mapped aggregates (averages, sums) of HYPE output variables. Values of HYPE variables at selected spatial points, e.g. large river outlets, are semi-quantitatively assessed through comparison with expected ranges based on external data, e.g. observations or previous HYPE model results, to make sure values are within a reasonable range. This procedure is made in Step 5.

3.1.2 Climate highlights

Timor-Leste's INC outlines trends in historical climate data and the results of climate scenarios generated with a Regional Climate Model (RCM) using the A1B emission scenario and with 20 Global Circulation Models (GCMs) using the range of Representative Concentration Pathways (RCPs) emission scenarios. The BoM and CSIRO research includes 26 Global Circulation Models that have been assessed to perform acceptably well over the Pacific region for the range of RCPs. The following are the highlights for Timor-Leste:

- Temperatures have warmed and will continue to warm with more hot days in the future.[79] Climpact analysis of historical temperature shows an increasing trend in hot days, increasing at a rate of 48 days per decade over the 1981–2010 period.
- Historical data suggests that during the 20th century and early 21st century there were shifts in the peak of the wet season.[80]

[77] Yang, W. *et al.,* 2010. Hydrology Research. Distribution-based scaling to improve usability of regional climate model projections for hydrological climate change impacts studies
[78] Arheimer, B. *et al.,* 2020. Hydrology and Earth System Sciences. Global catchment modelling using World-Wide HYPE (WWH), open data, and stepwise parameter estimation
[79] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report.
[80] Timor-Leste. State Secretary of Environment. (2014). Timor-Leste's Initial National. Communication under United Nations Framework Convention on Climate Change. Available at: https://unfccc.int/resource/docs/natc/tlsnc1.pdf (Accessed: 09 January 2020).

- Rainfall is highly variable due to the influence of the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD).[81] There is consensus that extreme ENSO events are expected to increase in frequency in the future.[82]
- Decreases in rainfall are projected in some parts of the country, as well as changes in its seasonal distribution, with respect to the 1981–2010 conditions.[83] For example, the drier area on the northern coast of the country (annual rainfall less than 1000 mm) will expand in the future.[84] While there is a range of projections in average annual rainfall, more extreme rain events are anticipated.[85]
- Drought frequency is projected to remain similar to the current climate.[86]
- Sea level has risen near Timor-Leste by about 9mm per year since 1993.[87] This rising pace is two to three times faster than the global average. The Coupled Model Intercomparison Project 5 (CMIP5) models simulate a rise of between approximately 8–18 cm by 2030 (very similar values for different RCPs).[88]

"Timor-Leste has a hot tropical climate with a dry season, May–November, and a wet season, December–April. The temperature on the coast is usually between 25–35°C and in the mountains at higher elevation the weather is much cooler—sometimes wet and misty and at other times clear and invigorating. There are many different micro-climates from dry barren hill sides to thickly forested peaks interspersed with cultivated areas." [89]

Year-to-year variations in Timor-Leste's precipitation are due to the West Pacific Monsoon, the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). The seasonal arrival of the West Pacific Monsoon usually brings a switch from very dry to very wet conditions. El Niño events generally bring drier conditions to Timor-Leste, and often lead to a late onset and early finish to the wet season.[90] El Niño events result in less overall rainfall bringing a prolonged dry season and have significant impacts on the availability and quality of water. La Niña generally brings an extended wet season and higher rainfall throughout the dry season.

Timor-Leste is highly exposed to natural hazards and experiences recurrent disasters associated with droughts, floods, and landslides resulting from the combination of heavy monsoon rain, steep topography, widespread deforestation, cyclones and strong wind.

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[81] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report; Timor-Leste. State Secretary of Environment. (2014). Timor-Leste's Initial National. Communication under United Nations Framework Convention on Climate Change. Available at: https://unfccc.int/resource/docs/natc/tlsnc1.pdf (Accessed: 09 January 2020).

[82] Cai et al. 2014. Increasing frequency of extreme El Niño events due to greenhouse warming. Nature Climate Change, 4 (2), pp. 111-116; Cai, W., Wang, G., Santoso, A., Mcphaden, M.J., Wu, L., Jin, F.-F., Timmermann, A., Collins, M., Vecchi, G., Lengaigne, M., England, M.H., Dommenget, D., Takahashi, K., Guilyardi, E. Increased frequency of extreme La Niña events under greenhouse warming (2015) Nature Climate Change, 5 (2), pp. 132-137; Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M.S. Karim, L. Levin, S. O'Donoghue, S.R. Purca Cuicapusa, B. Rinkevich, T. Suga, A. Tagliabue, and P. Williamson, 2019: Changing Ocean, Marine Ecosystems, and Dependent Communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

[83] Timor-Leste. State Secretary of Environment. (2014). Timor-Leste's Initial National. Communication under United Nations Framework Convention on Climate Change. Available at: https://unfccc.int/resource/docs/natc/tlsnc1.pdf (Accessed: 09 January 2020).

[84] Ibid.

[85] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report

[86] Ibid.

[87] BoM (Australian Bureau of Meteorology) and CSIRO, 2014.

[88] Ibid.

[89] https://www.timorleste.tl/east-timor/about/geography-climate/

[90] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report.

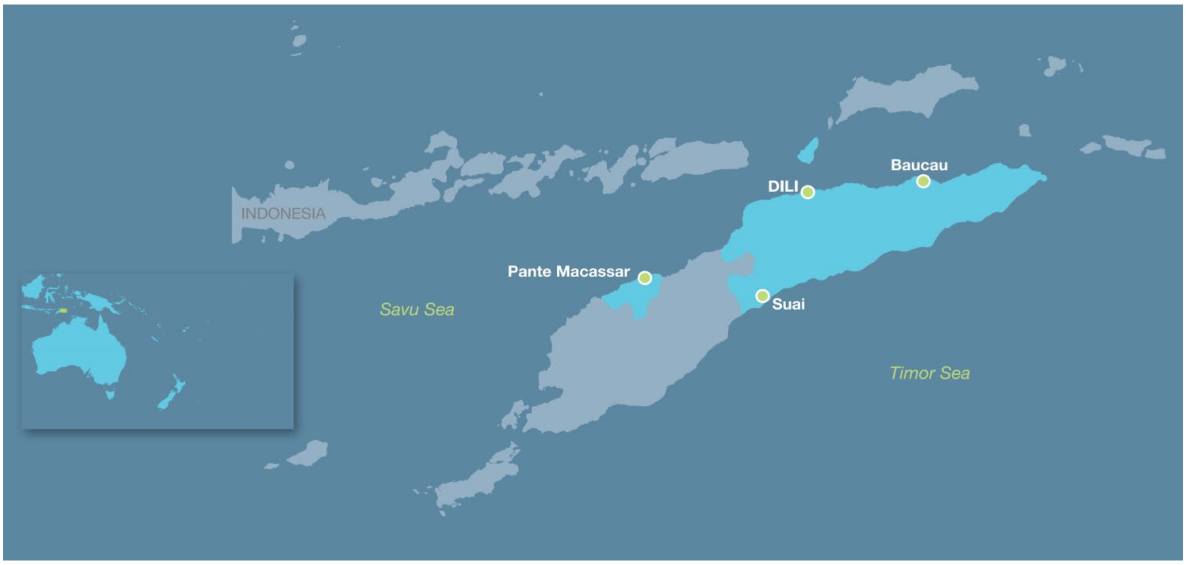

Figure 4: Timor-Leste: (Map source: BoM and CSIRO, 2014)

3.2 – STATE OF THE CLIMATE

3.2.1 Rainfall

Climate normals

Based on the historical rainfall and temperature record, the region is divided into three different climatic zones: North coast region, characterised by average mean temperature of more than 24°C, annual rainfall amount less than 1500 mm, with a dry season lasting for around five months; Mountainous region, characterised by average mean temperature less than 24°C, annual rainfall amount more than 1500 mm and dry season lasting for four months; and South coast region, characterised by average mean temperature more than 24°C, annual rainfall amount of about 2500 mm, and dry season lasting for only three months.[91]

Year-to-year variations in Timor-Leste are due to the West Pacific Monsoon, El Niño–Southern Oscillation and the Indian Ocean Dipole. The West Pacific Monsoon is driven by large differences in temperature between the land and the ocean.[92] It moves north to mainland Asia during the Southern Hemisphere winter and south to Australia in the Southern Hemisphere summer.[93] Its seasonal arrival usually brings a switch from very dry to very wet conditions.

Timor-Leste has a very marked wet season from December to May and a dry season from June to November (Figures 3 and Figure 4). For most of the wet season average monthly rainfall is above 225 mm per month while most of the dry season it is less than 100 mm per month. Temperature variations are moderate along the year. Figure 3 was developed using a satellite estimated precipitation dataset (CHIRPS)[94] and reanalysis temperature data (ERA5) (C3S, 2017) for temperature. Figure 4 was developed using monthly rainfall averages from 36 stations across Timor-Leste.

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[91]Kirono, D. G. C., 2010: Climate change in Timor-Leste – a brief overview on future climate projections.
[92] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report
[93] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report
[94] Funk, C.C., Peterson, P.J., Landsfeld, M.F., Pedreros, D.H., Verdin, J.P., Rowland, J.D., Romero, B.E., Husak, G.J., Michaelsen, J.C., and Verdin, A.P., 2014, A quasi-global precipitation time series for drought monitoring: U.S. Geological Survey Data Series 832, 4 p. http://pubs.usgs.gov/ds/832/

Satellite-derived precipitation estimations (CHIRPS)[95] and reanalysis temperature data (ERA5) (C3S, 2017) were used to analyse trends in historical extreme events using the 27 extreme indices defined by the World Meteorological Organization's (WMO) Expert Team on Climate Change Detection and Indices (ETCCDI) and the WMO's Expert Team on Sector-specific Climate Indices (ET-SCI). Station data (in situ observations) of high quality are always preferred to calculate historical trends or when conducting analysis, but the available station data in this case were not of sufficient quality or completeness. Several studies (e.g. Hersbach et al., 2019[96]) have shown that satellite-derived precipitation estimates and reanalysis temperature are generally well correlated with station precipitation and temperature. Thus, CHIRPS and ERA5 datasets were used to calculate climate indices using Climpact 2.0.[97] The indices are defined in such a way they reveal changes in the climate extremes over time. The point locations for CHIRPS and ERA5 are shown in Figure5. Climpact 2.0 plots for precipitation, temperature, and the seasonal analyses are also provided below.

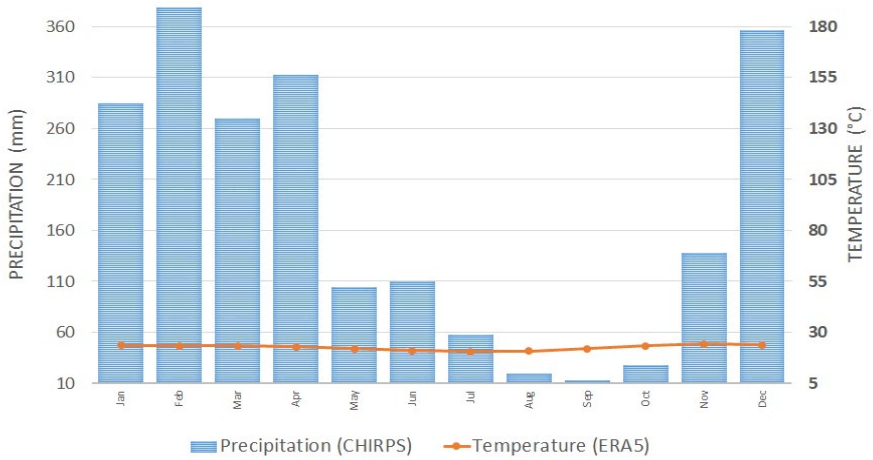


Figure 5: Climogram (1981-2010) for a gridpoint located at the centre of Timor-Leste depicting precipitation (CHIRPS) and temperature (ERA5) monthly mean variability. (Source: WMO ET-SCI, 2020)

[95] Ibid.
[96] Hersbach, Hans; Bell, Bill; Berrisford, Paul; Biavati, Gionata; Dee, Dick; Horányi, András; Nicolas, Julien; Peubey, Carole; Radu, Raluca; Rozum, Iryna; Muñoz-Sabater, Joaquín; Schepers, Dinand; Simmons, Adrian; Soci, Cornel; Thépaut, Jean-Noël; Vamborg, Freja (2019). The ERA5 Global Atmospheric Reanalysis at ECMWF as a comprehensive dataset for climate data homogenization, climate variability, trends and extremes. 21st EGU General Assembly, EGU2019, Proceedings from the conference held 7-12 April 2019 in Vienna, Austria, id.10826.
[97] Alexander L and Herold N 2015 Climpactv2 Indices and Software. A document prepared on behalf of the Commission for Climatology (CCl) Expert Team on Sector-Specific Climate Indices (ET-SCI).

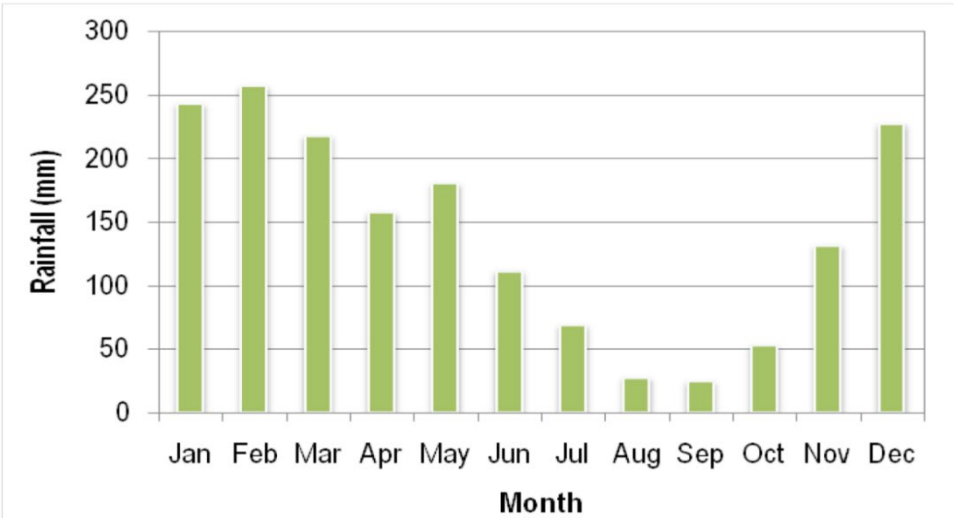


Figure 6: Monthly rainfall based on average at 36 stations in Timor-Leste (Source: Timor-Leste, State Secretary of Environment (2014). Timor-Leste’s Initial National. Communication under United Nations Framework Convention on Climate Change.

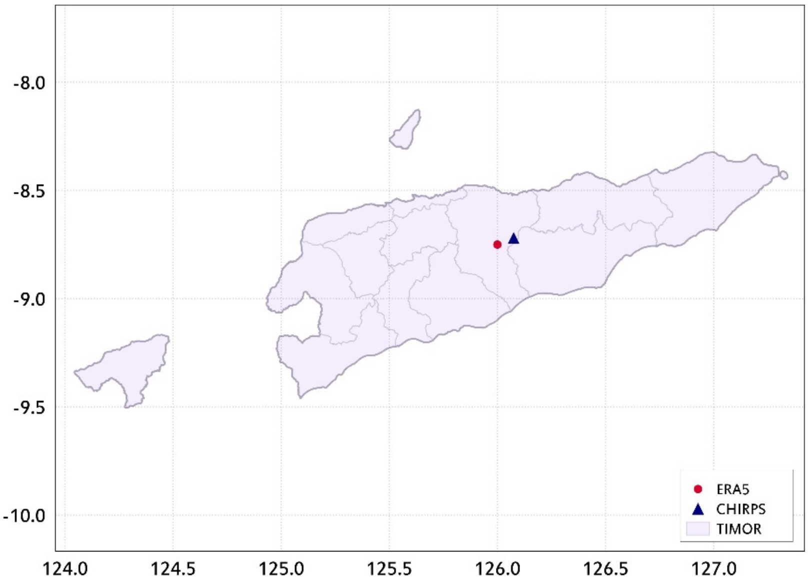


Figure 7: Gridpoints extracted from satellite estimated precipitation (CHIRPS) and temperature reanalysis (ERA5) to characterize recent past/present climate change in Timor-Leste. (Source: WMO ET-SCI, 2020)

Rainfall patterns in Timor-Leste vary from the driest area in the north east corner to wetter areas in the western part of the country. There are five dominant rainfall types found in the country based on a Principal Component Analysis (PCA) of monthly rainfall climatology developed as part of Timor-Leste’s Initial National Communication under the United Nations Framework Convention on Climate Change (UNFCCC).[98] The PCA-cluster analysis of monthly rainfall climatology is shown in Figure 6. The differences between these types are mostly found in the amount of their wet season rainfall. The Type 1 rainfall region represents areas in the western part of the country with the highest rainfall during the wet season, especially in February and March, reaching around 400 mm in average. The Type 2 rainfall region is also located in the western part adjacent to the Type 1 location. In the Type 2 region,

[98] Timor-Leste. State Secretary of Environment. (2014). Timor-Leste’s Initial National. Communication under United Nations Framework Convention on Climate Change. Available at: https://unfccc.int/resource/docs/natc/tlsnc1.pdf (Accessed: 09 January 2020).

the characteristic Monsoonal rainfall is dominant with the rainfall peak reaching around 275 mm, especially in December, January and February. The Type 3 rainfall region has a peak rainfall around 225 mm and is found adjacent to the north coast region, running from the west to the east of the main region as well as in the separated region in the west. The southwestern part of the country also has the same Type 3 characteristic. The Type 4 rainfall region is located mainly in the centre of the country with a rainfall peak lower than the previous types, i.e. around 175 mm. The north coast region is predominantly characterized by Type 5 rainfall. It has the lowest rainfall compared to the other four rainfall types. The peak of wet season rainfall in a Type 5 area is not more than 150 mm.

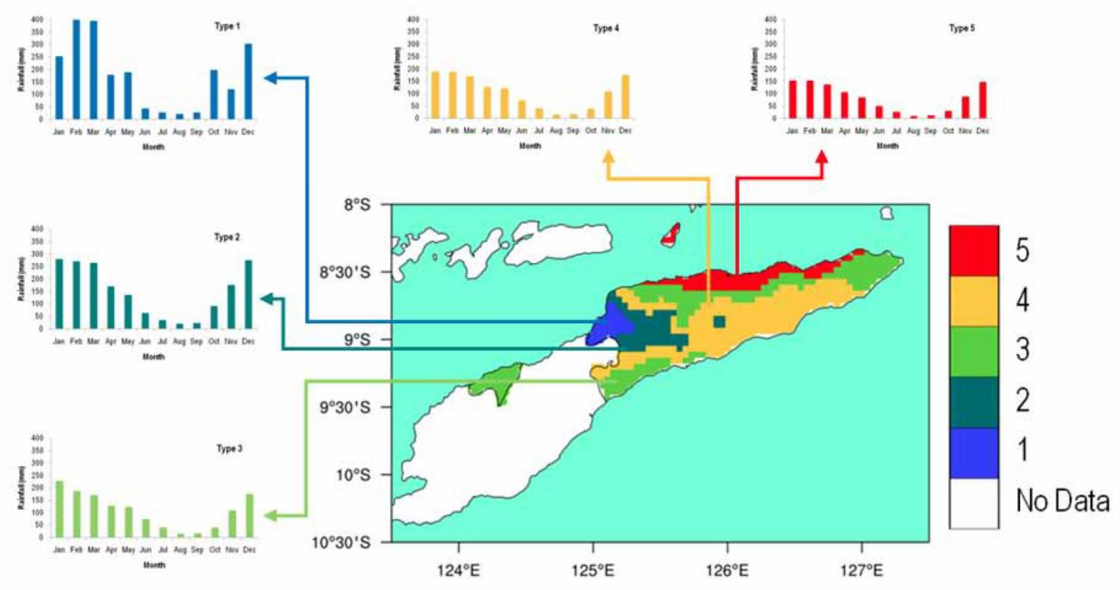


Figure 8: Patterns of Monthly rainfall in Timor-Leste based on a PCA cluster analysis (Source: Timor-Leste, 2014)

Rainfall Trends

Long-term rainfall variability in Timor-Leste contributes to the change in rainfall climatology over different periods. This is shown by the comparison of the monthly rainfall climatology in different 30-year periods with ten-year intervals (Figure 7). The changes of rainfall climatology are mostly apparent in December, January, March and May, indicating an increase of rainfall during the rainy season. In contrast, there are no considerable changes found in the dry season, particularly in July, August and September (Timor-Leste, 2014).

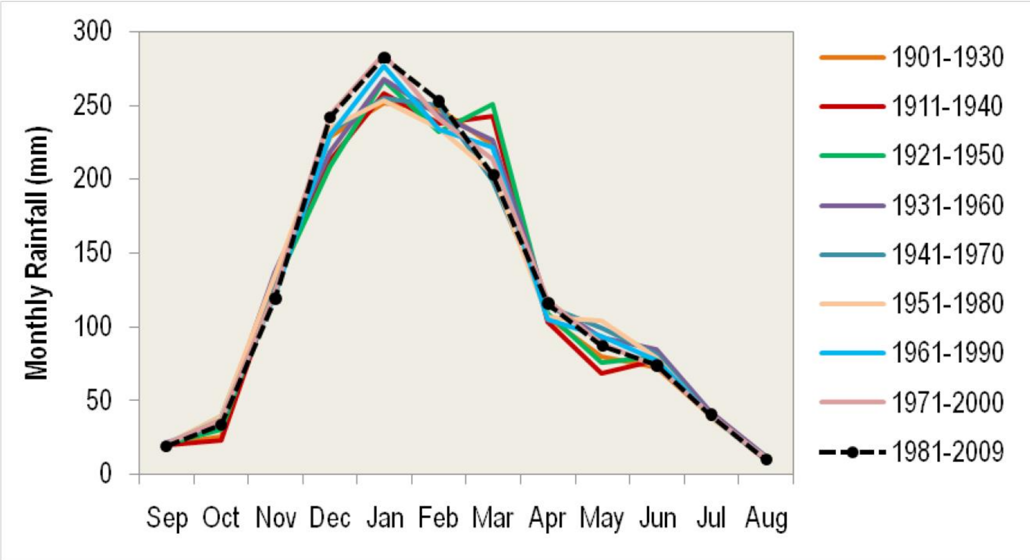


Figure 9: Comparisons of seasonal cycles of rainfall in Timor-Leste calculated from every 30-years monthly rainfall climatology with 10-years interval based on CRU TS 3.1 dataset (Source: Timor-Leste, 2014)

Timor-Leste experienced rainfall changes during the 20th century and in the beginning of the 21st century. The rate of decadal trend of annual rainfall climatology in Timor-Leste is estimated at around 6.4 mm/decade (Figure 8). The rates of decadal rainfall trends are different for each season (Figure 9). A consistently increasing trend is found only in the December, January and February (DJF) season with an approximate rate of 7.16 mm/decade. An increasing trend in rainfall is also found in September, October and November (SON) with a rate of 0.4 mm/decade, but with a decreasing trend tendency after 1980 (see Figure 9). In contrast, decreasing rainfall trends are shown in March, April and May (MAM) and June, July and August seasons. These long-term downward trends are mostly due to a dominant decrease of rainfall within the last few decades in those two seasons.

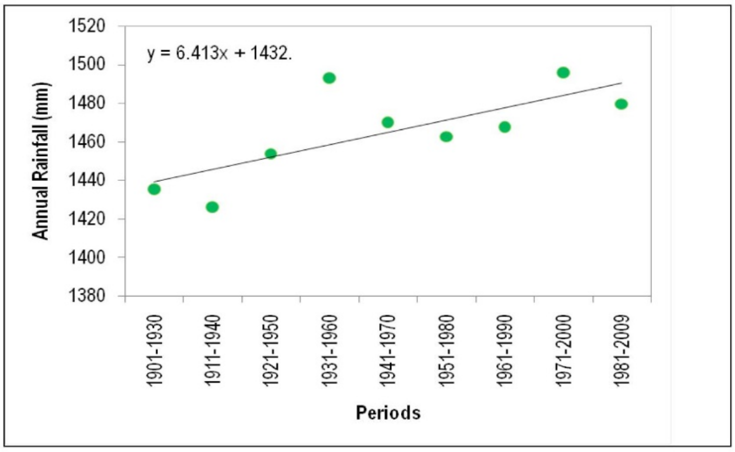


Figure 10: Decadal trend of mean annual rainfall over Timor-Leste based on CRU TS 3.1 (Source: Timor-Leste, 2014)

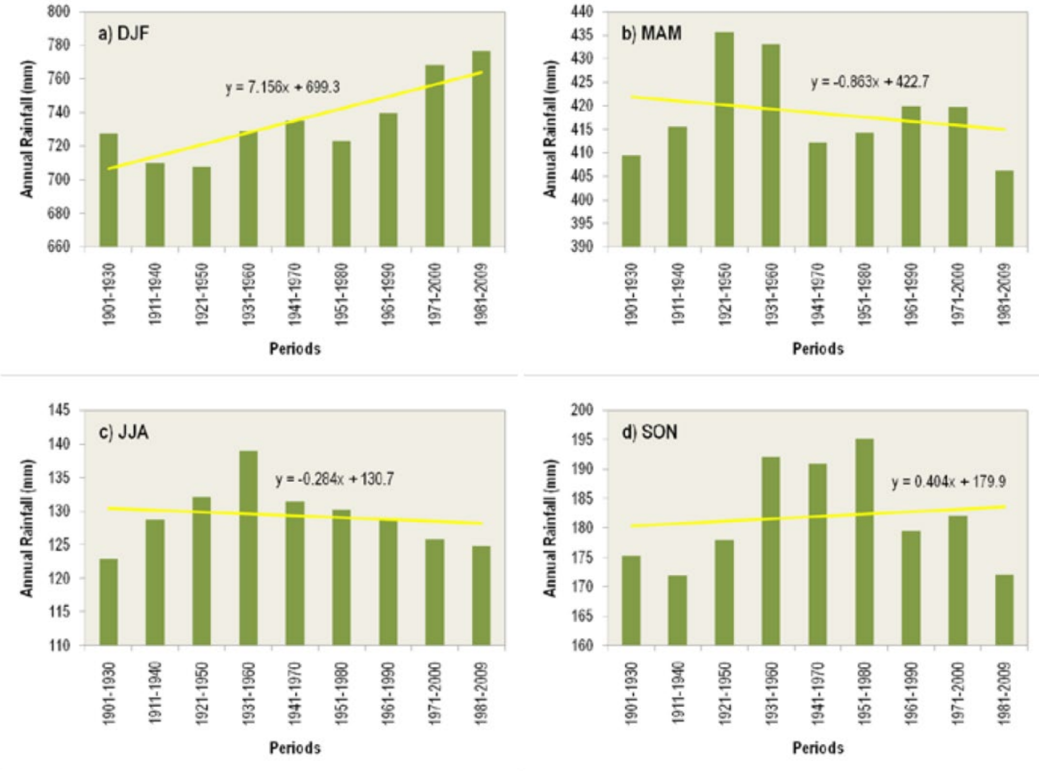


Figure 11: Time series of seasonal rainfall over Timor-Leste taken from CRU TS 3.1 (1901-2009 periods) (Source: Timor-Leste, 2014)

Rainfall Variability

The annual rainfall amounts in Timor-Leste are also different each year and show strong inter-annual variability associated with annual increases or decreases in rainfall that link to possible extreme climate events such as drought and flood. The considerable signs of rainfall variability with very little long-term trends are shown in the seasonal rainfall time series in Figure 10.

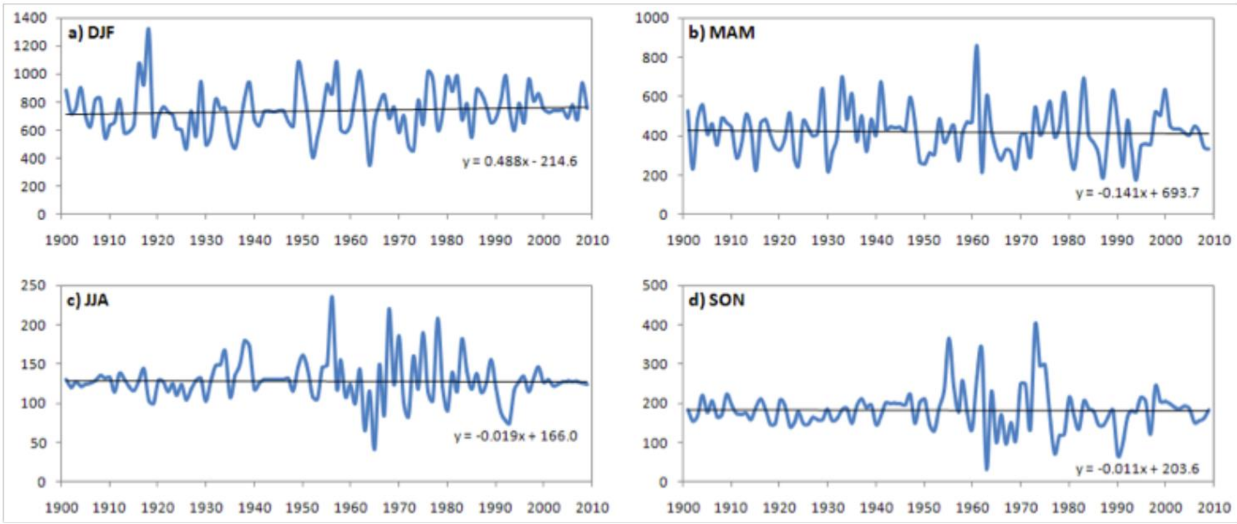


Figure 12: Time series of seasonal rainfall over Timor-Leste taken from CRU TS 3.1 (1901-2009 periods). (Source: Timor-Leste, 2014)

It should be noted that both Figures 9 and 10 provide an analysis of the seasonal rainfall over Timor-Leste for 1901-2009, which are provided by the same source – the Climate Research Unit (CRU) of the

East Anglia University. However, the difference between the figures is that in Figure 9, the 3-monthly precipitation normal is calculated over a 30-year period (e.g., 1901-1930, 1911-1940, etc.), while in Figure 10 the same normal is calculated over a 10-year period (e.g., 1900-1910, 1910-1920, etc.). As advised by WMO technical experts who prepared the climate rationale, Figure 9 is appropriate to visualize the long-term trends (in this case, the 30-year period), while Figure 10 shows the annual fluctuations in precipitation. When a normal is distributed over a 30-year period (i.e. Figure 9) the long-term increasing and decreasing trends are more visible. While in a 10-year period, in the absence of a rapid and continuous change, the trend appears flat, as shown in Figure 10.

Many studies have shown that the El Niño-Southern Oscillation (ENSO) significantly affects rainfall variability in the Maritime Continent region;[99] and this is also the case in Timor-Leste. Figure 11 shows the spatial correlations between Sea Surface Temperature Anomalies (SSTA) in the Indo-Pacific region with the area-averaged rainfall anomalies in the country based on different time lags. Consistent negative correlations at different time lags are found in the central tropical Pacific, indicating considerable influence of ENSO to the rainfall variability in Timor-Leste. The ENSO signal impacting rainfall variability could be identified from the previous 3 months of SSTA data in the central Tropical Pacific, providing potential uses of SSTA data for seasonal climate predictions.

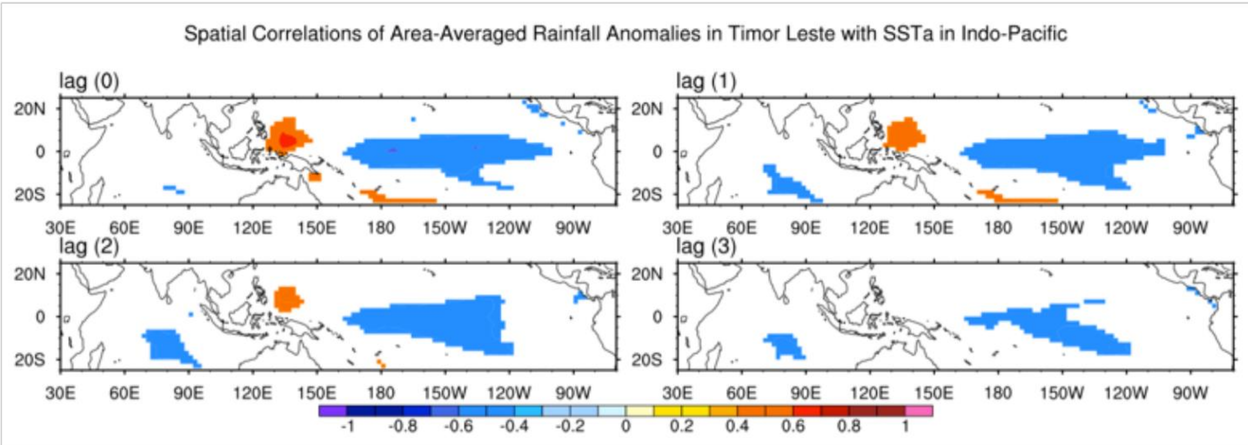


Figure 13: Spatial correlations of area-averaged monthly rainfall anomalies in Timor-Leste with sea surface temperature anomalies in the Indo-Pacific region (Source: Timor-Leste, 2014)

Figure 12 depicts observed annual average values of total rainfall (bars) at Dili Airport. Light blue, dark blue and grey bars denote El Niño, La Niña and neutral years respectively. The solid black trend line shows a least squares fit.[100] As shown in the figure, El Niño events generally bring drier conditions to Timor-Leste, and often lead to a late onset and early finish to the wet season.[101] El Niño events result in less overall rainfall bringing a prolonged dry season and has significant impacts on the availability and quality of water.[102] There is often higher rainfall in January during an El Niño due to the late start

[99] Aldrian, E., and R. D. Susanto, 2003: Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. International Journal of Climatology, 23, 1435-1452; Aldrian, E., L. D. Gates, and F. H. Widodo, 2003: Variability of Indonesian rainfall and the influence of ENSO and resolution in ECHAM4 simulations and in the reanalysis, 346; Boer, R., and A. Faqih, 2004: Global climate forcing factors and rainfall variability in West Java: case study in Bandung district. Indonesian Journal of Agricultural Meteorology, 18, 1-12; Faqih, A., 2010: Rainfall variability in the Austral-Indonesian region and the role of Indo-Pacific climate drivers. Dissertation, Department of Biological and Physical Sciences, The University of Southern Queensland; Hendon, H. H., 2003: Indonesian rainfall variability: Impacts of ENSO and local air-sea interaction. Journal of Climate, 16, 1775-1790.

[100] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report

[101] Ibid.

[102] UNDP, 2016. Timor-Leste: Stay Connected – Reducing Climate Risks, Building the Future.

and early finish of the wet season.[103] El Niño can affect agriculture, as planting too early could lead to crop failure with plants perishing due to a false start in the wet season.[104]

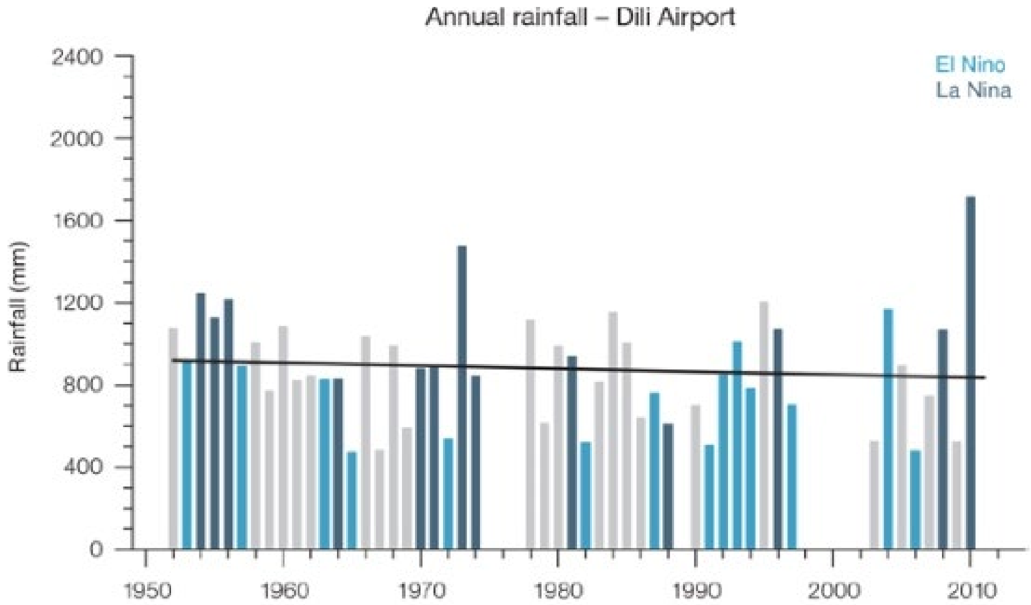


Figure 14: Observed annual average values of total rainfall (bars) at Dili Airport. Light blue, dark blue and grey bars denote El Niño, La Niña and neutral years respectively. Solid black trend line indicates a least-squares fit. (source: BoM and CSIRO, 2014)

During La Niña events, dry season rainfall tends to be above normal, and the wet season often starts earlier and finishes later.[105] La Niña generally brings an extended wet season and higher rainfall throughout the dry season.[106] In the agriculture sector, La Niña can create problems during the harvesting and drying of crops, as the moisture level is too high to safely store grain. However, as La Niña has an impact on the bimodal wet season, this can allow for the planting of a second crop in areas where only a single crop was planted.[107]

The Indian Ocean Dipole is a climate pattern that affects weather around the Indian Ocean basin.[108] During a positive phase of the Indian Ocean Dipole dry season rainfall in Dili is lower than normal.[109]

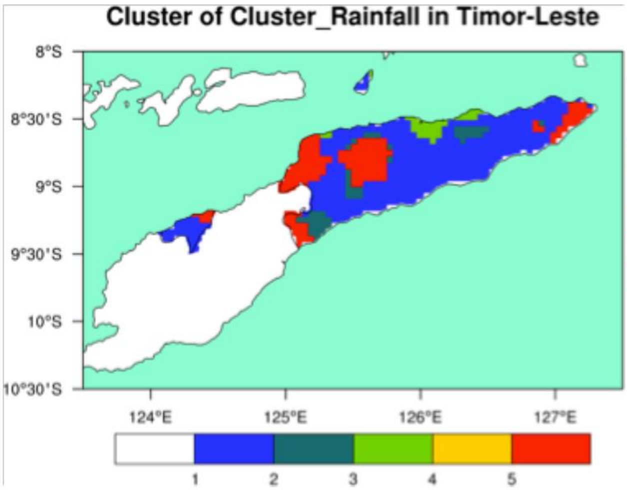
Climpact 2.0 plots for precipitation in Timor-Leste are provided in Appendix 3.

Onset, End and Length of Seasons

The season onsets are especially important for agricultural and water resource management. The onset of the wet season in Timor-Leste usually occurs in early November to early December with different timing across different regions. The advance or delay of the onset could reach around 15 days in respect of the mean onset date. Figure 14 shows the spatial pattern for the average timing of the wet season onset across different areas in Timor-Leste. The usual timing for the onset of the dry season is early to mid-April each year. However, due to the impact of climate drivers affecting climate

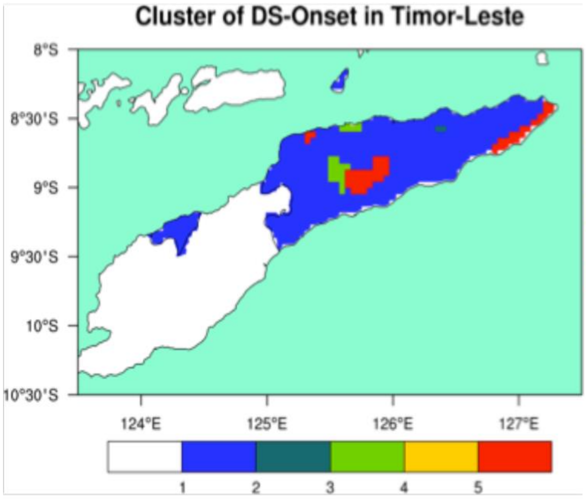
[103] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report
[104] Ibid.
[105] Timor-Leste, 2013. The impact of the El Niño Southern Oscillation on Rainfall Variability in Timor-Leste. Available at: https://www.pacificclimatechangescience.org/wp-content/uploads/2013/10/12.-Timor-Leste-GH-Poster.pdf (Accessed: 23 January 2020).
[106] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report
[107] Timor-Leste, 2013. The impact of the El Niño Southern Oscillation on Rainfall Variability in Timor-Leste.
[108] BoM (Australian Bureau of Meteorology) and CSIRO, 2014.
[109] Ibid.

variability, the onset could shift earlier or later with standard deviations up to 28 days from the mean onset date (Figure 14).



Wet Season Onsets				
Cluster Region	Distribution Parameters			Onset Date
	Shape	Scale	Location	
1	-0.679	14	306	2 Nov ± 14 days
2	-0.624	7	318	14 Nov ± 7 days
3	-0.377	15	324	20 Nov ± 15 days
4	-0.631	4	328	24 Nov ± 4 days
5	-0.315	4	337	3 Dec ± 4 days

Figure 15: Patterns of onset of the rainy seasons in Timor-Leste based on the result of cluster analysis. The onsets were calculated by using corrected TRMM data within 1998-2012 periods (Source: Timor-Leste, 2014)



Dry Season Onsets				
Cluster Region	Distribution Parameters			Onset Date
	Shape	Scale	Location	
1	-0.028	19	93	3 Apr ± 19 days
2	-0.152	11	93	3 Apr ± 11 days
3	-0.033	17	100	10 Apr ± 17 days
4	-0.371	10	104	14 Apr ± 10 days
5	-0.206	28	104	14 Apr ± 28 days

Figure 16: Patterns for the end of the rainy seasons in Timor-Leste based on the result of cluster analysis. The cessation time of the wet seasons were calculated by using corrected TR MM data within 1998-2012 periods. (Source: Timor-Leste, 2014)

The variability of the onset of both dry and wet seasons are clearly shown in the time series plot (Figure 16). The onset of the dry and wet seasons in Timor-Leste were analysed using gridded station-based observed data from APHRODITE dataset.[110] The methodology for the calculations follow the onset definition used by Liebmann et al.[111] The length of both dry and wet seasons can also be seen from Figure 16 based on the combination of the onset of those two seasons.

[110] Yatagai, A., K. Kamiguchi, O. Arakawa, A. Hamada, N. Yasutomi, and A. Kitoh, 2012: APHRODITE: Constructing a long-term daily gridded precipitation dataset for Asia based on a dense network of rain gauges. Bull. Amer. Meteor. Soc., 93, 1401–1415.
[111] Liebmann, B., and Co-authors, 2007: Onset and end of the rainy season in South America in observations and the ECHAM 4.5 atmospheric general circulation model. J. Climate, 20, 2037-2050.

The onset of the dry and wet seasons in Timor-Leste indicates strong variability with a relatively slow rate of decreasing trends, i.e. between -0.15 and -0.17 days per year for the dry and wet season, respectively.[112] The strong variability is consistent with the period of climate events, especially ENSO, as shown from the strong deviations during the El Niño and La Niña year. The onset of the wet season tends to delay (advance) during a strong El Niño (La Niña) years. This occurs similarly for the end of the wet season (the dry season onset), but with some exceptions, depending on the El Niño (La Nina) intensity and duration. For example, the end of the wet season came earlier in 1982 at the beginning of El Niño event which was followed by the delay of onset within the same year. Meanwhile, in the 1972/73 El Niño event, the dry season onset came earlier in 1974 not long after the delay of the onset in 1973. The differences in the responses of the onset and end of the rainy season to ENSO behaviour may influence the length of the wet season in the country. As a result, the relationship between the length of the wet season and ENSO is potentially lower than the relationship of onset and end of the wet season with ENSO.

Climpact 2.0 plots for seasonal analyses in Timor-Leste are provided in Appendix 5.

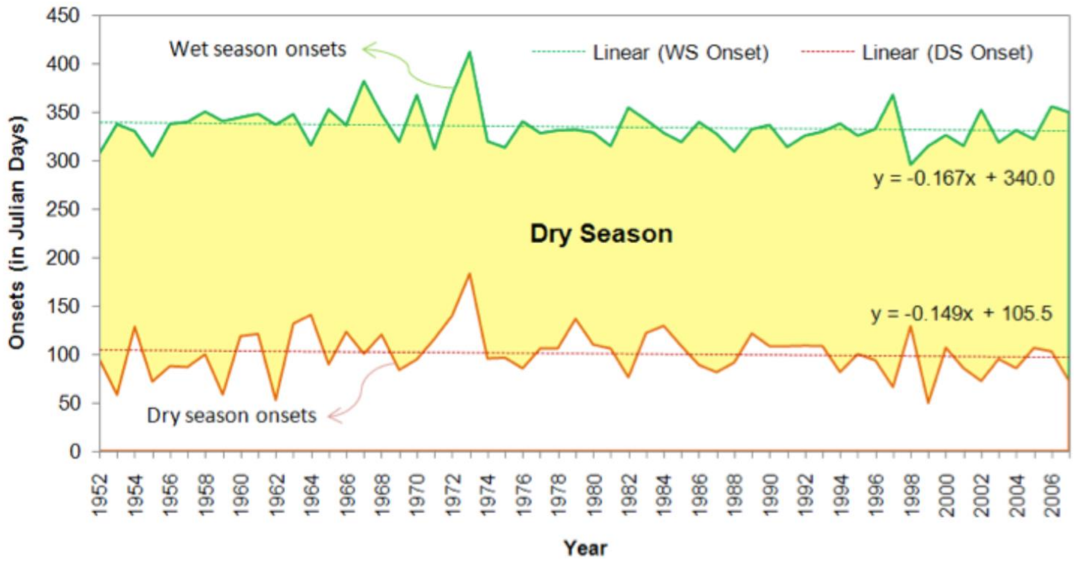


Figure 17: Variability and trend of onset and end of the wet season over Timor-Leste (area-averaged) during 1951-2007 periods. Calculations are based on the methodology used by Liebmann et al. (2007). Daily rainfall data from Aphrodite was used.

3.2.2 Temperature

Climate normals

The climatology of monthly mean temperatures in Timor-Leste varies across different areas (Figure 13). Based on the climatology of mean temperatures of 11 climate stations located in different altitudes in Timor-Leste, the highest monthly mean temperature generally occurs during the peak of the rainy season when the optimum solar radiation occurs and there is intensive surface heating. During the wet season, the mean temperature ranges from around 20°C to 30°C.[113] During the dry season, the temperatures are lower, ranging from 16°C to 27°C.[114]

[112] Timor-Leste. State Secretary of Environment. (2014). Timor-Leste's Initial National. Communication under United Nations Framework Convention on Climate Change. Available at: https://unfccc.int/resource/docs/natc/tlsnc1.pdf (Accessed: 09 January 2020)

[113] Timor-Leste. State Secretary of Environment. (2014). Timor-Leste's Initial National. Communication under United Nations Framework Convention on Climate Change. Available at: https://unfccc.int/resource/docs/natc/tlsnc1.pdf (Accessed: 09 January 2020).

[114] Ibid.

Climpact 2.0 plots for temperature in Timor-Leste are provided in Appendix 4.

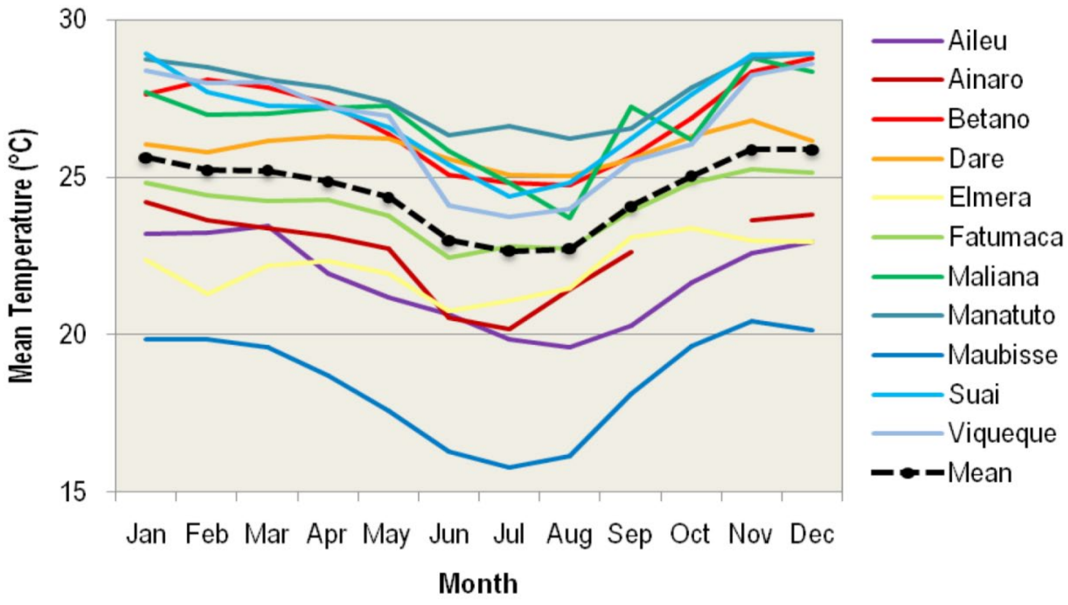


Figure 18: Monthly mean temperature at 11 climate stations in Timor-Leste (Source: Timor-Leste, 2014)

3.3 – HIGH IMPACT EVENTS

3.3.1 Tropical Cyclones

Tropical cyclones normally occur around Timor-Leste between November and April; however, their effect tends to be weak due to proximity to the equator.[115] In the 42-year period between the 1969 and 2010 seasons, seven tropical cyclones developed within or passed through the Timor-Leste Exclusive Economic Zone, all of them less than Category 3. Besides cyclones, Timor-Leste is affected annually by tropical storms. These tropical storms (wind speed of 36-117 km/hr) can be as devastating as a cyclonic activity as they can deposit extremely high amounts of rainfall in a short time period.[116] Unfortunately, available data are not suitable for assessing long-term trends of these events.

3.3.2 Floods

Floods are one of the most frequently occurring extreme events in Timor-Leste, resulting from a combination of heavy monsoon rain, steep topography and widespread deforestation.[117] There are two types of floods in Timor-Leste: (i) flash floods that occur when heavy seasonal rain water in high catchment basins converges in tributaries as it descends downward resulting in the rapid rise of discharge along the water courses; and (ii) riverine floods that occur when water accumulates in lowland or upland flood plains and river banks have insufficient capacity to contain the flow resulting in an overflow of the river.[118]

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[115] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report

[116] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report

[117] Timor-Leste. State Secretary of Environment. (2014). Timor-Leste's Initial National. Communication under United Nations Framework Convention on Climate Change. Available at: https://unfccc.int/resource/docs/natc/tlsnc1.pdf (Accessed: 09 January 2020)

[118] Ibid.

During La Niña years above-normal rainfall leads to increased flooding and landslides in Timor-Leste.[119] Major flood events in Timor-Leste were reported in 2001, 2003, 2007, 2010, and 2011; all except one of those years were during a La Niña phase.[120] The 2010-2011 La Niña caused increased rainfall over a prolonged period of time in Timor-Leste resulting in flooding over the two-year period.[121]

The Climpact plots for precipitation are provided in Appendix 3 and seasonal analyses in Appendix 5. In general, there isn't a strong positive or negative trend in precipitation extremes, which could indicate that the variability in the system is too great to detect a climate change signature should one exist.

3.3.3 Landslides

Landslides induced by flooding are reported to be one of the most common disasters in Timor-Leste.[122] High occasional rainfall, steep slopes, high weathering rates and slope material with low shear resistance or high clay content are the main preconditions for landslides.[123] A recent analysis of the landslide risk revealed that the eastern half of the country is highly prone to landslide.[124] Deforestation, vegetation destruction by fire or other sources and inappropriate agricultural activities in Timor-Leste have contributed to creating conditions that make areas prone to landslides.[125]

Economic damages due to high and very high intensity landslide could reach 186.6 million USD to properties and 13.4 million USD to total income lost. In addition, 1,042 km of roads, 14,250 road beneficiaries, 15 water supply sources and 1,767 ha of land are at risk of damages.[126]

3.3.4 Drought

Droughts can arise from a range of hydro-meteorological processes that suppress precipitation and/or limit surface water or groundwater availability, creating conditions that are significantly drier than normal or otherwise limiting moisture availability to a potentially damaging extent. Authoritative guidance on drought characterization is provided in WMO-No. 1173, Handbook of Drought Indicators and Indices and on that basis SPI indices are calculated for Timor-Leste using Climpact (Appendix 3).

As noted above, El Niño years are generally associated with dry conditions and in many cases, extreme drought. During these conditions, water supply wells have become brackish or run dry. Acute food and water shortages, as well as the spread of disease, often prompt affected island nations to issue disaster declarations in order to receive assistance. During the 2015-2016 El Niño as shown in Figure 17, Timor-Leste experienced a severe drought.

Figure 17 depicts important drought episodes and Figure 18 depicts a decreasing trend in consecutive dry days. A seasonal analysis of SPI indices is included in Figure 19 and in Appendix 5 in which the El Niño and La Niña signature is apparent (decrease and increase in rainfall, respectively).

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[119] BoM (Australian Bureau of Meteorology) and CSIRO, 2014.
[120] World Bank, 2015. Report No: ACS13123 -Democratic Republic of Timor-Leste Building Disaster/Climate Resilience in Timor-Leste
[121] Ibid.
[122] Ibid.
[123] UNDP, 2016. Timor-Leste: Stay Connected – Reducing Climate Risks, Building the Future
[124] Ibid.
[125] Ibid.
[126] UNDP 2018, op cit

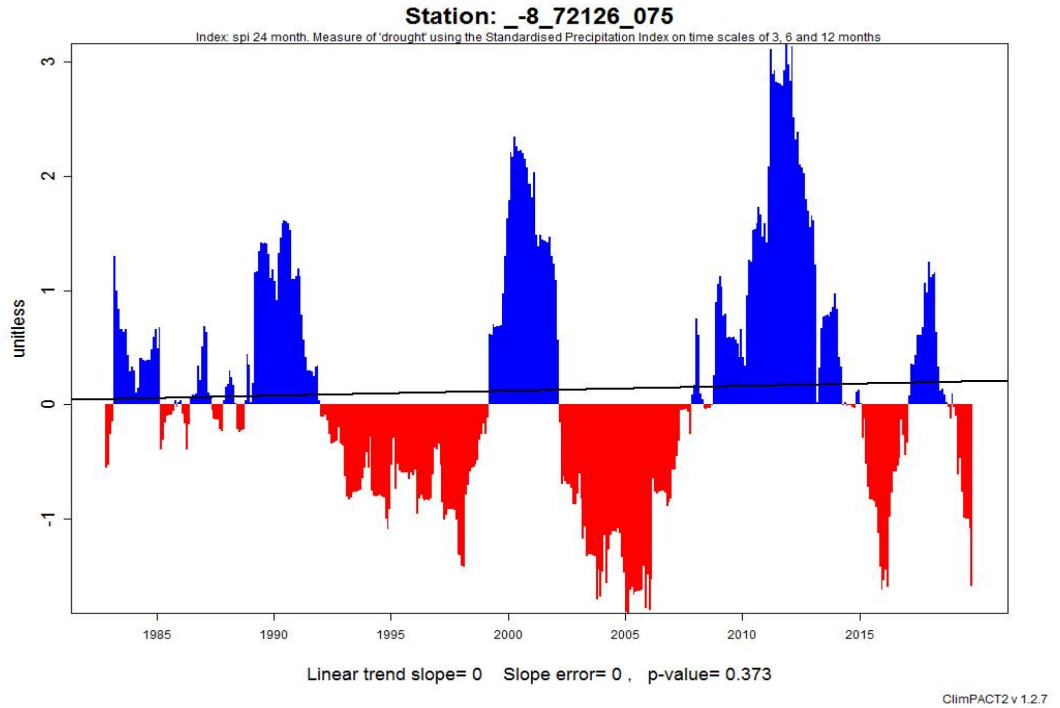

Figure 19: SPI 24 month in Timor-Leste. Prolonged drought happens in Timor-Leste periodically from one to another decade. Very important drought was observed during the decades of 1990's and 2000's (Source: WMO ET-SCI, 2020)

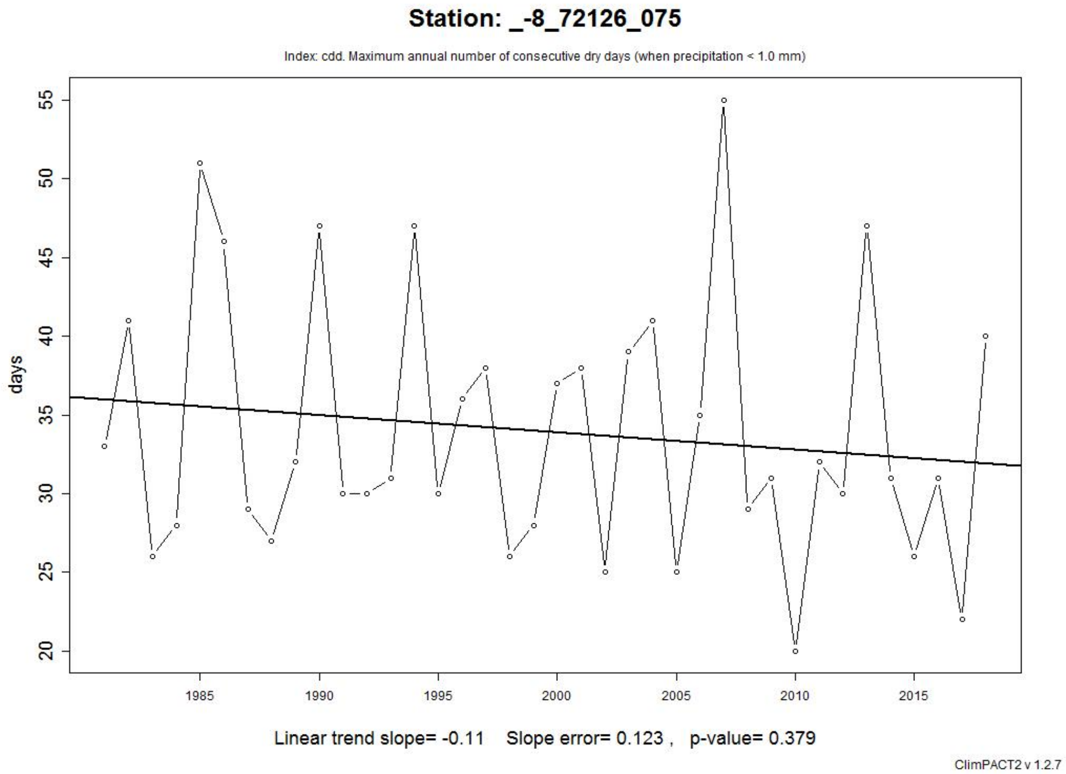

Figure 20: Consecutive Dry Days (CDD) in Timor-Leste. Maximum annual number of consecutive dry days in Timor-Leste. A decreasing trend is observed for this index. (Source: WMO ET-SCI, 2020)

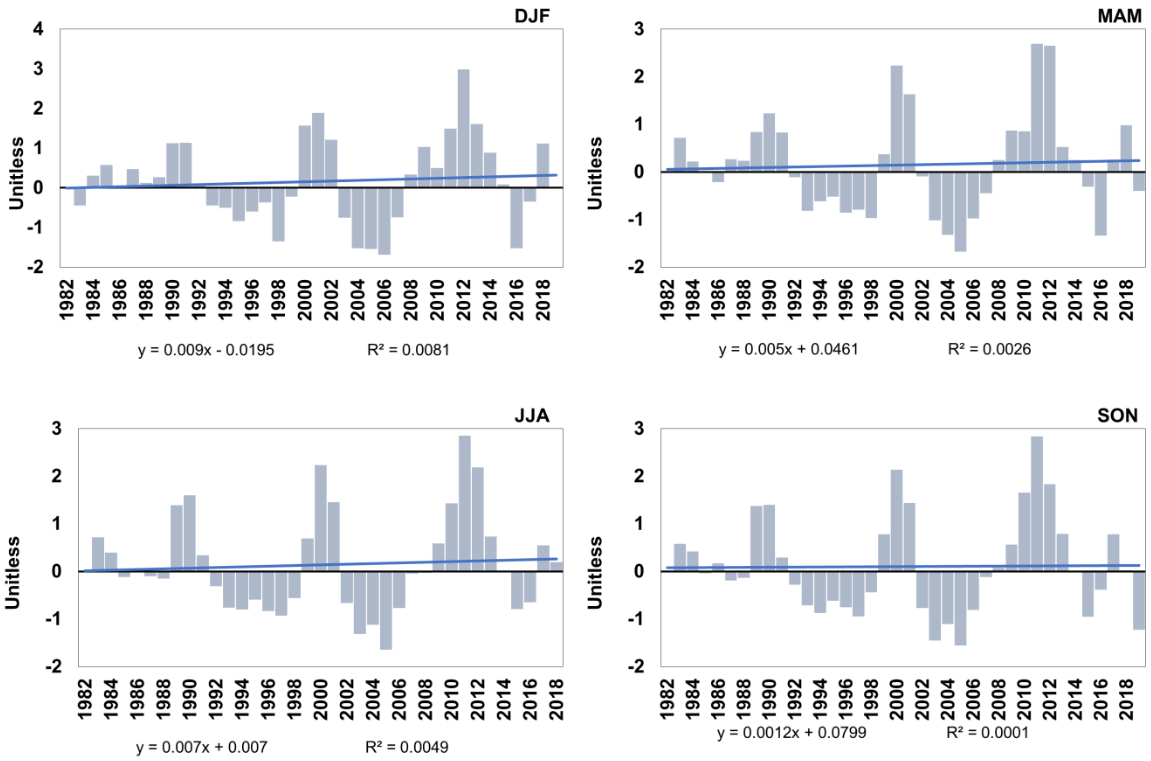

Figure 21: SPI 24-month index in Timor-Leste. Seasonal measure of "drought". Index for a gridpoint located at the centre of Timor-Leste (CHIRPS data).

3.3.5 Wildfire

Global trends

The years 2019 and 2020 have seen large wildfires causing havoc across the world. Australia recently battled its largest bushfire on record,[127] while parts of the Arctic,[128] the Amazon[129] and Central Asia[130] have also experienced unusually severe blazes. Increasing trends of damaging wildfire had already been observed earlier. These events have stimulated several studies on the link between climate change and an increase in the frequency and/or severity of fire weather around the world.

Wildfire Definition

Any unplanned and uncontrolled wildland fire which regardless of ignition source may require suppression response, or other action according to agency policy. (2) Any free burning wildland fire unaffected by fire suppression measures which meets management objectives (cf. Wildland, Wildland Fire, Prescribed Natural Fire, Prescribed Fire). [Definition source Terminology (A10.6)/CSCM, FAO, 2010. Wildland Fire Management Terminology, FAO (Updated July 2010)]

Globally, 4% of all fires in landscape are ignited by natural causes, mainly lightning.[131] Of the remaining fire events, more than 90% are human caused. However, a human-induced fire can become a wildfire. Climate change does not cause fire, but climate strongly influences weather and hence global fire activity.

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[127] https://www.carbonbrief.org/media-reaction-australias-bushfires-and-climate-change
[128] https://www.carbonbrief.org/jet-stream-is-climate-change-causing-more-blocking-weather-events
[129] https://www.newscientist.com/article/2247213-major-fires-hit-the-amazon-and-the-arctic-for-the-second-year-in-a-row/
[130] http://www.xinhuanet.com/english/2020-04/01/c_138937828.htm
[131] https://www.carbonbrief.org/explainer-how-climate-change-is-affecting-wildfires-around-the-world

Using three climate models and three fire danger indices, a recent study (Jolly *et al*., 2015[132]) has developed an annual metric of fire weather season length, and mapped spatio-temporal trends from 1979 to 2013. The study shows that fire weather seasons have lengthened across 29.6 million km^2 (25.3%) of the Earth's vegetated surface, resulting in an 18.7% increase in global mean fire weather season length. They also show a doubling (108.1% increase) of global burnable area affected by long fire weather seasons (more than 1 standard deviation above the historical mean) and an increased global frequency of long fire weather seasons across 62.4 million km^2 (53.4% of the Earth) during the second half of the period 1979 – 2013. If these fire weather changes are coupled with ignition sources and available fuel, they could markedly impact global ecosystems, societies, economies and climate.

Andela *et al.* analysed burned area from satellite data and found that, while global area burned by fires declined by 25% between 1998 and 2015, there is an increasing trend of burned area in closed canopy forest. Decreases were concentrated in regions with low and intermediate levels of tree cover, where conversion of natural savannahs and grasslands to agriculture or agriculture intensification are taking place. The study also shows that rainfall patterns explained much of the interannual variability in burned area but little of the long-term decline.[133]

A review of 116 scientific articles published since 2013 around the world strengthens the evidence that climate change increases the frequency and/or severity of fire weather – periods with a high fire risk due to a combination of high temperatures, low humidity, low rainfall and often high winds – in many regions around the world.[134]

While many fires are caused by humans, climate change is likely to result in more of these fires actually becoming "wildfires" being unplanned or uncontrolled as a result of the weather, drier and longer fire seasons.

Trends in neighbouring Indonesia

Timor-Leste shares similar climate features as in neighbouring Indonesia. The fire season occurs during the same dry season period, from June to November. In Indonesia, drought-driven fires occur typically during the warm phase of the El Niño-Southern Oscillation. This was the case of the events of 1997 and 2015 that resulted in months-long hazardous atmospheric pollution levels in Equatorial Asia and record greenhouse gas emissions. Active fire seasons have also been observed in non-drought years. A study using climate models shows that temperature sharply increases wildfire probability. Near-term regional climate projections reveal that a continuing warming trend will heighten wildfire probability over the next few decades especially in non-drought years.[135]

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[132] W. Matt Jolly, Mark A. Cochrane, Patrick H. Freeborn, Zachary A. Holden, Timothy J. Brown, Grant J. Williamson & David M.J.S. Bowman. 2015 Climate-induced variations in global wildfire danger from 1979 to 2013. Nature Communications. DOI:10.1038/ncomms8537

[133] N. Andela, D.C. Morton, L. Giglio, Y. Chen, G.R. van der Werf, P.S. Kasibhatla, R. S. DeFries, G. J. Collatz, S. Hantson, S. Kloster, D. Bachelet, M. Forrest, G. Lasslop, F. Li, S. Mangeon, J. R. Melton, C. Yue, and J.T. Randerson, 2017, A human-driven decline in global burned area, Science, 2017 356(6345): 1256-1362. https://science.sciencemag.org/content/356/6345/1356

[134] Smith, A.J.P., Jones, M.W., Abatzoglou, J.T., Canadell, J.G. & Betts, R.A. ScienceBrief Review: Climate change increases the risk of wildfires, September 2020. In: *Critical Issues in Climate Change Science*, edited by: C. Le Quéré, P. Liss, P. Forster. https://doi.org/10.5281/zenodo.4570195

[135] Fernandes, K. *et al.,* 2017. Environmental Research Letters. Heightened fire probability in Indonesia in non-drought conditions: the effect of increasing temperatures

Trends in Timor-Leste

General observations: Wildfire hazard levels are classified as 'high' in almost all of Timor-Leste, meaning that there is more than 50% chance of encountering weather that could support a significant wildfire that is likely to result in both loss of life and property in any given year.[136]

Consistent with the global scenario, fires in Timor-Leste are mostly human-induced and related to slash and burn agriculture practices. Other reasons for human-induced fire includes fire lit for hunting, renewing grass cover on pastureland, protecting village assets by removing all potential fuel ahead of the slash and burn activities or simply for pleasure. Natural occurrences, caused by lightning, are possible but expected to be rare.

Slash and burn subsistence agriculture is practiced by almost all farmers in Timor-Leste. The practice involves the annual use of 'fire' for crop cultivation as well as livestock, pasture and forest management. The activity of cutting and slashing forest is practiced by 87.1% of farmers for at least 10 years.[137] Timorese farmers are astute at managing fire. However, at times fire gets out of control and creeps out from the slash and burned fields into neighbouring landscapes. With an estimated 123,000 farming households slashing and burning forests, bush, crop residues and grasslands in Timor-Leste,[138] uncontrolled fires from slash and burn agriculture are the main cause of damaging wildfire events. The peak of slash and burn activities in Timor-Leste is during the months of September to November.

Timor-Leste's climate is characterised by a wet season from December to May and a very marked dry season from June to November with less than 100 mm per month. From August to October, rainfall is lower than 50 mm per month on average. During the dry season, the vegetation dries, leaving significant highly combustible biomass. Rugged terrain, with about half of the national territory with a slope of 40 degrees[139] and a contrasting bimodal rainfall pattern is resulting in a high land vulnerability of the landscape to wildfire. The fire season starts in June and ends in December. Uncontrolled fires ignited during the dry season are often observed to keep burning for days on the landscape.

As indicated in Section 3.4, modelled projections of future climate include an increase in surface-air temperature with more hot days,[140] lower soil moisture, greater variance in rainfall, a doubling of extreme El Niño frequency[141] and an extension of the dry season.[142] Also, while increased rainfall is expected overall, the drier area on the northern coast of the country (annual rainfall less than 1000 mm) will expand in the future and drought may become more frequent.[143]

As a result of these anticipated changes, the fire season is likely to increase in duration, and include a greater number of days with weather conditions that support wildfire spread because of longer periods without rain during the fire season. Modelled projections of future climate identify a likely increase in the frequency of fire weather occurrence in Timor-Leste, including an increase in surface-

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[136] GFDRR, 2021. ThinkHazard! Timor-Leste – Wildfire. Available at: https://thinkhazard.org/en/report/242-timor-leste/WF

[137] Jesus, M., Henriques, P., Laranjeira, P., Narcisco, V. and da Silva Carvelho, M. L. 2012 The impact of shifting cultivation in the forestry ecosystems of Timor-Leste. CEFAGE-UE Working Paper 2012/16. CEFAGE-UE, Universidade de Évora 16 pp.

[138] 87.1% of the total farmers enumerated by the 2019 Agriculture Census. Ministry of Agriculture and Fisheries, 2019, Timor-Leste Agriculture Census 2019.

[139] Thompson S., 2011. 'Geology and Soils in Timor-Leste', Seeds of Life.

[140] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report.

[141] El Niño events generally bring drier conditions to Timor-Leste, and often lead to a late onset and early finish to the wet season.

[142] Timor-Leste. State Secretary of Environment. (2014). Timor-Leste's Initial National. Communication under United Nations Framework Convention on Climate Change.

[143] Ibid.

air temperature with more hot days, lower soil moisture, greater variance in rainfall and a doubling of extreme El Niño frequency.[144] Also, while increased rainfall is expected overall, the drier area on the northern coast of the country (annual rainfall less than 1000 mm) will expand in the future and drought may become more frequent. If these fire weather changes are coupled with ignition sources and available fuel, they could result in an increased frequency, extend and severity of fire, increasing the damage and loss they cause. Wildfires are also a major source of fine particulate matter (PM2.5), which is a significant concern for public health.[145]

Under all climate change scenarios, wildfire will continue to be mostly human-induced. However, the frequency, extend and severity of these fires is affected by climate change.

Frequency of fire events trends: A rapid remote sensing analysis conducted in 2019 by FAO showed that fire events occur during and toward the end of the dry season, peaking between October and November, just before the start of the main cropping season for land preparation, before planting crops. The VIIRS imagery (Figure 20) shows an increasing trend in fire events between 2012 and 2019. It is important to note that remote sensing detects large fire events that burn across the landscape, but do not detect the smaller, but far more numerous and widespread, slash and burn fires on agriculture land that, generally, remain under control. Therefore, the VIIRS imagery largely illustrates trends on wildfire, or uncontrolled fire events. These trends are likely to persist under the modelled projections of future climate.

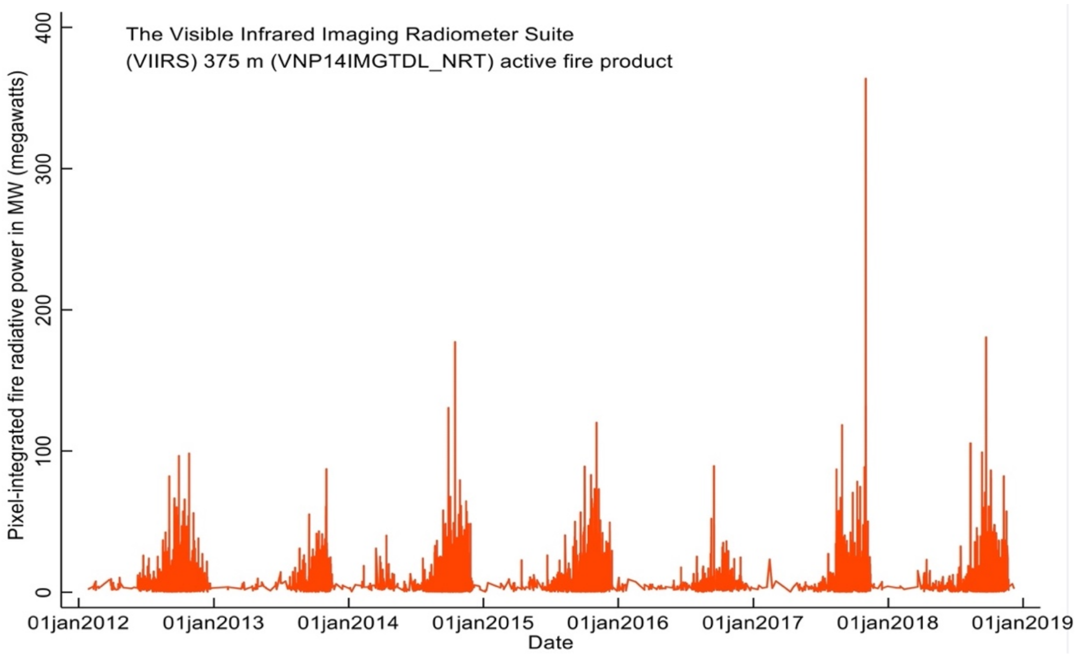


Figure 22: Distribution of fire incidences in Timor-Leste across the years from 2012 to 2018, identified in the 375-m spatial resolution Visible Infrared Imaging Radiometer Suite (VIIRS) active fire product (FAO, 2019)

Focus-group discussions on fire events held in 12 communities in November 2020 by FAO showed that on the drier north coast region, communities expressed that there are more fire events now than during the Indonesian occupation (1975-1999), while on the wetter south coast region, communities considered that there are less fire events now. These observations are consistent with climate change scenarios. Yet, communities in the southern part of the country considered there were more fire

[144] Cai, W. *et al.* 2014. Nature Climate Change. Increasing frequency of extreme El Niño events due to greenhouse warming

[145] Aguilere, R. *et al.,* 2021. Nature Communications. Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California

events in the past, suggested this was due to the Indonesian military regularly burning all forest areas in the country. There are less of such forested areas on the dryer northern coast region.

Extent of fire trends: An on-going FAO study in Timor-Leste has presented preliminary 30 years estimates of the burned area. The estimates were produced with Landsat imageries. The 2001-2020 timeseries have been post-classified, using Moderate Resolution Imaging Spectroradiometer (MODIS) as a filter, and therefore estimates are in a different range. However, both timeseries indicate an increasing trend in burned areas over the past 30 years. Landsat imagery is also likely not picking up smaller slash and burn fire on farmers field and therefore, these trends represent larger burned areas most commonly from wildfire.

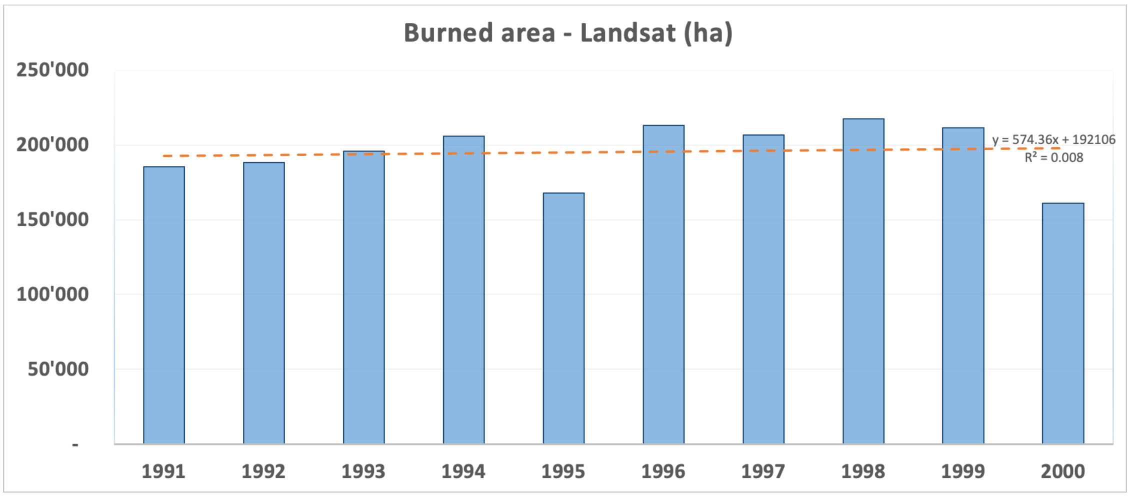


Figure 23: Preliminary estimates of burned area, analysis Landsat imageries at 30-metre spatial resolution for the time period 1991 – 2090 (FAO ongoing assessment)

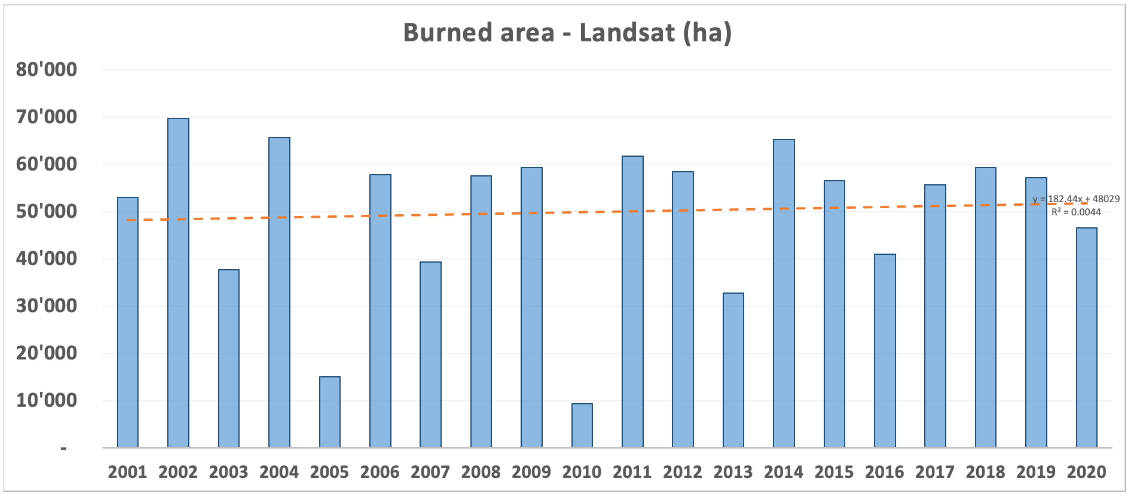


Figure 24: Preliminary estimates of burned area, analysis Landsat imageries at 30-metre spatial resolution for the time period 2001 – 2020 (FAO ongoing assessment)

Climate change is also anticipated to result in reduced crop yield, and crop failures, during the El Niño years. As a result of lower agriculture productivity, Timorese farmers are likely to increase the area under slash and burn to compensate for the losses in production. According to the 2019 Agriculture Census, approximately 140,000 ha of land is cultivated with rice and corn in Timor-Leste, much of which is burned every year. In turn, this projected trend on agriculture land is also expected to increase the incidence of wildfire, or uncontrolled fire events.

Extent of fire trends and Vegetation Health Index: An analysis was done with the MODIS Vegetation Index and superposed the average Vegetation Health Index (VHI) values for the peak fire activities in Timor-Leste, from September to November, when farmers are actively engaged in slash and burn activities. The VHI is based on a combination of products extracted from vegetation signals, namely the Normalized Difference Vegetation Index (NDVI, providing information on the vegetation canopy greenness)[146] and the Land Surface Temperature.[147] VHI is used for drought monitoring, such as in the Agriculture Stress Index System (ASIS) drought early warning[148]. The VHI values were extracted from the Global Information and Early Warning System (GIEWS) database and values for the months of September to November were averaged, illustrating the relationship that exists between VHI and burned area.

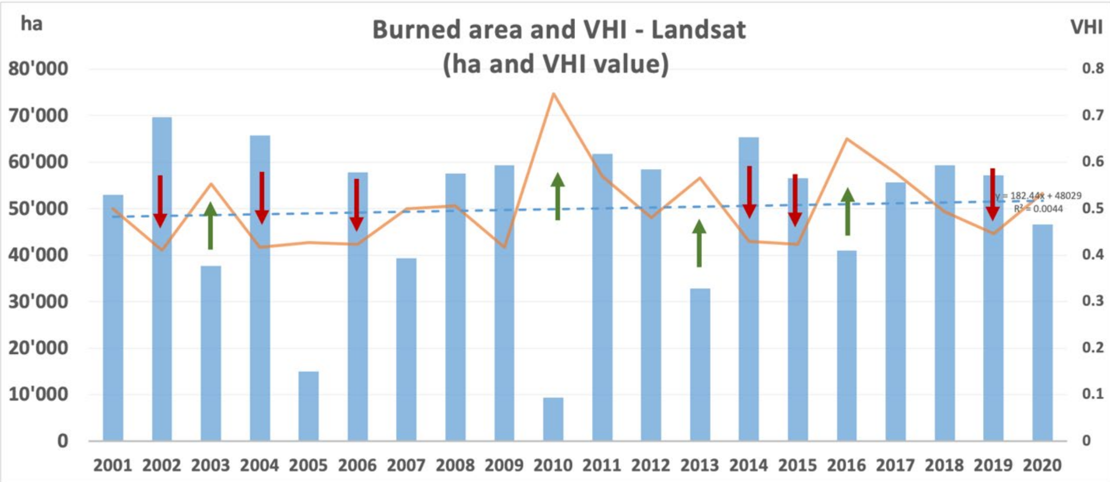


Figure 25: Preliminary estimates of burned area, superimposed with VHI values. (FAO ongoing assessment and FAO GIEWS database)

Extent of fire trends and surface temperature: A review of MODIS Land Surface Temperature[149] superposed the average Land Surface Temperature values for the peak fire activities in Timor-Leste, from September to November, when farmers are actively engaged in slash and burn activities. The Land Surface Temperature data were accessed from https://www.earthmap.org. These observations are consistent with Fernandes *et al*. (2017) study[150] in neighbouring Indonesia.

Although a statistical analysis was not conducted, the data suggests a correlation exists between burned areas and the Vegetation Health Index as well as burned areas and surface temperature. This supports the correlation between climate change projections – characterized by increased in surface-air temperature with more hot days, lower soil moisture, greater variance in rainfall, a doubling of extreme El Niño frequency and an extension of the dry season – will indeed increase the frequency, extent and severity of fires in Timor-Leste.

[146] https://modis.gsfc.nasa.gov/data/dataprod/mod13.php
[147] https://modis.gsfc.nasa.gov/data/dataprod/mod11.php
[148] FAO, 2019, Country-Level ASIS: an Agriculture Drought Monitoring System.
[149] https://modis.gsfc.nasa.gov/data/dataprod/mod11.php
[150] Fernandes, K. *et al.,* 2017. Environmental Research Letters. Heightened fire probability in Indonesia in non-drought conditions: the effect of increasing temperatures

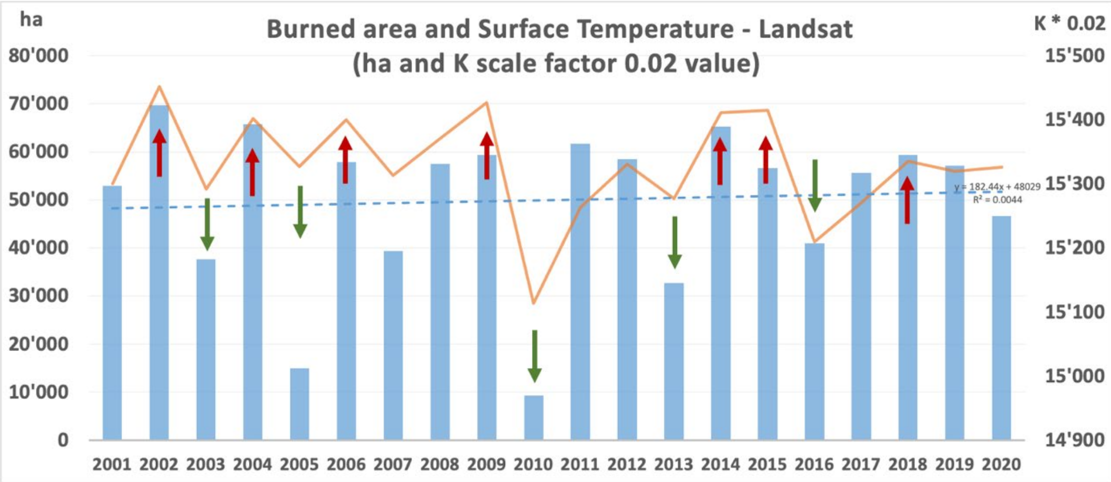


Figure 26: Preliminary estimates of burned area, superimposed with Land Surface Temperature values. (FAO ongoing assessment and FAO GIEWS database)

High impact events – new trends: Most of the damaging fires occur between June and November and more serious events are associated with El Niño. In November 2020, FAO conducted a community fire management assessment in 12 villages and found that 8 out of 12 communities indicated that they experienced at least one or more damaging wildfire events since 2018.

Timorese have been managing fire for centuries and are implementing successful strategies that have been effective overtime to limit loss of lives and assets as a result of uncontrolled fire events. These strategies include the clearing of vegetation around houses throughout the year and, at the beginning of the fire season, the cleaning and burning of biomass in and around villages. Customary laws also foresee penalties for farmers who do not control fire on their farmland that subsequently damage community assets.

The largest recorded damaging wildfire in Timor-Leste occurred in the municipality of Ermera on 2nd – 3rd October 2019. The impact of this disaster was exacerbated by significant damage to houses in adjoining areas caused by the prevailing strong winds. The State Secretariat for Civil Protection surveyed the damage in the affected areas and found that 119 houses were destroyed by the fire and 2 people were injured. It also found that in Urahou village, four sacred houses, seven schools, two churches and 238 coffee plantations were destroyed and that all households affected by fire had lost livestock, including goats, pigs, sheep and chickens.[151]

Focus-group discussions held by FAO at Urahou village suggest that a new trend is occurring with fires in Timor-Leste that traditional management practices are not able to address. Consistent with climate projections with fires become hotter and larger (due to higher air temperature and lower soil moisture), the community in Urahou has described the October 2019 fire event as being particularly intense. Coupled with a strong wind on that day, intense fires produced burning fuel thrown up in the air by heat-generated convection and transported by wind to neighbouring locations, lighting new wildfires and destroying traditional houses, village assets and coffee plantations.

Addressing fire issues

Addressing the practice of slash and burn: Farmers in Timor-Leste have used fire for centuries and have become very astute in managing fire related risks. However, as indicated above, climate change

[151] Democratic Republic of Timor-Leste, 2019. 'Multi-Sectoral Rapid Needs Assessment: Fire and Strong Wind Impact in Ermera Municipality', December 2019.

is generating a new set of problems that are challenging customary practices and norms. The farmer slashing and burning his field in Ermera on a windy day in October 2019 was not prosecuted neither by the formal or customary justice system precisely because the spread of fire was beyond the customary practice control.

The main factors that could influence Timorese farmers to change their farming practices is to have access to proven Climate-Resilient Agriculture technologies and practices – and a market to sell agricultural produce from these new farming practices – that offers alternatives to traditional fire-based land management systems. FAO has supported the Ministry of Agriculture and Fisheries (MAF) to redefine the three principles of Conservation Agriculture (CA) in Timor-Leste, placing "no burning" as the first principle, with "minimum tillage" and "growing a high-biomass producing cover crop" as the other two principles. While it is globally accepted that the three principles of CA are "minimum tillage", "permanent soil cover" and "crop rotation", these adaptations were made to underline that without stopping the practice of burning, none of the climate-resilient agriculture technology can be implemented in Timor-Leste.

FAO in Timor-Leste is promoting conservation agriculture, agroforestry, rotational grazing and participatory land use planning to break the cycle of shifting slash and burn farming and address the negative impacts of uncontrolled fire at landscape level. A short video illustrating the issue was produced by FAO in Timor-Leste and is accessible at the following link: https://www.youtube.com/watch?v=Tw_f1wGT_iU&t=18s

3.4 – COUNTRY-LEVEL CLIMATE PROJECTIONS

3.4.1 Rainfall

There is uncertainty around rainfall projections as model results are not consistent. Projections generally suggest that long-term rainfall over Timor-Leste will remain similar to the current climate (Figure 21). Wet and dry years will still occur in response to natural variability.[152] Rainfall associated with the West Pacific Monsoon is projected to generally increase.[153]

The output of CMIP5 models show a range of projected rainfall change from an increase to a decrease, and the model average is near zero.[154] The range is greater in the highest emissions scenarios (Figure 20), and the pattern is similar for both dry season and wet season rainfall.[155] There will still be wet and dry years and decades due to natural variability, and a wetter or drier future is possible in the long term.[156] The effect of climate change on average rainfall may not be obvious in the short or medium term due to natural variability.[157]

[152] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report
[153] Ibid.
[154] Ibid.
[155] Ibid.
[156] Ibid.
[157] Ibid.

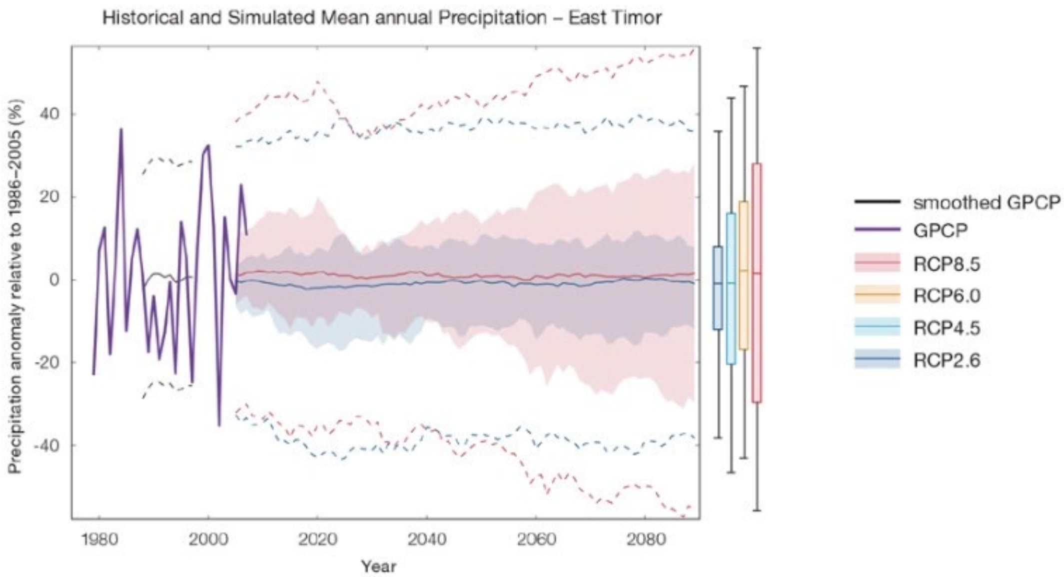


Figure 27: Historical and simulated annual average rainfall time series for the region surrounding Timor-Leste

The graph above shows that the anomaly (from the base period 1986–2005) in rainfall from observations (the GPCP dataset, in purple), and for the CMIP5 models under the very high (RCP8.5, in red) and very low (RCP2.6, in blue) emissions scenarios. The solid red and blue lines show the smoothed (20-year running average) multi-model mean anomaly in rainfall, while shading represents the spread of model values (5–95th percentile). The dashed lines show the 5–95th percentile of the observed interannual variability for the observed period (in black) and added to the projections as a visual guide (in red and blue). This indicates that future rainfall could be above or below the projected long-term averages due to interannual variability. The ranges of projections for a 20-year period centred on 2090 are shown by the bars on the right for RCP8.5, 6.0, 4.5 and 2.6.[158]

Changes of rainfall types

The spatial patterns of rainfall in Timor-Leste are expected to change in the future. This is shown by the changes in the total area of each rainfall type as shown in Figure 22 and Figure 23. Consistent decreases are found at all periods in the RCP2.6 scenario for total rainfall area in Type 1, 2 and 4, with the decrease reaching 10% of the current total area. Similar consistent decreases for the same rainfall types are also found in the RCP6.0 scenario but only during the 2041-2070 and 2071-2100 periods with the decreases less than 8%. The decreases of total area having Type 1, 2 and 4 rainfall regions contribute to the increase of total area having Type 3 and 5 rainfall regions.

[158] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report

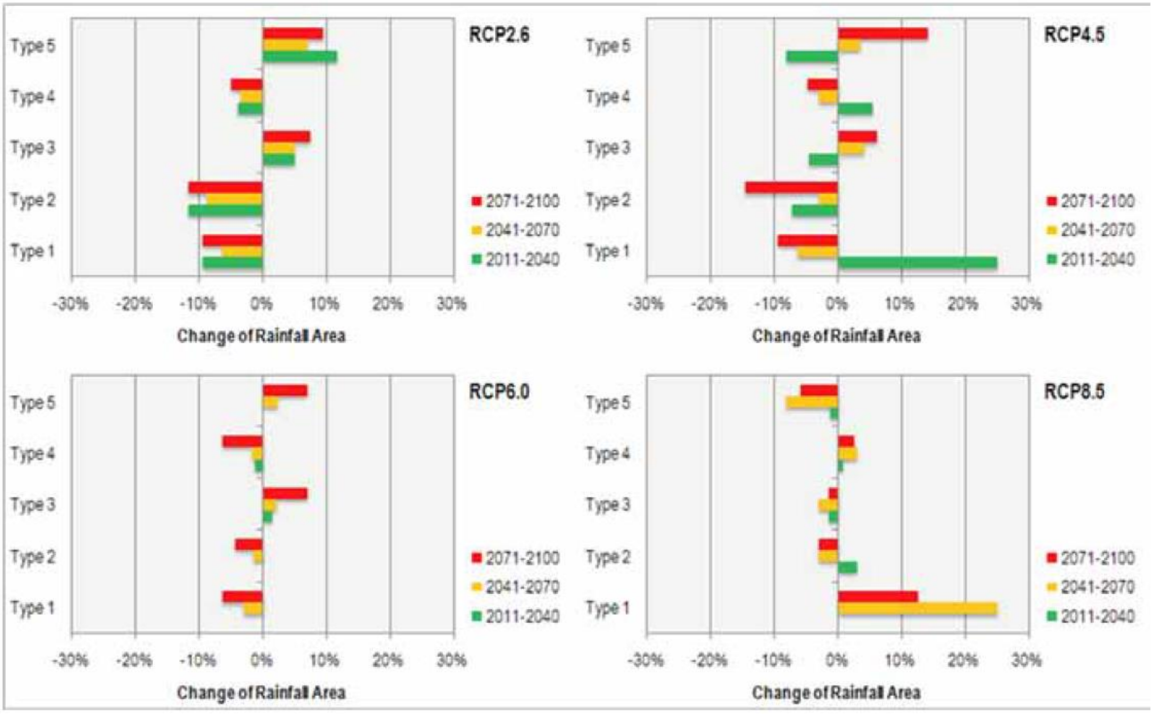


Figure 28: Projected changes of total area at different rainfall types (Source: Timor-Leste, 2014)

In the RCP4.5 scenario, the changes of total rainfall area across different rainfall types are varied at different periods. The highest increase is found in the Type 1 rainfall region during the period 2011–2040, reaching a more than 20% increase. Such an increase contributes to the decrease of areas having Type 2, 3 and 5 rainfall.

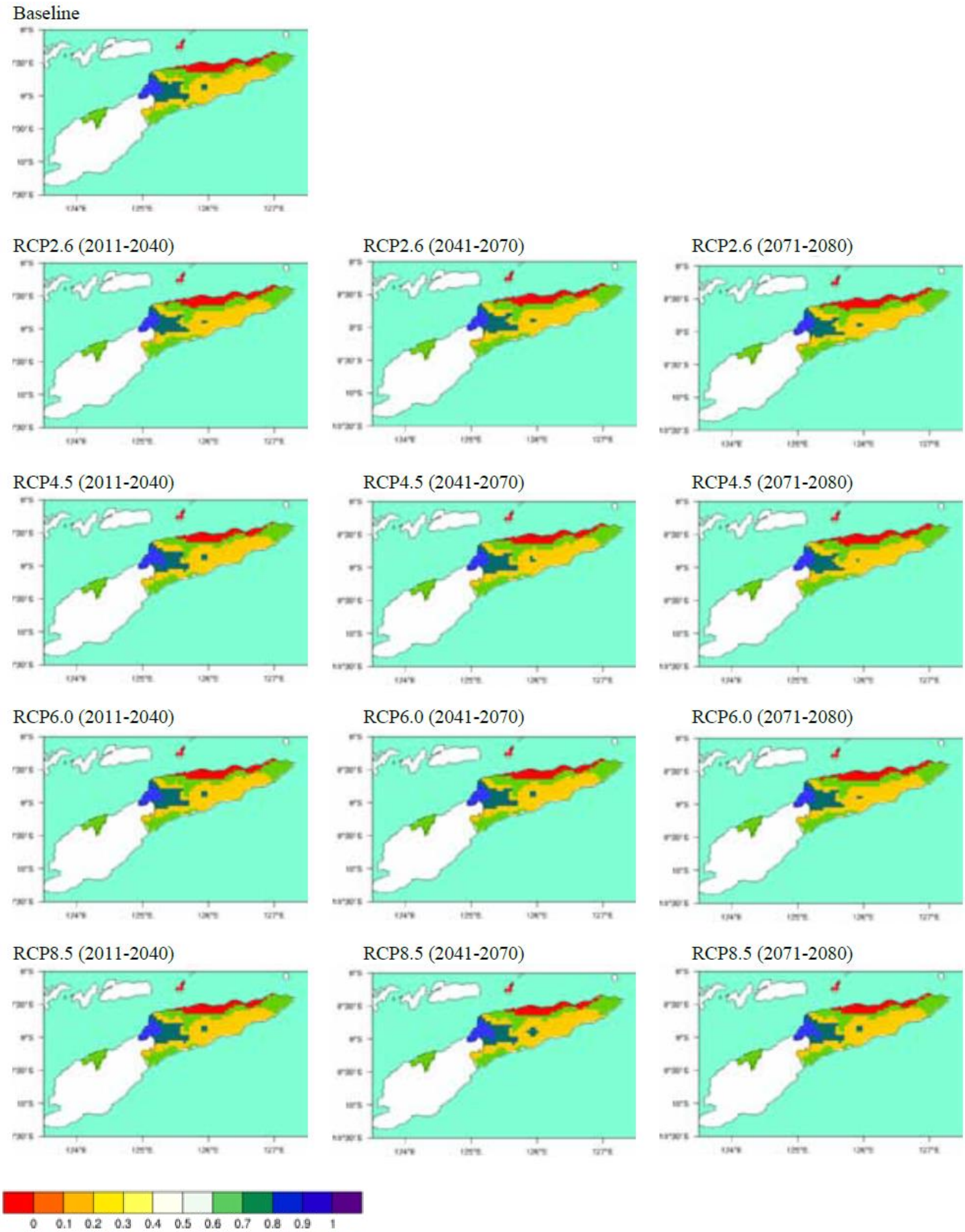


Figure 29: Changes in the spatial patterns of rainfall types in Timor-Leste based on the 20 GCMs multi- model ensemble projection under four RCP scenarios at three different future periods, i.e. in 2011-2040, 2041- 2070 and 2071-2100. (Source: Timor-Leste, 2014)

Changes in monthly and seasonal rainfall climatology

Timor-Leste is projected to experience some changes in monthly and seasonal rainfall climatology in the future, as has already happened in the past. Unlike the change of monthly rainfall climatology in the past where the changes were mostly found in the wet season, the future projections indicate that the change of rainfall will be expected to occur in the dry season and the transition of the season, especially from July to October in the 2011–2040 and 2071–2100 periods. The rainfall increases during those months may reach more than 10% of the current rainfall baseline. In 2041–2070, more rainfall is expected during transition periods in March, April and May, as well as in September. Meanwhile, rainfall is projected to decrease in June and July during that period (Figure 24).

Based on the consensus of 20 CMIP5 GCMs, it can be seen that in 2011–2040 and 2041–2070 under the RCP2.6 scenario, the models agree that the wet season rainfall in the DJF season is expected to decrease compared to the current baseline. Within the same scenario, the models agree that there will be an increase in MAM rainfall, especially during the 2041–2070 and 2071–2100 periods. For the JJA and SON periods, there is only around 0.5% probability that rainfall will increase in all periods, except for the SON rainfall in 2041–2070 where most models agree that the season will experience a rainfall decrease (Figure 25).

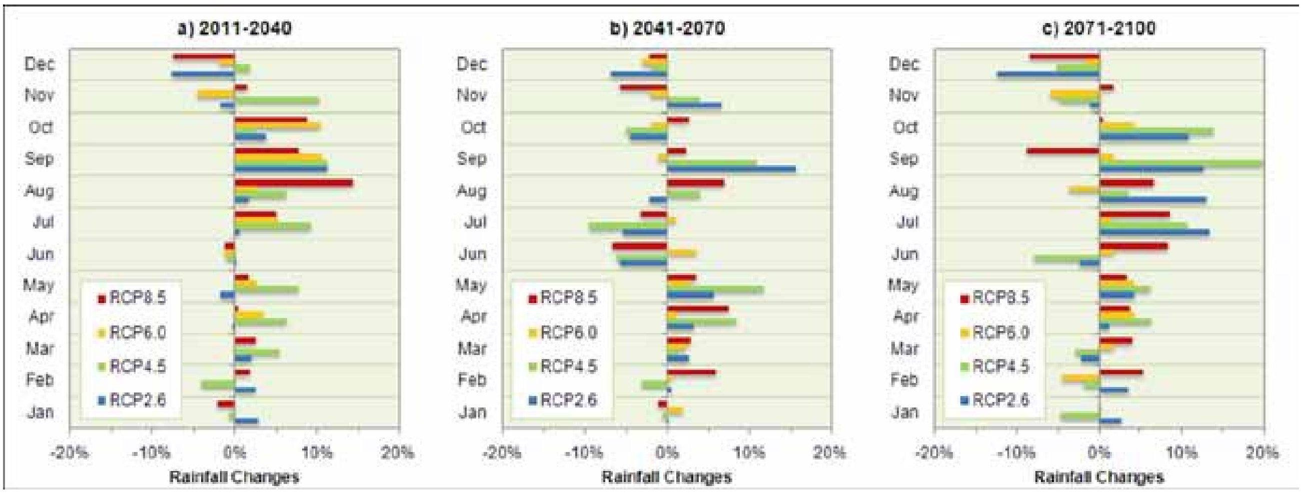


Figure 30: Changes of monthly rainfall climatology in Timor-Leste as projected by the median of 20 CMIP5 GCMs based on four RCP scenarios (Source: Timor-Leste, 2014)

Under the RCP4.5 scenario, different projections' results on future rainfall are shown (Figure 26). Unlike the RCP2.6 scenario, dry season rainfall under the RCP4.5 scenario is expected to increase in the future, especially during the 2011–2040 and 2041–2070 periods. Nevertheless, a similar result is projected for SON rainfall in 2041–2070 with the RCP6.0 scenario (Figure 27), where most models agree that the season will experience a rainfall decrease over some areas in the country. Especially for this season, most models project an increase in rainfall under the RCP6.0 scenario for all time periods assessed. Under the highest range scenario (RCP8.5; Figure 28), the models mainly show a nearly fifty-fifty change of agreement, indicating a very low consensus in future seasonal rainfall projections in Timor-Leste. Similarly, this is found in other RCP scenarios. The only clear model consensus is a projected increase in future rainfall in Timor-Leste under the RCP8.5 in MAM during the 2011–2040 and 2041–2070 periods.

RCP2.6

DJF MAM JJA SON

2011-2040

2041-2070

2071-2100

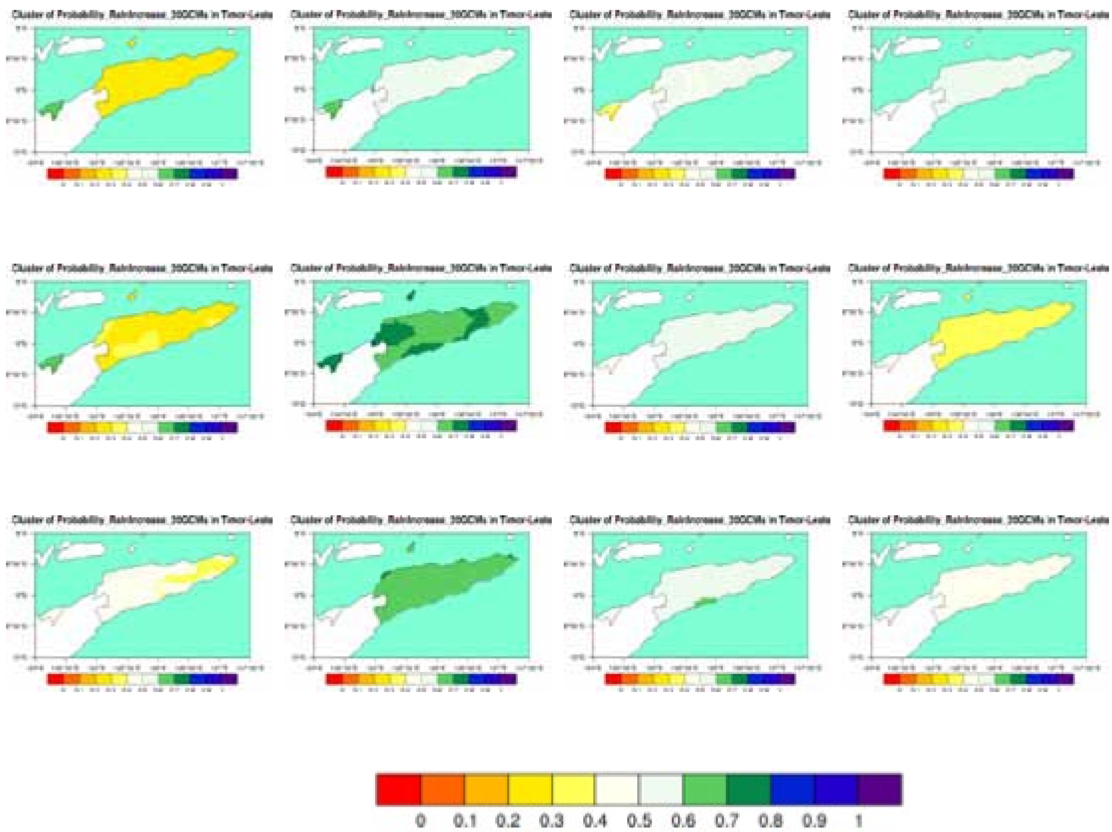


Figure 31: Level of probability of 20 CMIP5 GCM models under the RCP2.6 scenario in projecting seasonal rainfall increases in Timor-Leste (Source: Timor-Leste, 2014)

RCP4.5

DJF MAM JJA SON

2011-2040

2041-2070

2071-2100

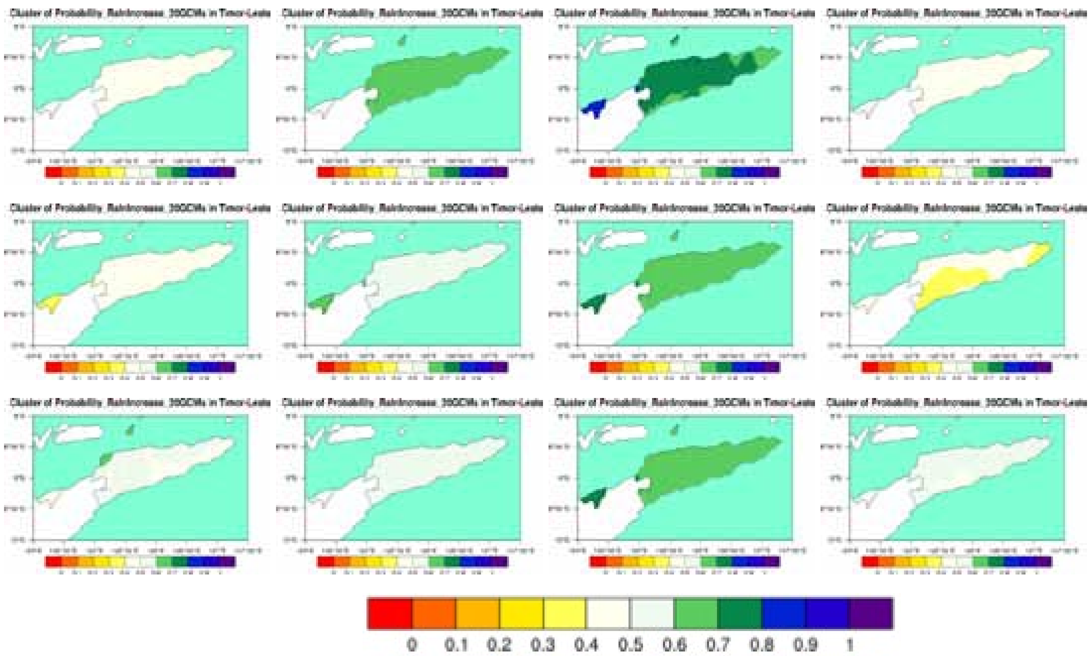


Figure 32: Level of probability of 20 CMIP5 GCM models under the RCP4.5 scenario in projecting seasonal rainfall increases in Timor-Leste (Source: Timor-Leste, 2014)

RCP6.0

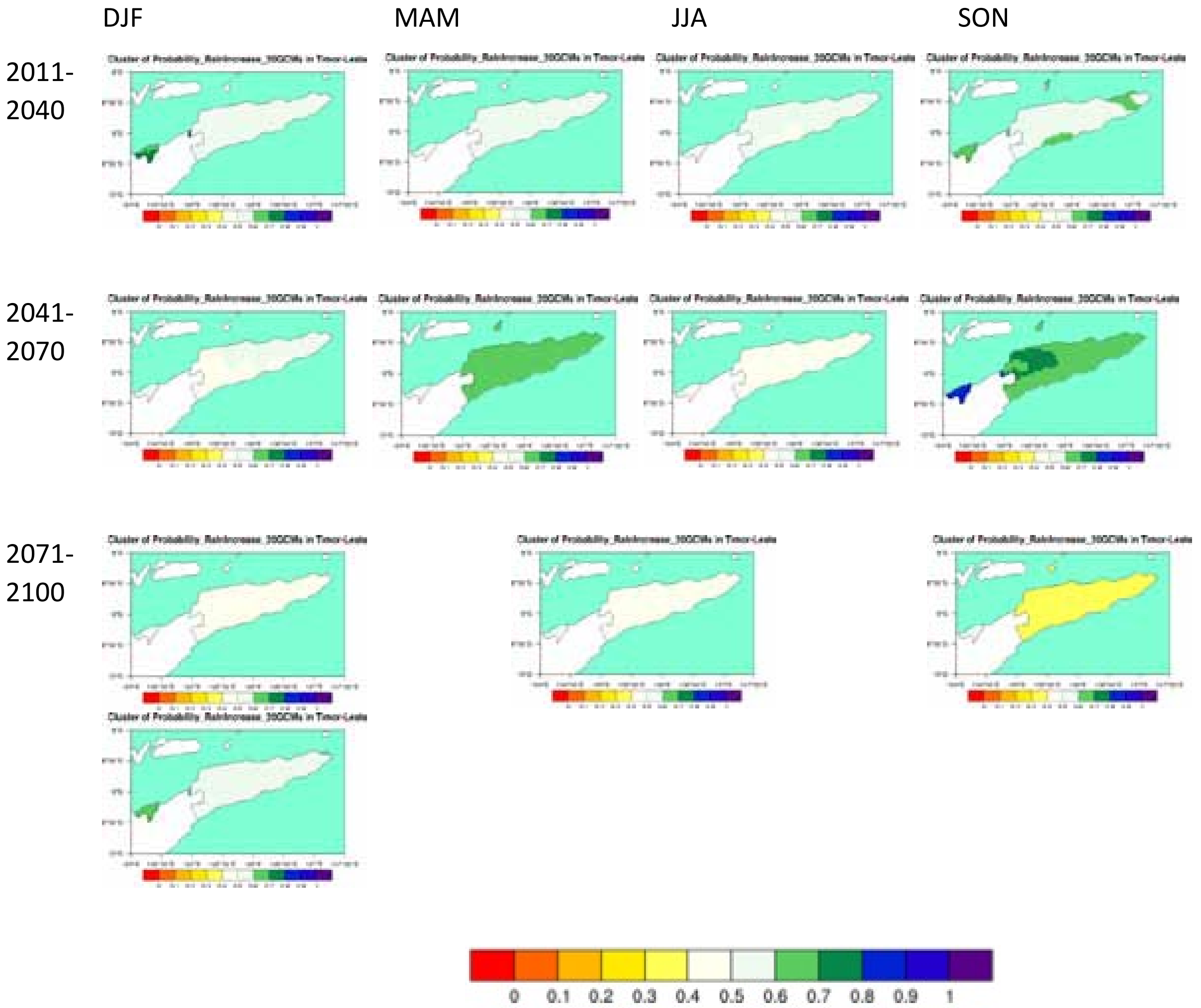
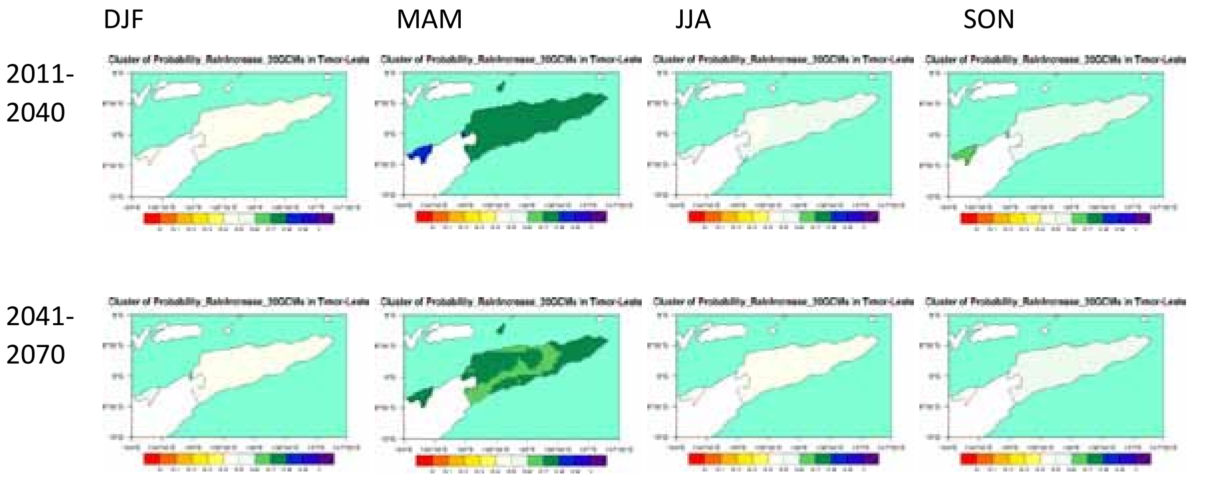


Figure 33: Level of probability of 20 CMIP5 GCM models under the RCP6.0 scenario in projecting seasonal rainfall increases in Timor-Leste (Source: Timor-Leste, 2014)

RCP8.5



2071-
2100

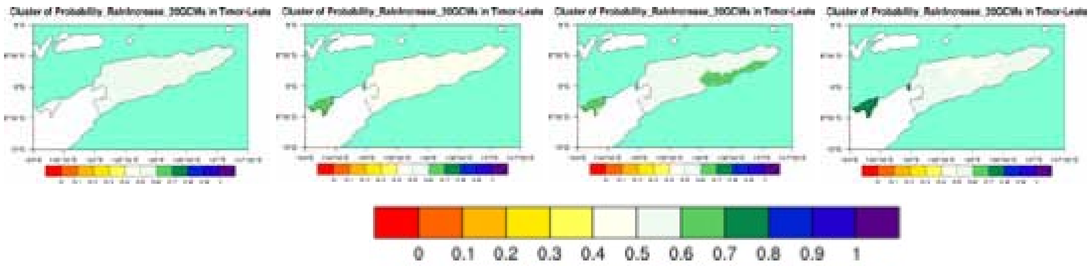


Figure 34: Level of probability of 20 CMIP5 GCM models under RCP8.5 scenario in projecting seasonal (Source: Timor-Leste, 2014

Onset, End and Length of the Seasons

In the future, the wet season onset may be delayed by about 20 days from the current climate pattern, while dry season onset may be delayed by as much as 11 days, depending on the period and emission scenarios. In addition, the drier area on the northern coast of the country (annual rainfall less than 1000 mm) will expand in the future.[159] These changes in both spatial and temporal rainfall distribution will have significant impacts on the water balance. Both subsistence and commercial farmers need local-scale advice on these changes to inform planting time, crop type and harvesting decisions.

Changes in Future Extreme Events Related to Precipitation

Floods: Based on analysis of daily rainfall data from a subset of CMIP5 models,[160] the frequency and intensity of extreme rainfall events are projected to increase.[161] The current 1-in-20-year daily rainfall amount is projected to increase by approximately 11 mm by 2030 for RCP2.6 and by 15 mm by 2030 for RCP8.5.[162] By 2090, it is projected to increase by approximately 18 mm for RCP2.6 and by 45 mm for RCP8.5.[163] The majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in-7-year event for RCP2.6 and a 1-in-5-year event for RCP8.5 by 2090.[164]

Droughts: For Timor-Leste, the overall proportion of time spent in drought is expected to decrease slightly under RCP8.5 and stay approximately the same under all other scenarios. Under RCP2.6 (very low emissions) the frequency and duration of events in all drought categories is projected to stay approximately the same from the present to 2090.[165]

There is low confidence in the projections of drought frequency and duration because there is low confidence in the magnitude of rainfall projections.[166] However, the frequency of extreme El Niño events is projected to double in the period 1991 – 2090 due to global warming.[167] This may result in the more frequent occurrence of extreme drought events in the future.[168]

3.4.2 Temperature

Changes in Historical Extreme Events

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[159] CSIRO. 2010. Climate change in Timor-Leste – a brief overview on future climate projections.
[160] Further details on the methodology used for the projections are provided in “Climate Variability, Extreme and Change in the Western Tropical Pacific: New Science and Updated Country Reports 2014”,[160] specifically Chapters 1 and 3.
[161] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report
[162] Ibid.
[163] Ibid.
[164] Ibid.
[165] Ibid.
[166] Ibid.
[167] Cai, W. *et al.*, 2014. Nature Climate Change. Increasing frequency of extreme El Niño events due to greenhouse warming
[168] Yale Environment 360, 2019. Climate Change is Making El Niños More Intense, Study Finds. Available at: https://e360.yale.edu/digest/climate-change-is-making-el-ninos-more-intense-study-finds

Since the historical daily temperature data were not of sufficient quality or completeness for assessing recent past and present extremes, ERA5 data were used to calculate the Climpact 2.0 temperature indices over the 1981-2010 period. Figure 29 shows an increasing trend in hot days, increasing at a rate of 48 hot days per decade. Figure 30 shows an increase in the annual percentage of days when the maximum temperature is above 90th percentile across all seasons for the 1981-2010 period. This is in line with regional and global trends.

The emerging trends in temperature have implications across a range of socio-economic sectors. Heatwaves in particular present wide-ranging health risks, including respiratory diseases, heat exhaustion, heat stroke and even death. They amplify existing conditions and result in premature death, disability and illness, including exacerbation of non-communicable diseases and the effects of air pollution.

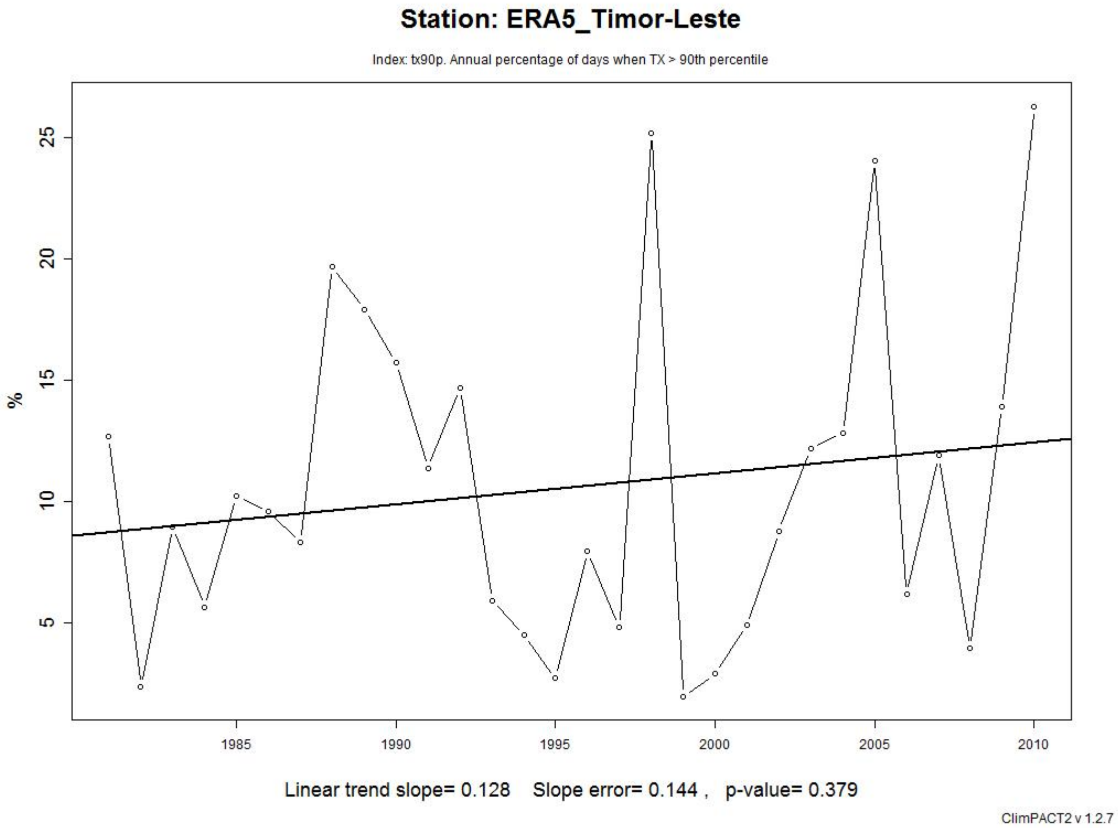
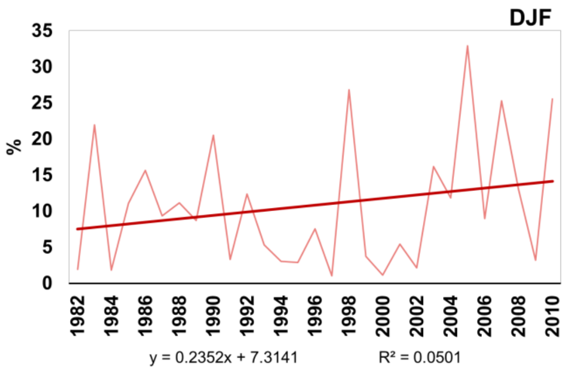
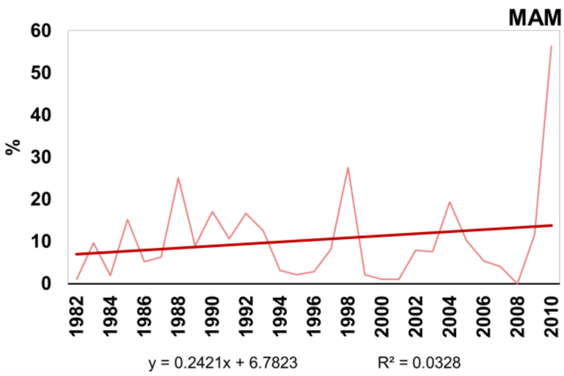


Figure 35: TX90p index in Timor-Leste. Annual percentage of days when maximum temperature is above the 90th percentile. (Source: WMO ET-SCI, 2020)





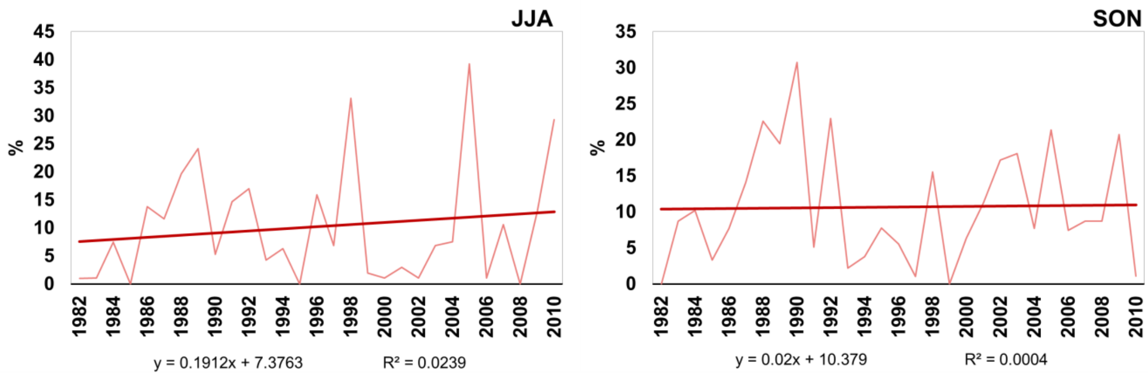


Figure 36: TX90p index in Timor-Leste. Seasonal percentage of days when TX > 90th percentile. (ERA5 data).

Projected Changes in Temperature

Projections for all emissions scenarios indicate that the annual average air temperature and sea-surface temperature will increase in the future in Timor-Leste (Figure 31). Under all RCPs, the warming is up to 1.1°C by 2030, relative to 1995, but after 2030 there is a growing difference in warming between each RCP.[169] For example, by 2090 a warming of 2.4 to 4.2°C is projected for RCP8.5 (very high emissions) while a warming of 0.5 to 1.2°C is projected for RCP2.6 (very low emissions).[170] While relatively warm and cool years and decades will still occur due to natural variability, there is projected to be more warm years and decades on average in a warmer climate.[171]

Given the observed upward trend in extreme heat (Figure 29) and the projected increase in temperature under the different scenarios (Figure 31), multi-hazard early warning systems inclusive of heat early warnings will be essential for resilience and adaptation efforts.

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[169] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report

[170] Ibid.

[171] Ibid.

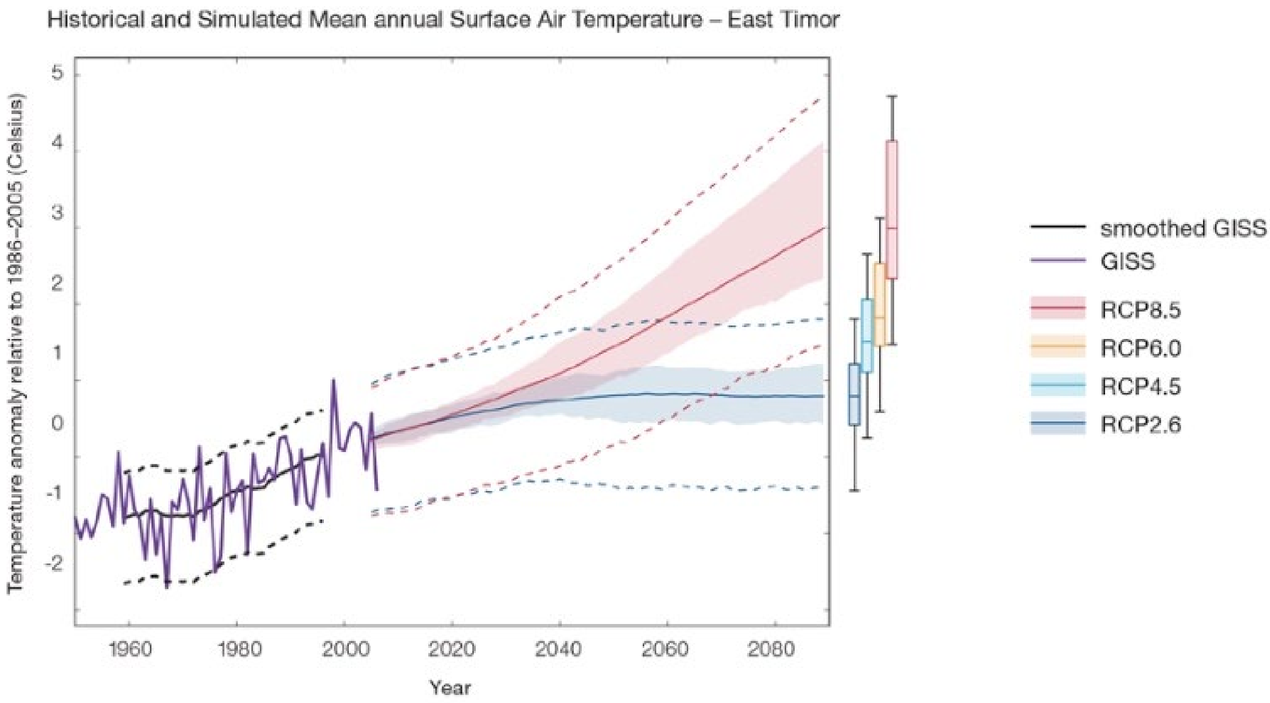


Figure 37: Historical and simulated surface air temperature time series for the region surrounding Timor-Leste. (Source: BOM and CSIRO, 2014)

The graph above shows the anomaly (from the base period 1986–2005) in surface air temperature from observations (the GISS dataset, in purple), and for the CMIP5 models under the very high (RCP8.5, in red) and very low (RCP2.6, in blue) emissions scenarios. The solid red and blue lines show the smoothed (20-year running average) multi-model mean anomaly in surface air temperature, while shading represents the spread of model values (5–95th percentile). The dashed lines show the 5–95th percentile of the observed interannual variability for the observed period (in black) and added to the projections as a visual guide (in red and blue). This indicates that future surface air temperature could be above or below the projected long-term averages due to interannual variability. The ranges of projections for a 20-year period centred on 2090 are shown by the bars on the right for RCP8.5, 6.0, 4.5 and 2.6.

3.4.3 Sea Level Rise

Sea level has risen near Timor-Leste by about 9mm per year since 1993.[172] This rising pace is two to three times faster than the global average. Mean sea level is projected to continue to rise over the course of the 21st century in Timor-Leste.[173] The CMIP5 models simulate a rise of between approximately 8–18 cm by 2030 (very similar values for different RCPs), with increases of 43–88 cm by 2090 under the RCP8.5.[174] There is medium confidence in the range of sea level rise mainly because there is still uncertainty associated with projections of the Antarctic ice sheet contribution.

[172] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report
[173] Ibid.
[174] BoM (Australian Bureau of Meteorology) and CSIRO, 2014.

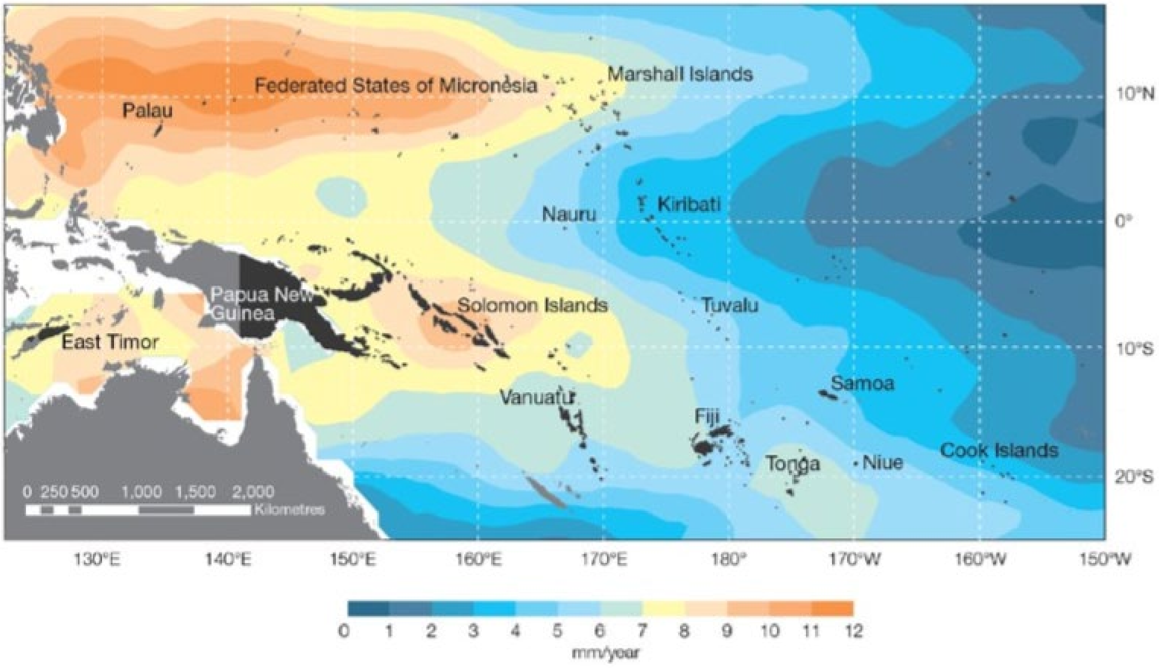


Figure 38: Distribution of sea level rise measured by satellite altimeters from January 1993 to December 2009. (Source: Australian BoM and CSIRO, 2014)

Interannual variability of sea level will lead to periods of lower and higher regional sea levels. In the past, this interannual variability has been about 24 cm (5–95% range, after removal of the seasonal signal, see dashed lines in the below figure) and it is likely that a similar range will continue through the 21st century.[175]

[175] Ibid.

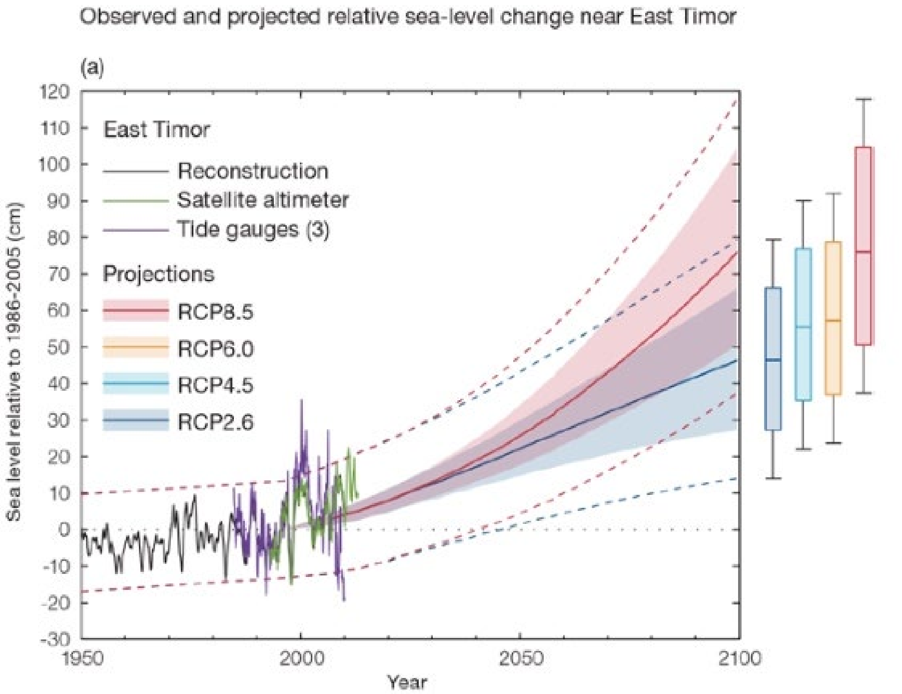


Figure 39: Observed and project relative sea-level change near Timor-Leste (Source: BoM and CSIRO, 2014)

In the graph above the observed tide-gauge records of relative sea-level (since the late 1970s) are indicated in purple, and the satellite record (since 1993) in green. The gridded (reconstructed) sea level data at Timor-Leste (since 1950) is shown in black. Multi-model mean projections from 1995–2100 are given for the RCP8.5 (red solid line) and RCP2.6 emissions scenarios (blue solid line), with the 5–95% uncertainty range shown by the red and blue shaded regions. The ranges of projections for four emission scenarios (RCPs 2.6, 4.5, 6.0 and 8.5) by 2100 are also shown by the bars on the right. The dashed lines are an estimate of interannual variability in sea level (5–95% uncertainty range about the projections) and indicate that individual monthly averages of sea level can be above or below longer-term averages.

The regional distribution of projected sea level rise under the RCP4.5 emissions scenario for 2081–2100 relative to 1986–2005 is shown in the figure below. The sea-level rise combined with natural year-to-year changes will accentuate the impact of storm surges and coastal flooding. As there is still much to learn, particularly how large ice sheets such as Antarctica and Greenland contribute to sea-level rise, scientists warn that larger rises than currently predicted could be possible.

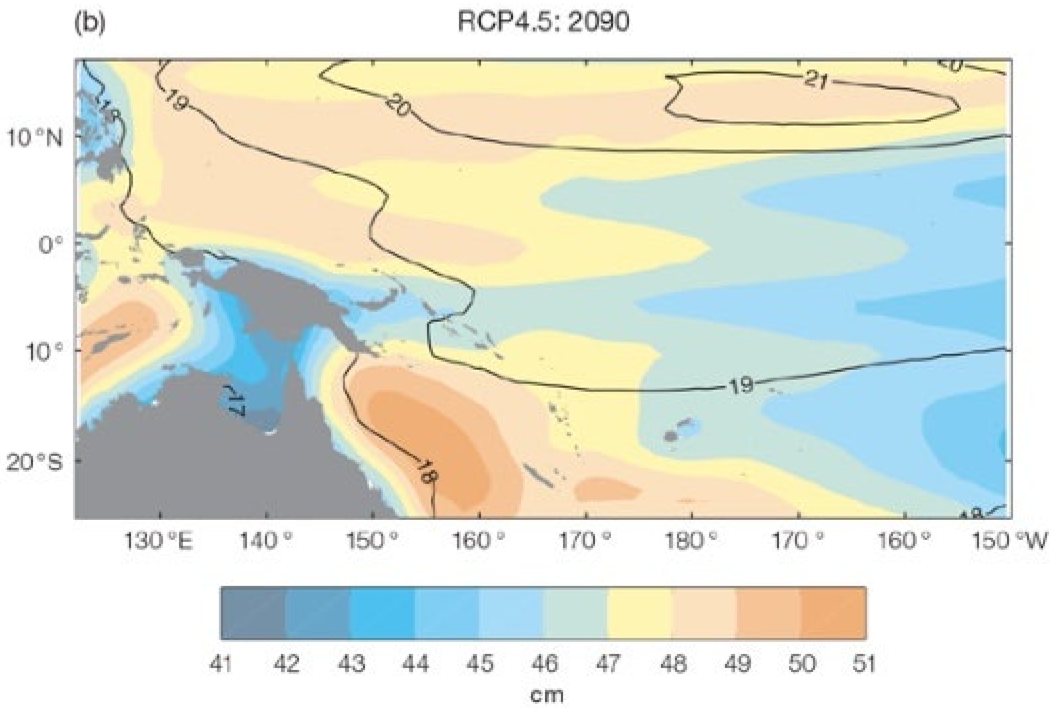


Figure 40: The regional distribution of projected sea level rise under the RCP4.5 emissions scenario for 2081–2100 relative to 1986–2005. Mean projected changes are indicated by the shading, with uncertainty indicated by contours (Source: BoM and CSIRO, 2014)

3.4.4 Ocean acidification and deoxygenation

Aragonite saturation states above ~4 are considered optimal for coral growth and for the development of healthy reef ecosystems. Values between 3.5 and 4 are considered adequate, values between 3 and 3.5 are considered marginal, while values below 3 are considered extremely marginal.[176] The acidification of the ocean will continue to increase over the course of the 21st century.

There is very high confidence in this projection as the rate of ocean acidification is driven primarily by the increasing oceanic uptake of carbon dioxide, in response to rising atmospheric carbon dioxide concentrations. "Since the beginning of the industrial era, oceanic uptake of CO_2 has resulted in acidification of the ocean; the pH of ocean surface water has decreased by 0.1 (high confidence), corresponding to a 26% increase in acidity, measured as hydrogen ion concentration. There is medium confidence that, in parallel to warming, oxygen concentrations have decreased in coastal waters and in the open ocean thermocline in many ocean regions since the 1960s, with a likely expansion of tropical oxygen minimum zones in recent decades."[177]

Projections from all analysed CMIP3 models indicate that the annual maximum aragonite saturation state will reach values below 3.5 by about 2025 and continue to decline thereafter.[178] The deoxygenation of sea water as surface temperatures rise will negatively impact corals and other marine organisms.[179] The rising ocean temperatures, increasing acidification and reduced oxygenation of sea water will reduce the availability of fish for inshore fishermen.

[176] Guinotte, J.M. et al. Coral Reefs. 2003. Future coral reef marginality: temporal and spatial effects of climate change in the Pacific basin
[177] IPCC, 2013. Climate Change 2013: The Physical Science Basis. Chapter 14.
[178] CSIRO, 2010. Climate Change in Timor-Leste – a brief overview on future climate projections
[179] IPCC, 2019. Special Report on the Ocean and Cryosphere in a Changing Climate

3.5 – DOWNSCALED CLIMATE PROJECTIONS

The following section provides downscaled climate projections for three selected regions, namely Dilli, Lospalos and Manufahi-Same for three periods: 2011 – 2040, 2041 – 2070 and 2071 – 2100. Two Representative Concentration Pathways (RCP) 4.5 and 8.5 are selected to better pronounce the changes in annual and monthly means of the following variables: temperature, precipitation, aridity and soil moisture.

3.5.1 Dilli

Dilli is located in the district of Díli, Timor-Leste at 8.56°S, 125.57°E.

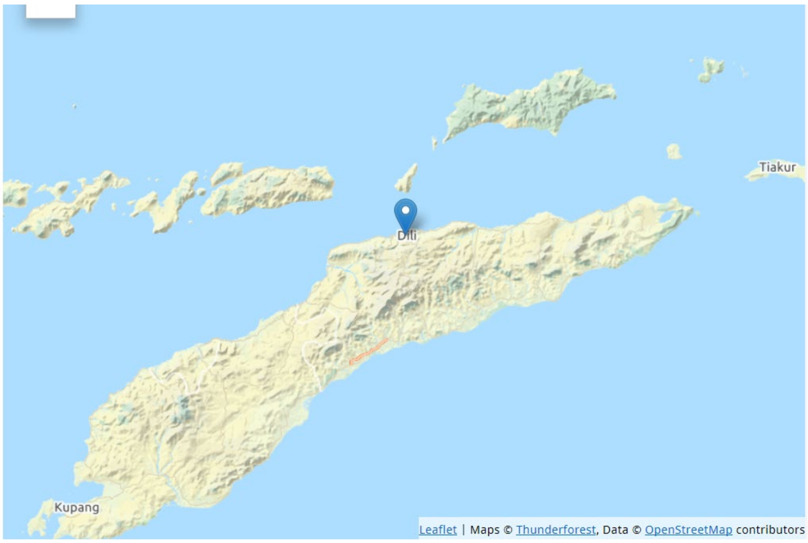


Figure 41: Location of Dilli, Timor-Leste (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2011 – 2040 under RCP4.5

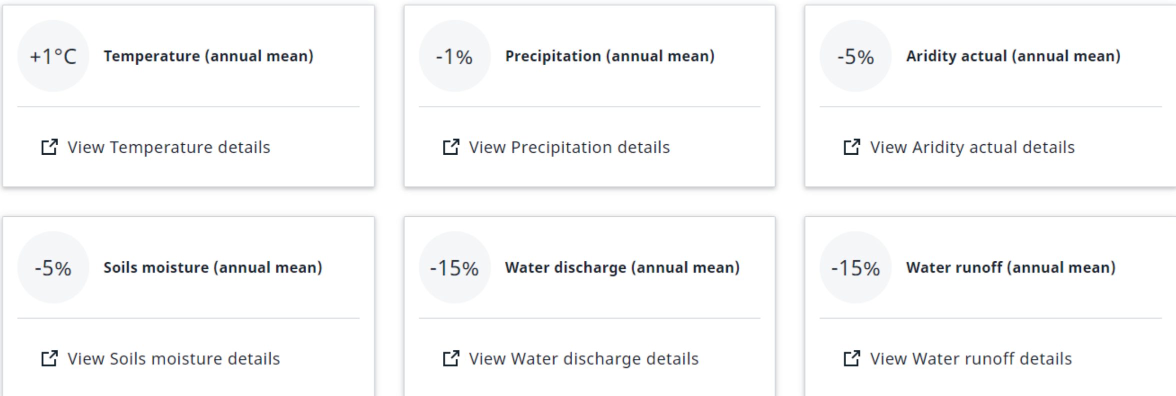
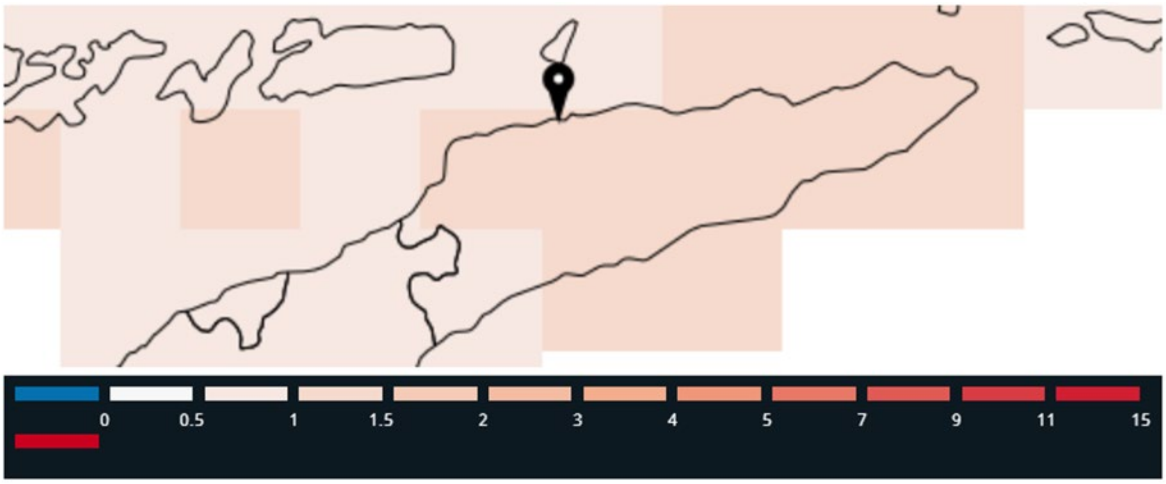


Figure 42: Future change in key indicators under RCP 4.5 in the time period 2011 – 2040 under RCP4.5 for Dilli, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

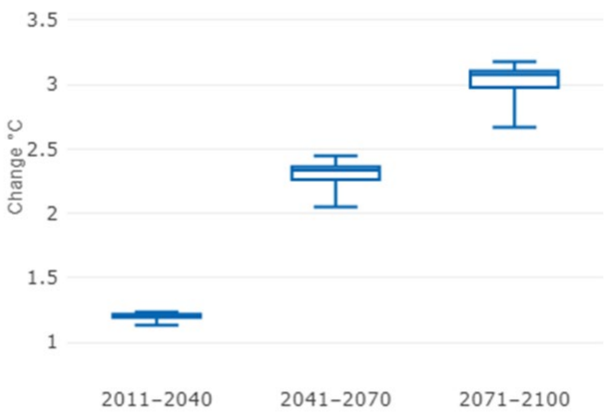
For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is 1.2 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 1.2 °C and 1.2 °C



Indicator: Temperature (annual mean), Time period: 2011-2040, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 43: Projected change in annual mean temperature under RCP 4.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



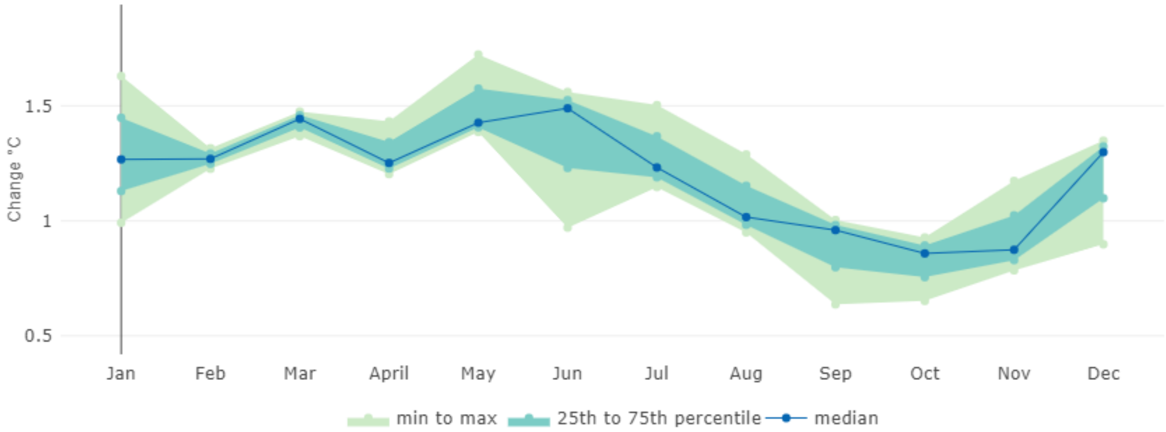
Indicator: Temperature (annual mean), Time period: 2011-2040, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 44: Projected change in annual mean temperature under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between 0.64 °C and 1.7 °C



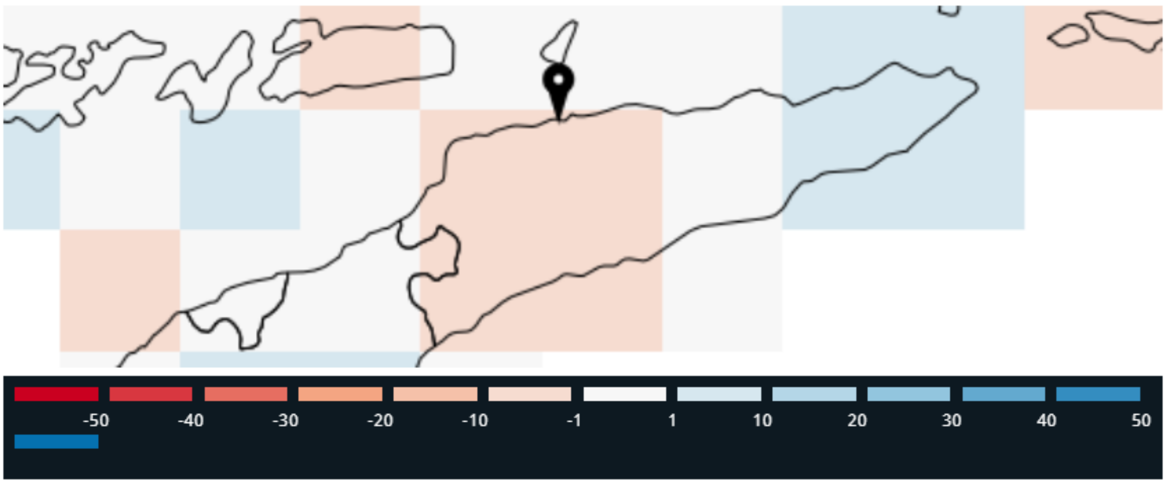
Indicator: Temperature (annual mean), Time period: 2011-2040, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 45: Projected change in monthly mean temperature under RCP 4.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is -1.4% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -3.4% and -0.67%



Indicator: Precipitation (annual mean), Time period: 2011-2040, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 46: Projected change in annual mean precipitation in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

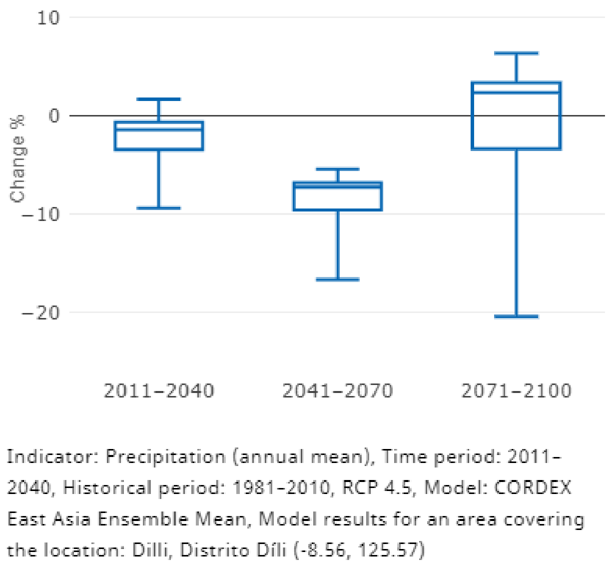


Figure 47: Projected change in annual mean precipitation under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -46% and 91%

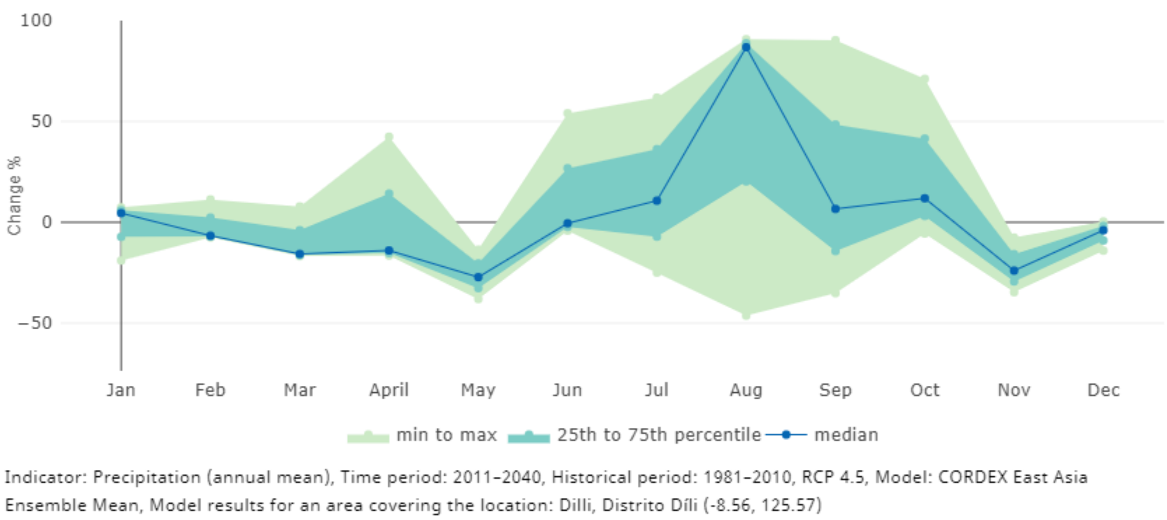
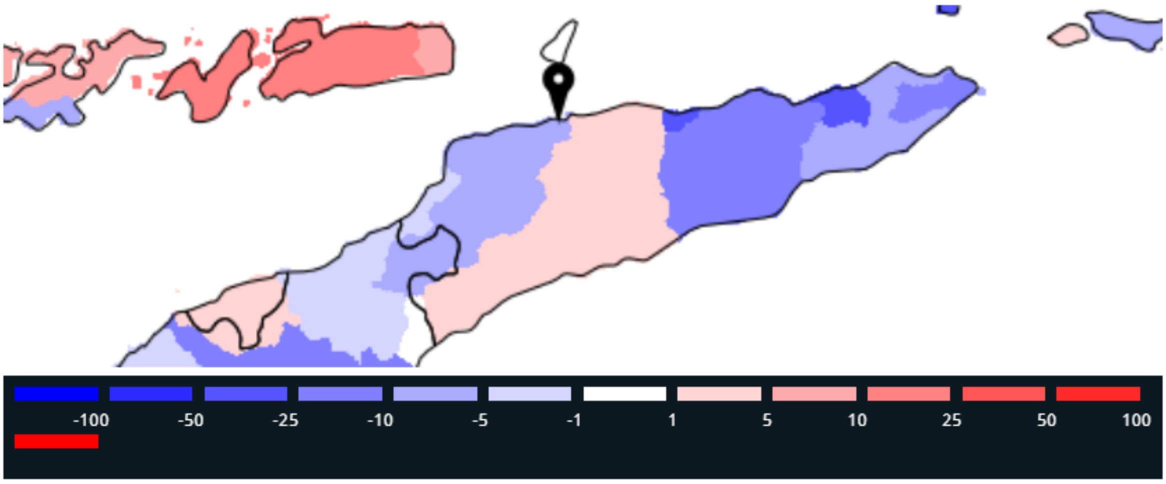


Figure 48: Projected change in monthly mean precipitation under RCP 4.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

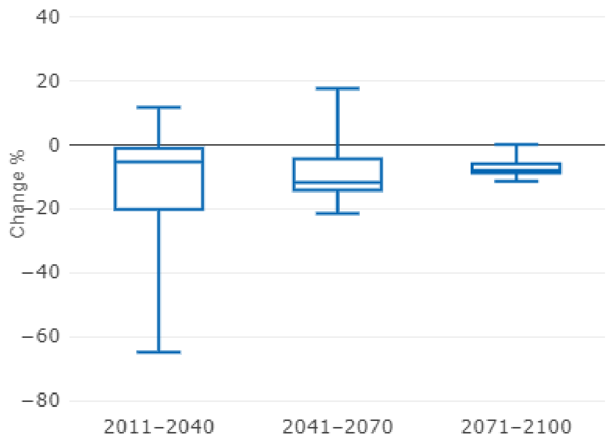
For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is -5.4% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -20% and -1.1%



Indicator: Aridity actual (annual mean), Time period: 2011–2040, Historical period: 1981–2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 49: Projected change in annual mean actual aridity under RCP 4.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



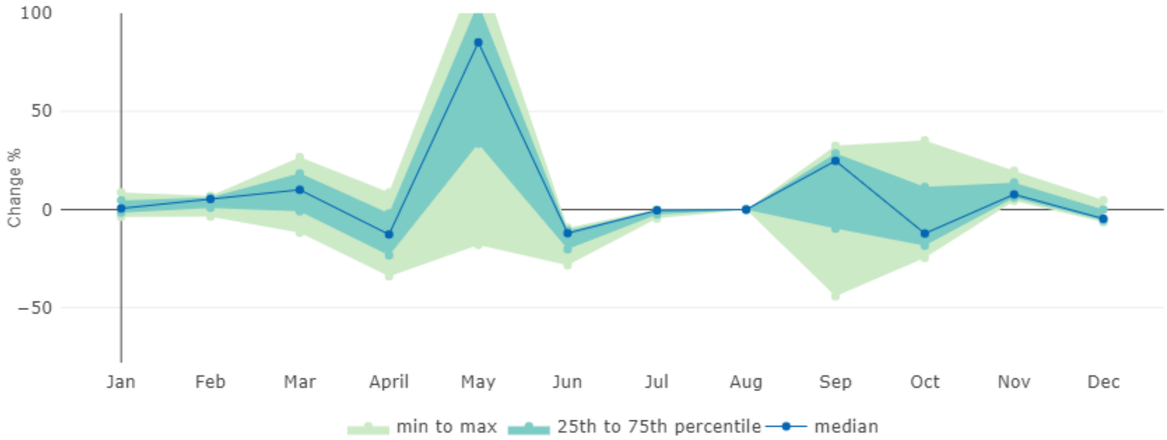
Indicator: Aridity actual (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 50: Projected change in annual mean actual aridity under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -44% and 130%



Indicator: Aridity actual (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 51: Projected change in monthly mean actual aridity under RCP 4.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is -4.6% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -5.2% and -4%

Indicator: Soils moisture (annual mean), Time period: 2011–2040, Historical period: 1981–2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 52: Projected change in annual mean soil moisture under RCP 4.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

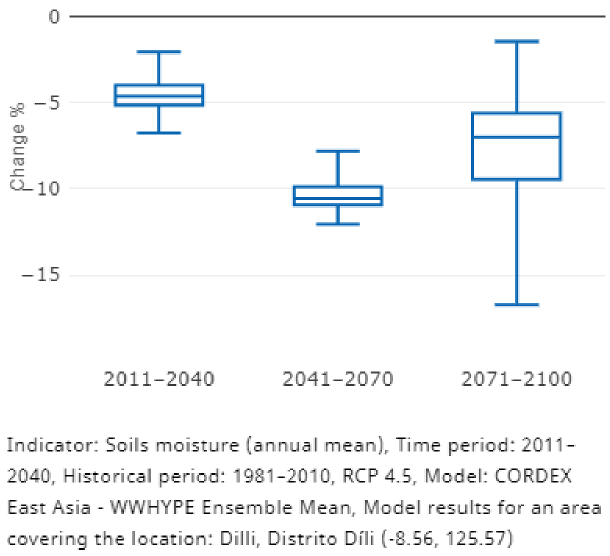


Figure 53: Projected change in annual mean soil moisture under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -30% and 35%

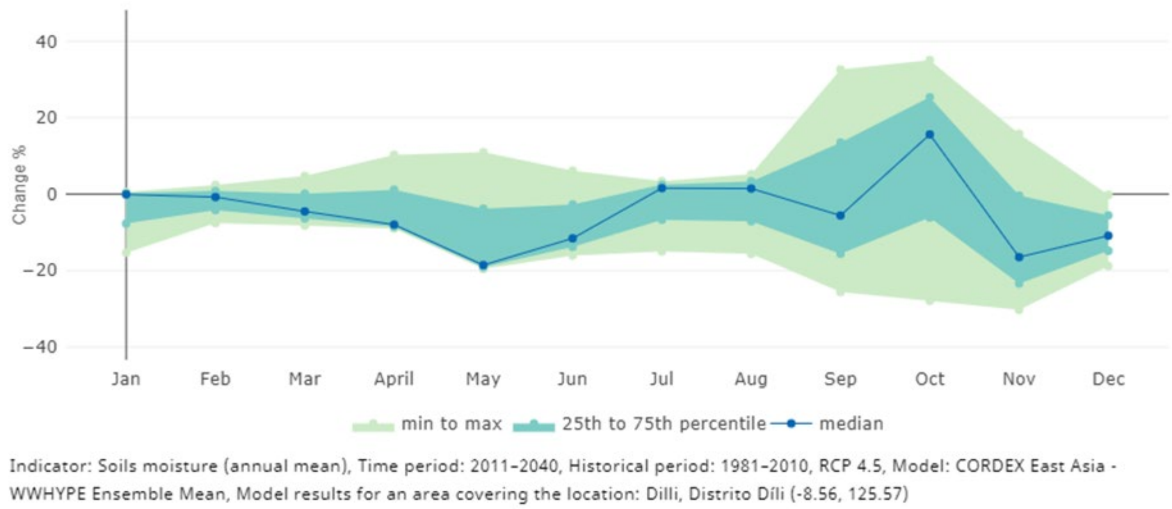


Figure 54: Projected change in monthly mean soil moisture under RCP 4.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2041 – 2070 under RCP4.5

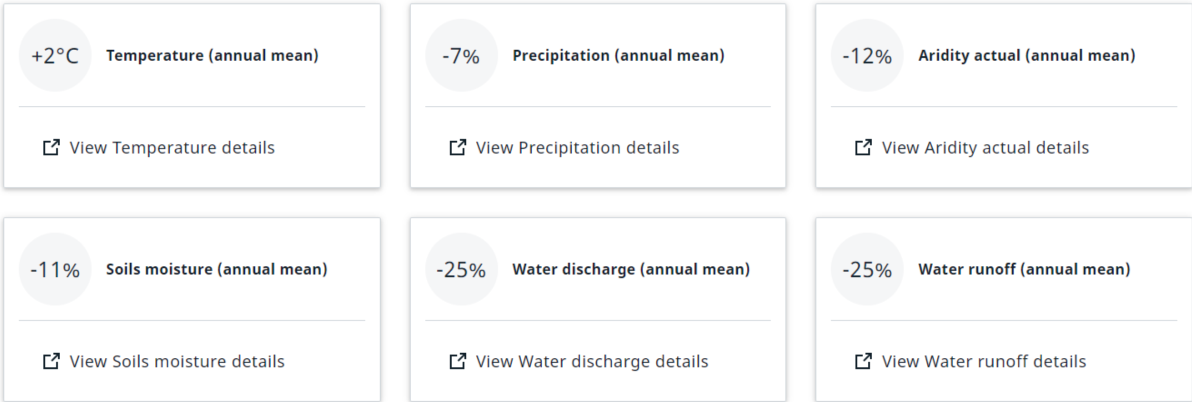


Figure 55: Future change in key indicators under RCP 4.5 in the time period 2041 – 2070 under RCP4.5 for Dilli, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is 2.3 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 2.3 °C and 2.4 °C

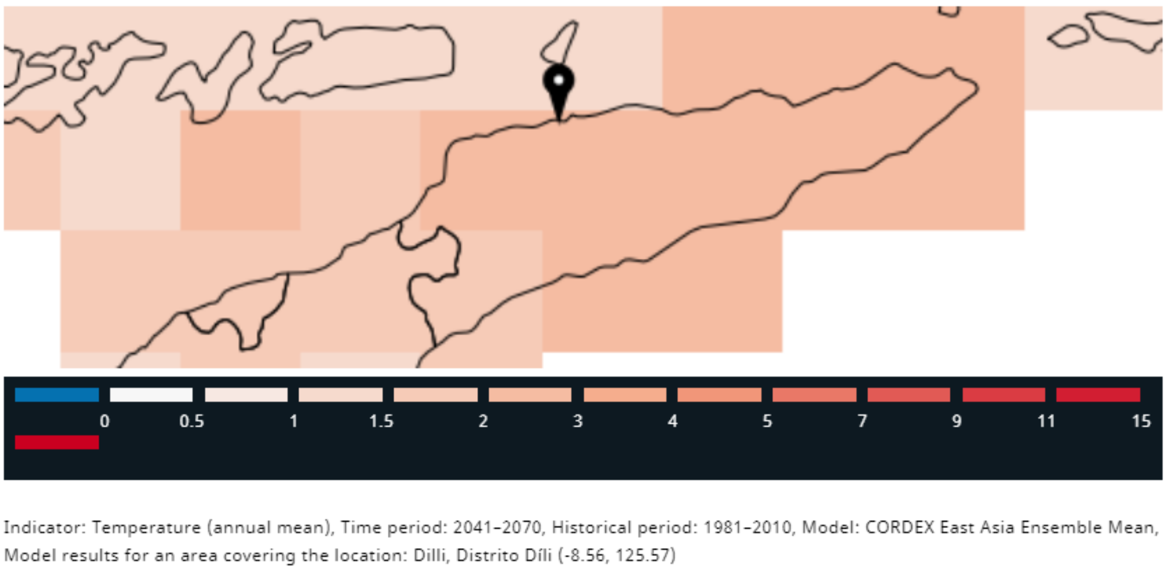
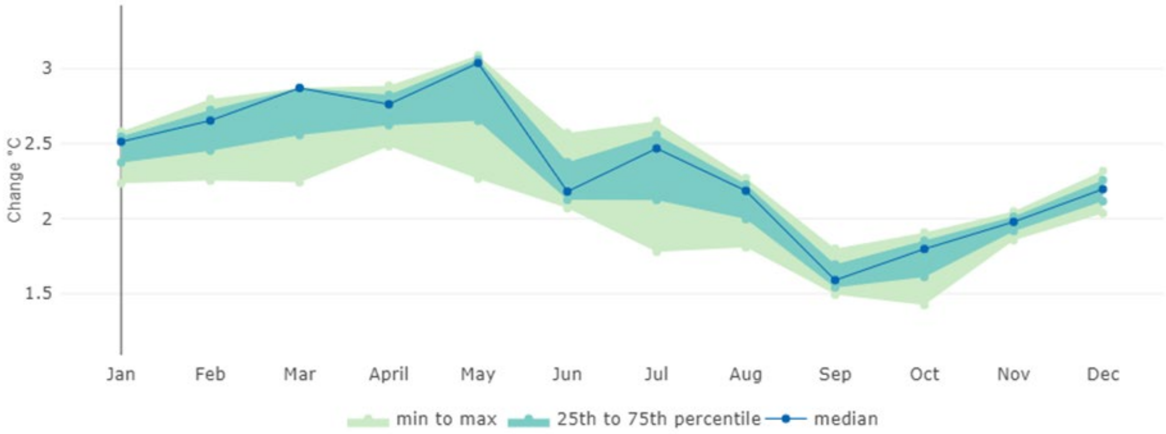


Figure 56: Projected change in annual mean temperature under RCP 4.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between 1.4 °C and 3.1 °C



Indicator: Temperature (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 57: Projected change in monthly mean temperature under RCP 4.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is -7.3% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -9.6% and -6.8%

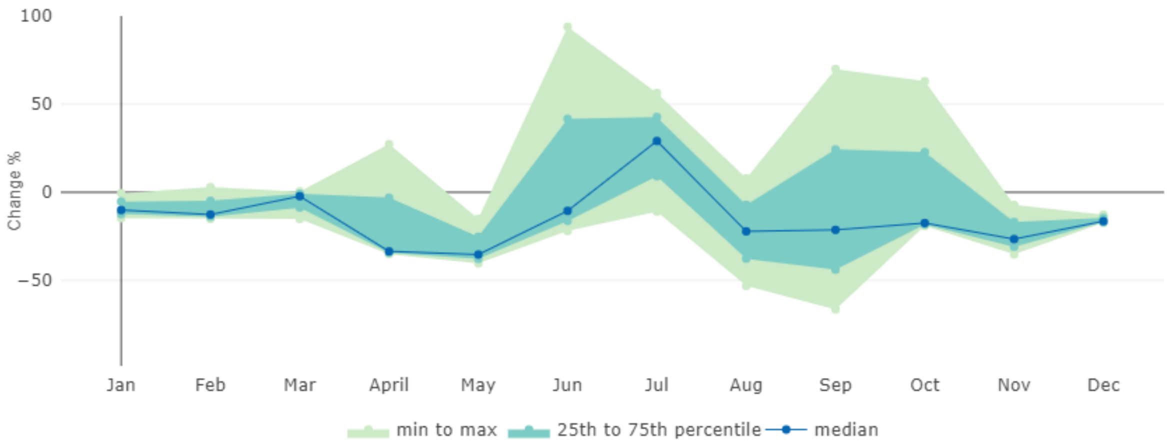
Indicator: Precipitation (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 58: Projected change in annual mean precipitation under RCP 4.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -66% and 94%



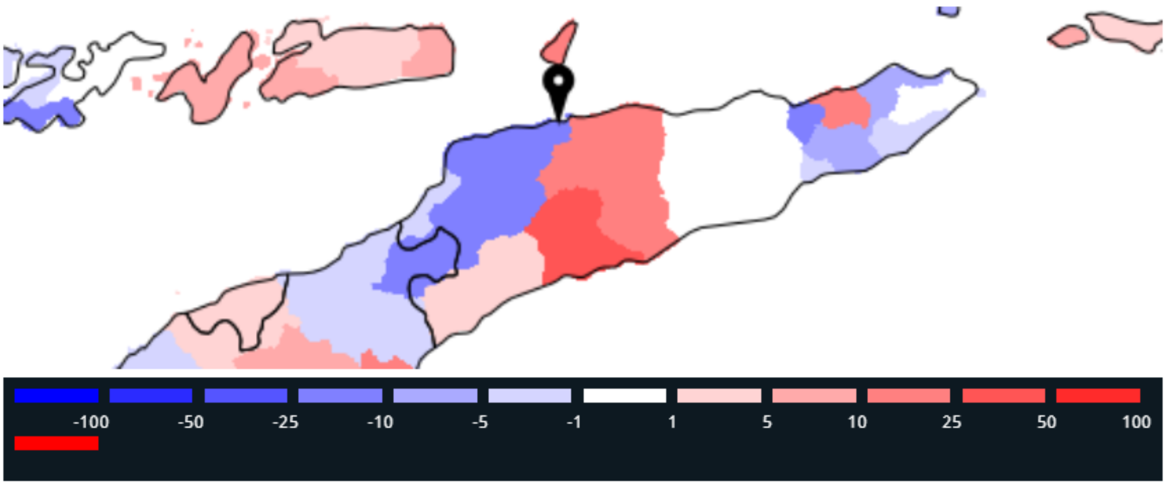
Indicator: Precipitation (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 59: Projected change in monthly mean precipitation under RCP 4.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is -12% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -14% and -4.5%



Indicator: Aridity actual (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 60: Projected change in annual mean actual aridity under RCP 4.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -49% and 170%

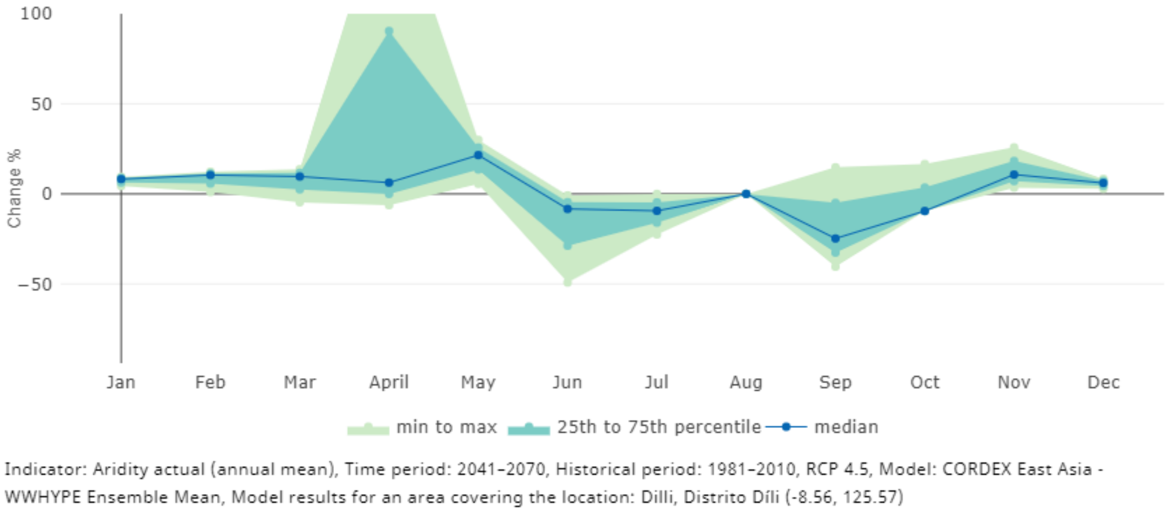


Figure 61: Projected change in monthly mean actual aridity under RCP 4.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is -11% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -11% and -9.9%

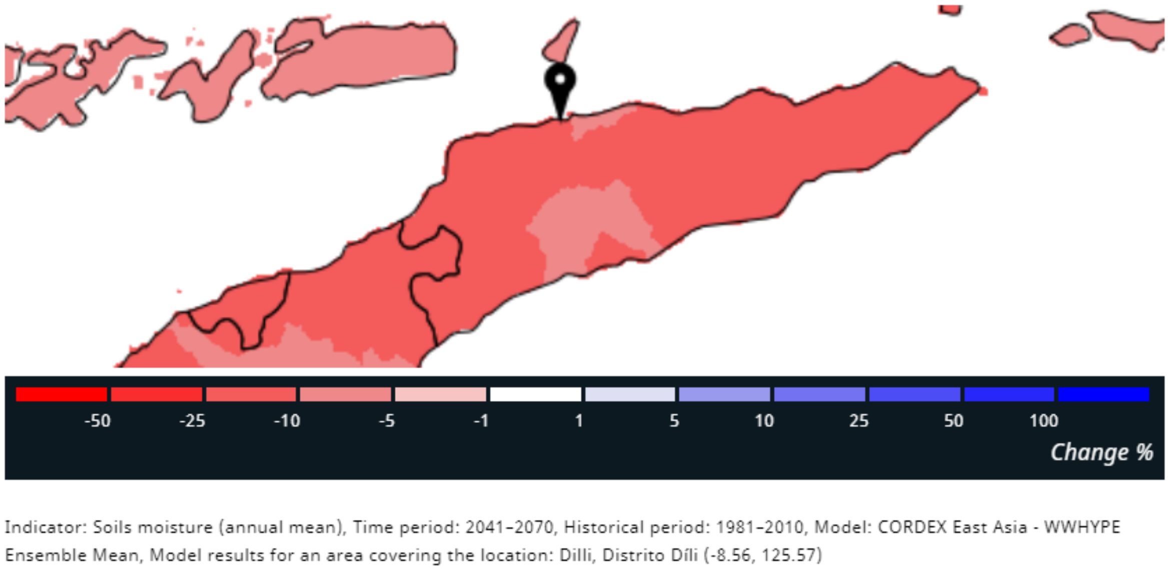
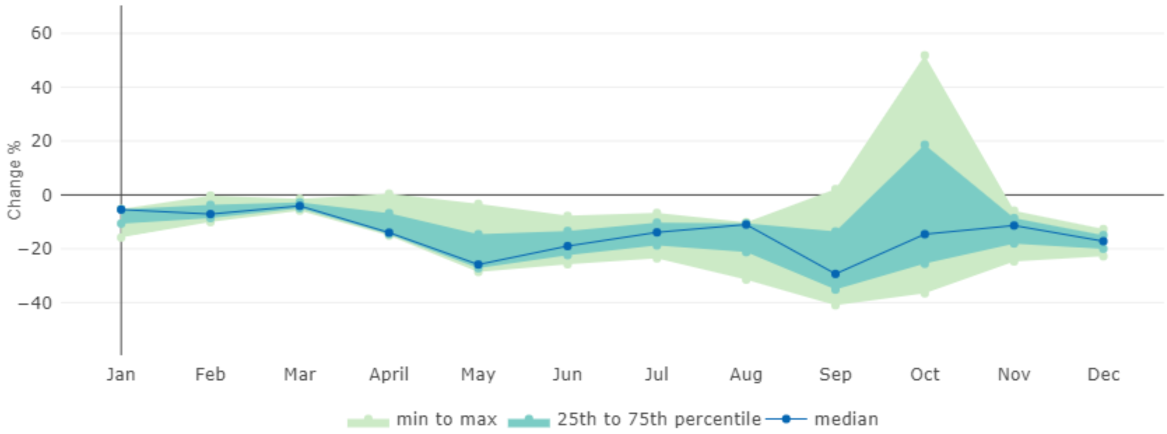


Figure 62: Projected change in annual mean soil moisture under RCP 4.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -41% and 52%



Indicator: Soils moisture (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 63: Projected change in monthly mean soil moisture under RCP 4.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2071 – 2100 under RCP4.5

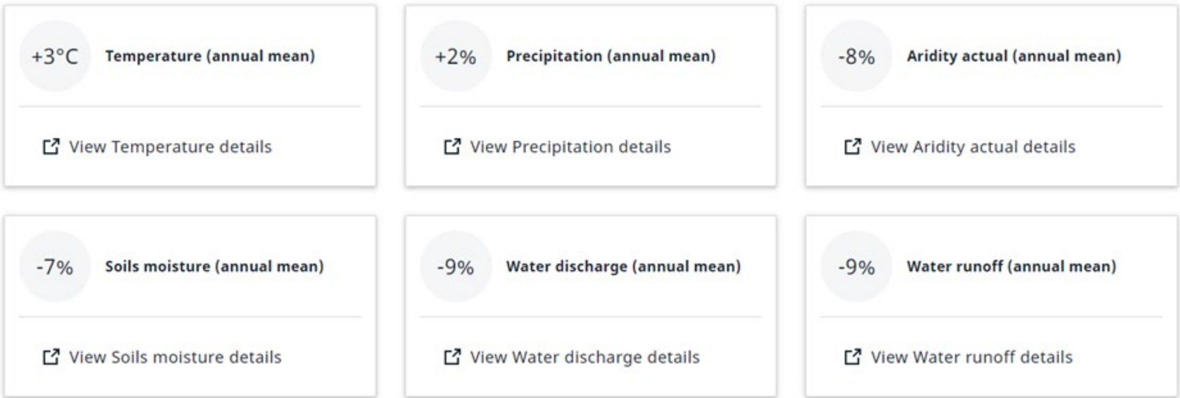
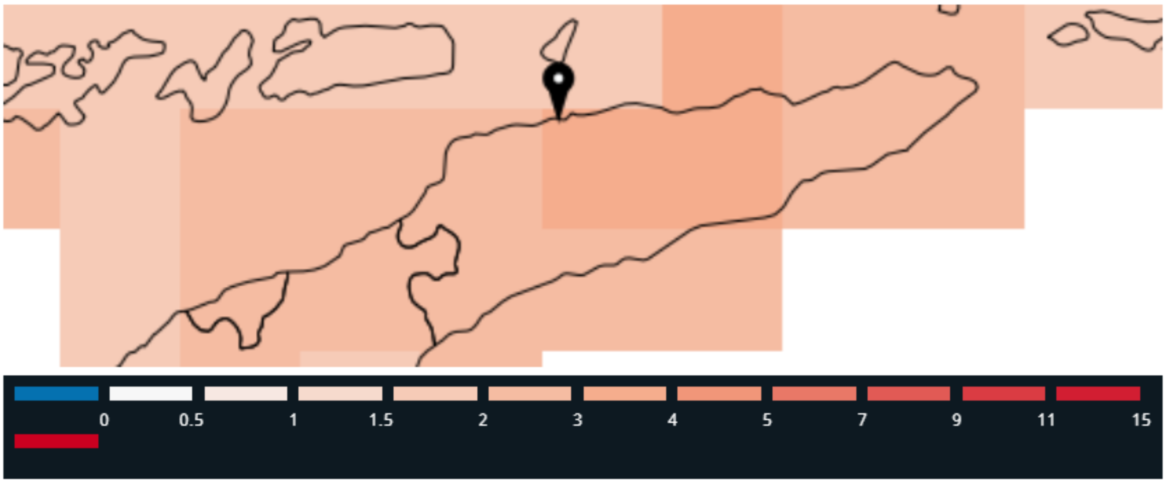


Figure 64: Future change in key indicators under RCP 4.5 in the time period 2071 – 2100 under RCP4.5 for Dilli, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is 3.1 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 3 °C and 3.1 °C



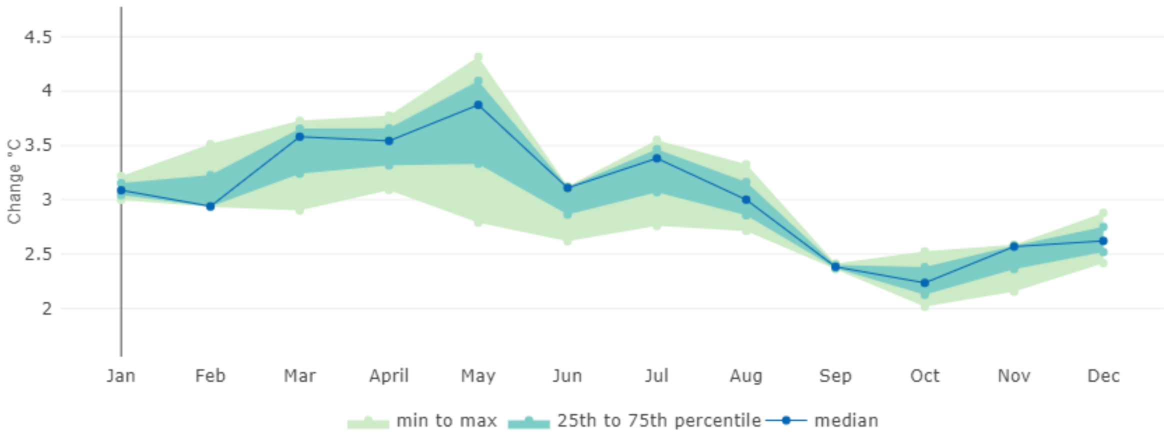
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 65: Projected change in annual mean temperature under RCP 4.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between 2 °C and 4.3 °C



Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 66: Projected change in monthly mean temperature under RCP 4.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is 2.3% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -3.4% and 3.3%

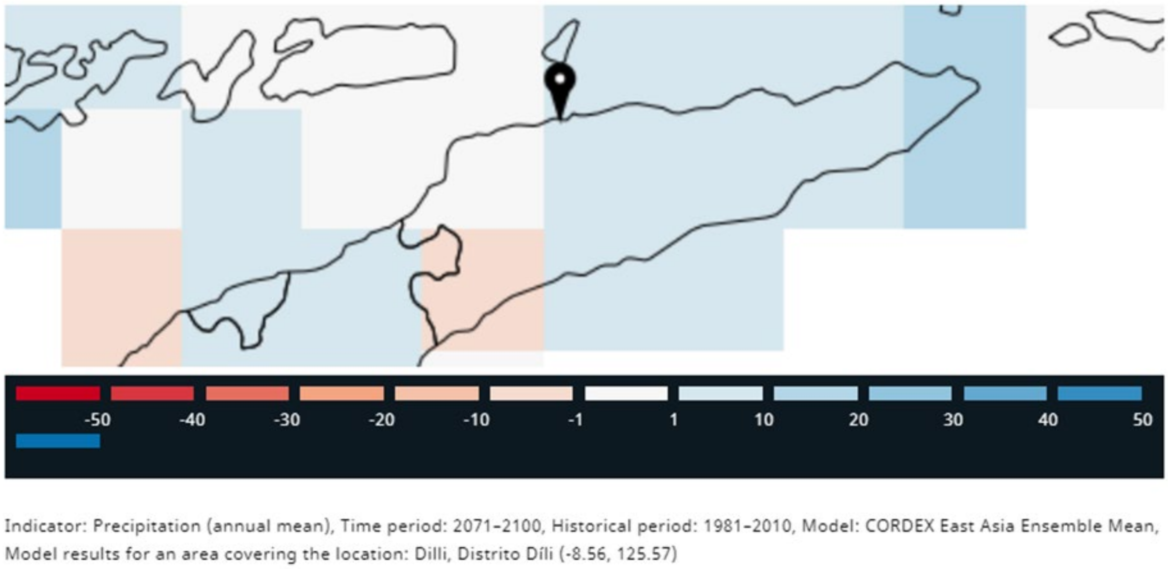


Figure 67: Projected change in annual mean precipitation under RCP 4.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -66% and 170%

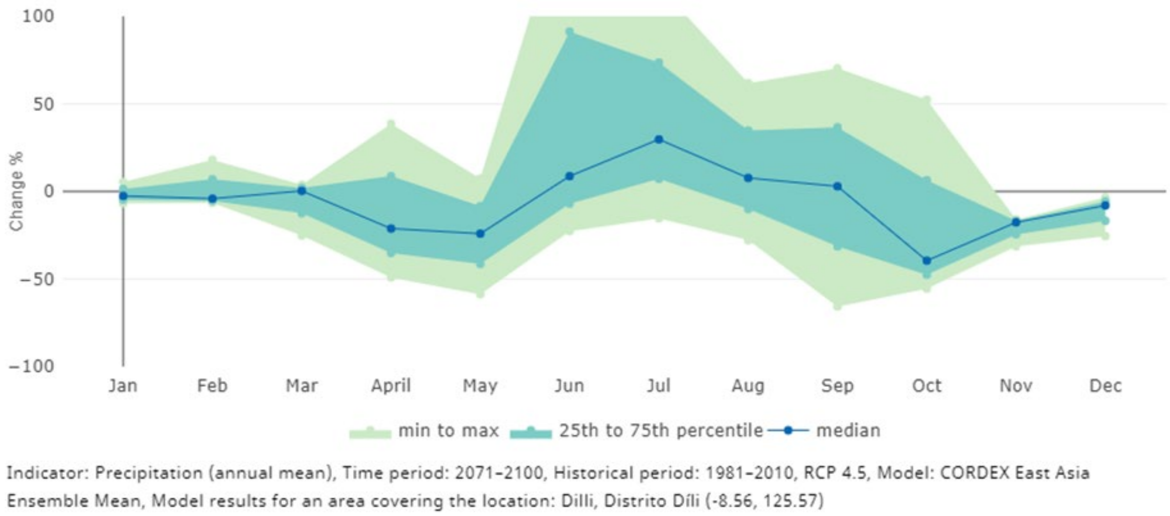


Figure 68: Projected change in monthly mean precipitation under RCP 4.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is -8.1% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -8.9% and -6%

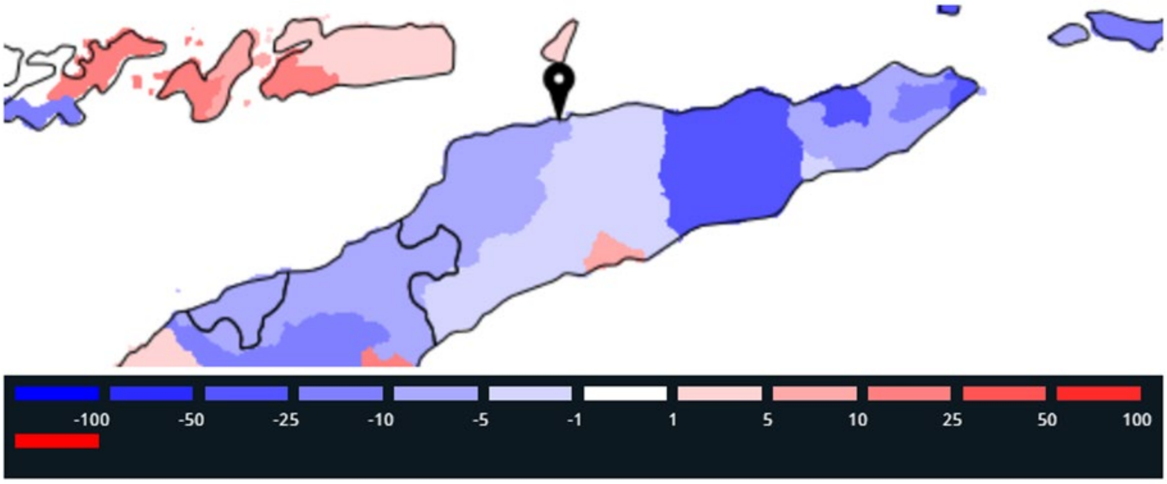


Figure 69: Projected change in annual mean actual aridity under RCP 4.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -31% and 90%

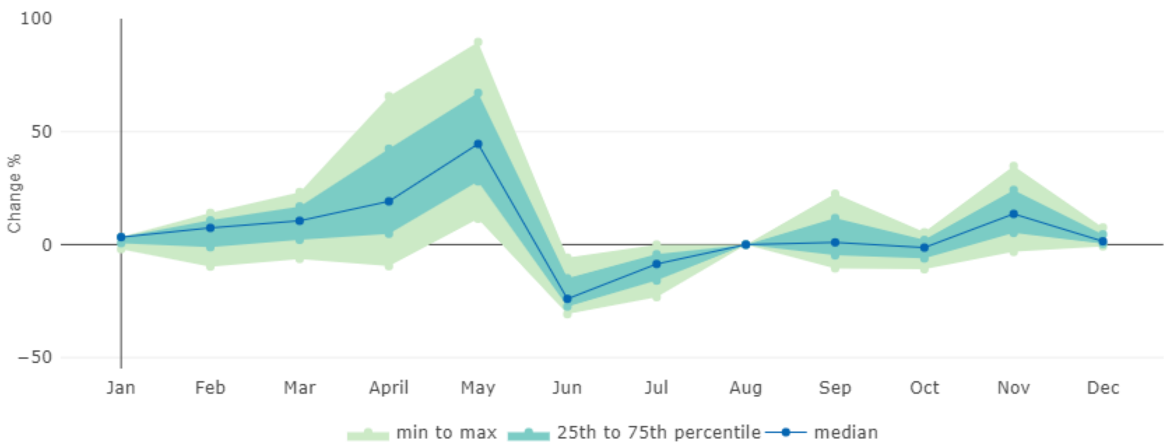
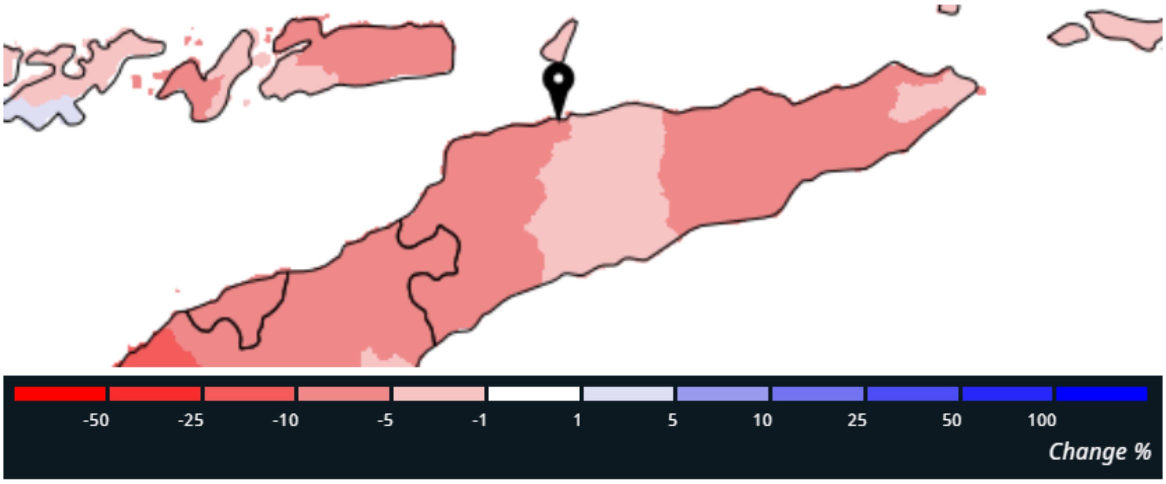


Figure 70: Projected change in monthly mean actual aridity under RCP 4.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is -7% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -9.4% and -5.6%



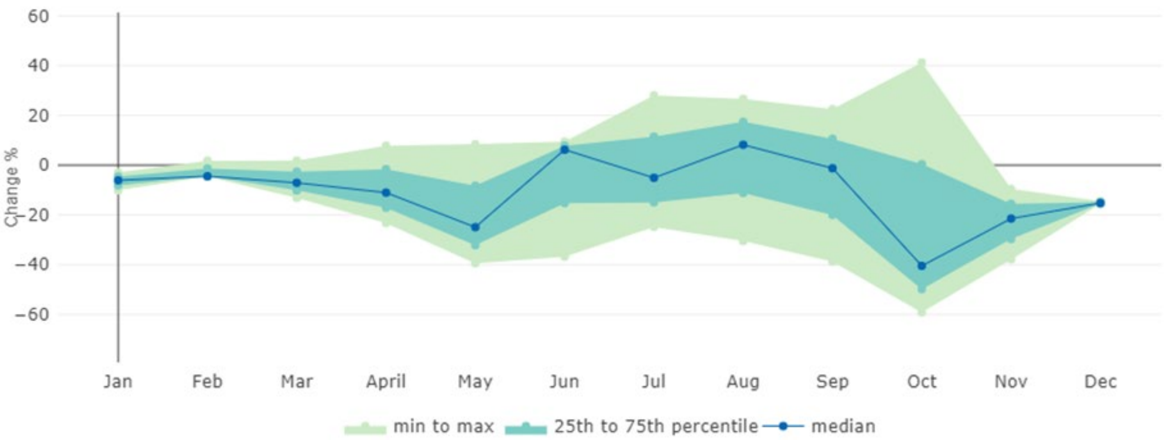
Indicator: Soils moisture (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 71: Projected change in annual mean soil moisture under RCP 4.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -59% and 41%



Indicator: Soils moisture (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 72: Projected change in monthly mean soil moisture under RCP 4.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2011 – 2040 under RCP8.5

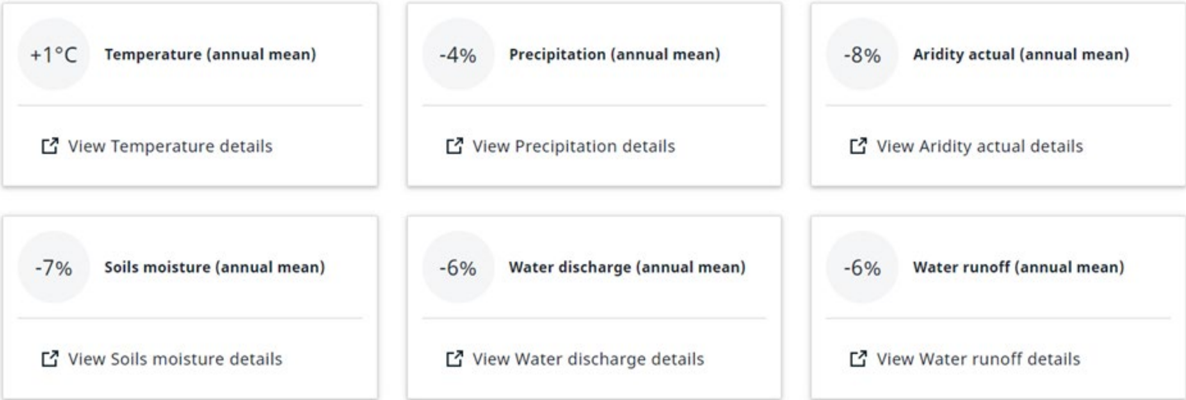
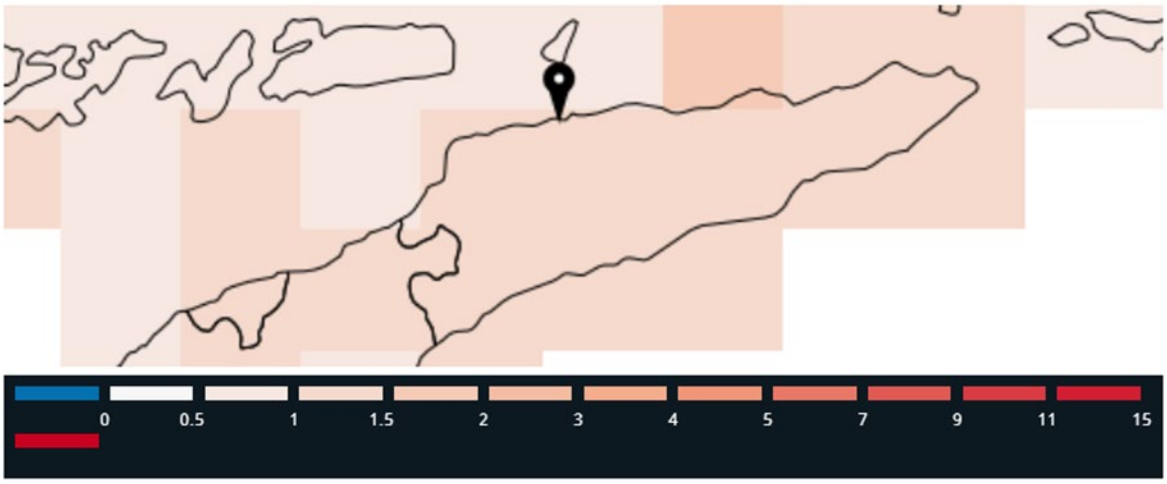


Figure 73: Future change in key indicators under RCP 8.5 in the time period 2011 – 2040 under RCP8.5 for Dilli, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is 1.4 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 1.4 °C and 1.4 °C



Indicator: Temperature (annual mean), Time period: 2011-2040, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 74: Projected change in annual mean temperature under RCP 8.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

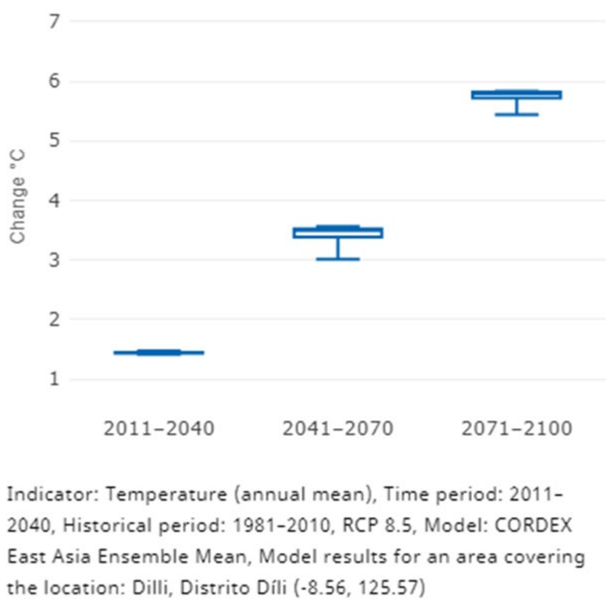


Figure 75: Projected change in annual mean temperature under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between 0.84 °C and 2.1 °C

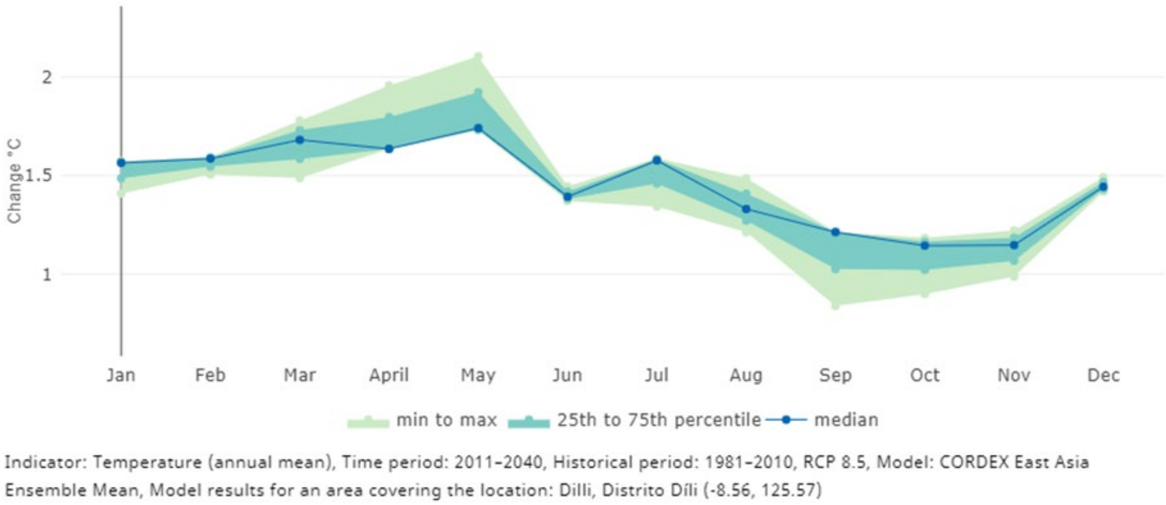


Figure 76: Projected change in monthly mean temperature under RCP 8.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

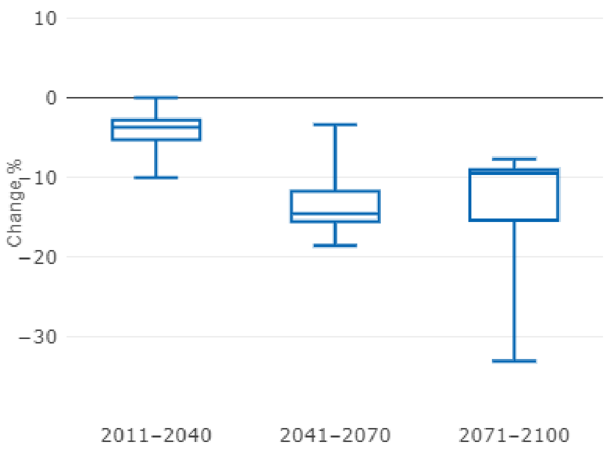
Key message for Precipitation (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is -3.7% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -5.2% and -2.7%

Indicator: Precipitation (annual mean), Time period: 2011-2040, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 77: Projected change in annual mean precipitation under RCP 8.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



Indicator: Precipitation (annual mean), Time period: 2011-2040, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 78: Projected change in annual mean precipitation under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -54% and 74%

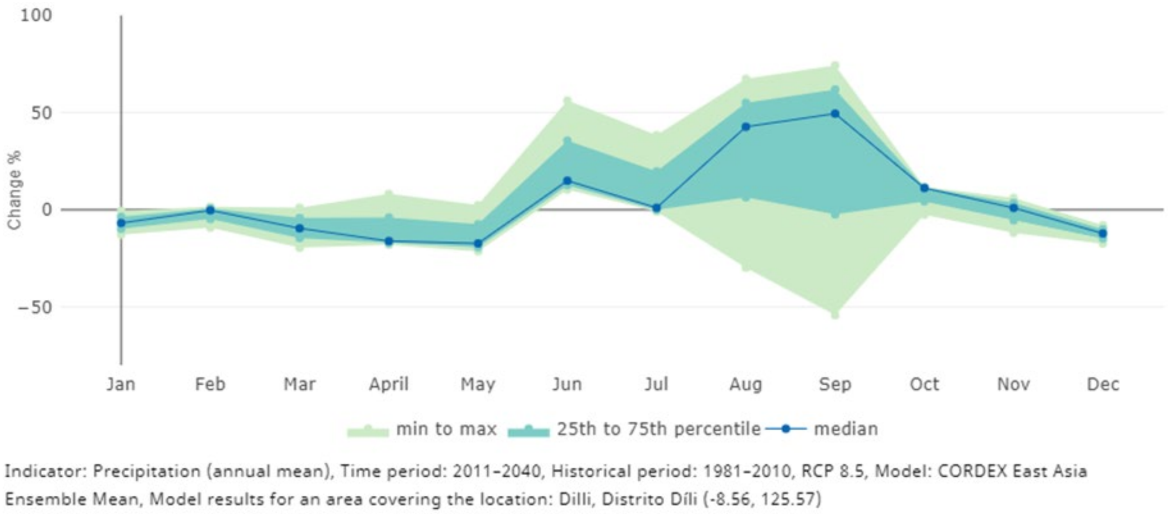


Figure 79: Projected change in monthly mean precipitation under RCP 8.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is -8.1% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between --8.3% and -3.3%

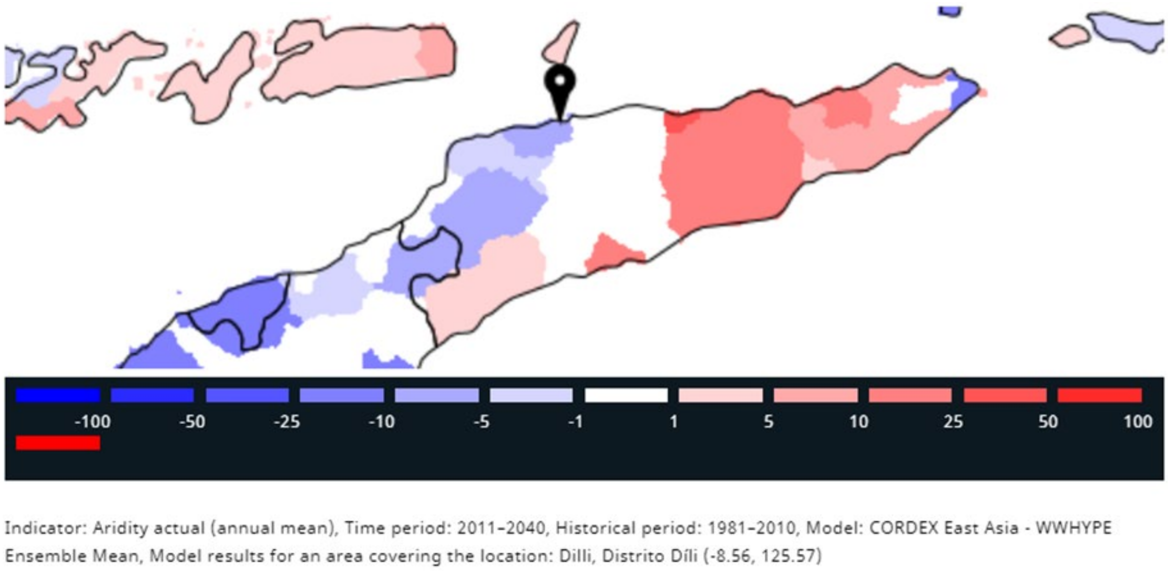
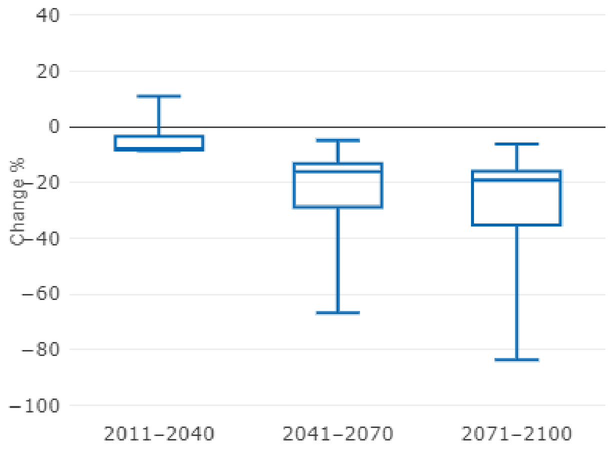


Figure 80: Projected change in annual mean actual aridity under RCP 8.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



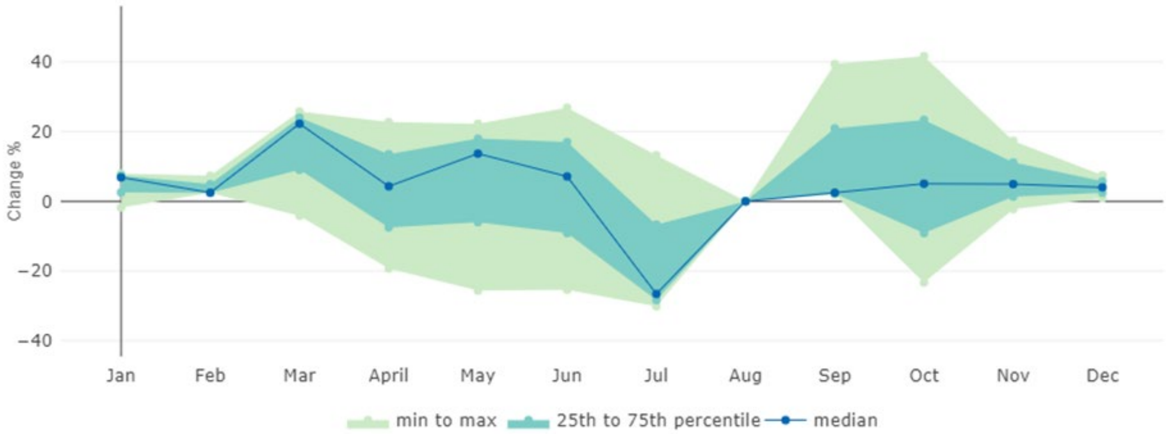
Indicator: Aridity actual (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 81: Projected change in annual mean actual aridity under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -30% and 42%



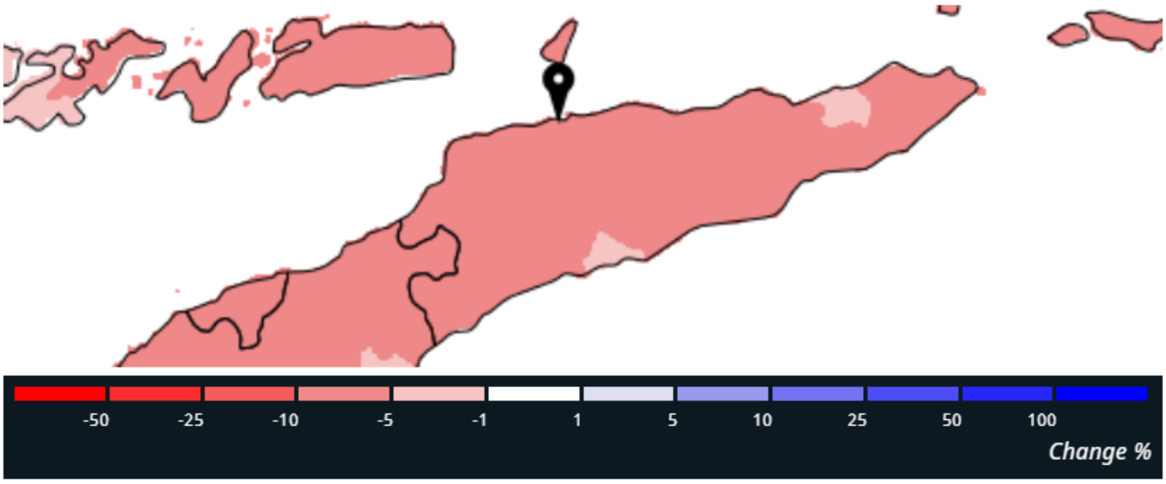
Indicator: Aridity actual (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 82: Projected change in monthly mean actual aridity under RCP 8.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

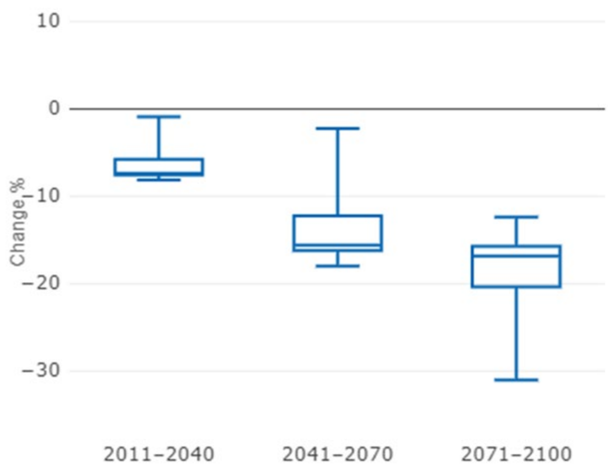
For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is -7.5% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -7.6% and -5.8%



Indicator: Soils moisture (annual mean), Time period: 2011-2040, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 83: Projected change in annual mean soil moisture under RCP 8.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



Indicator: Soils moisture (annual mean), Time period: 2011-2040, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 84: Projected change in annual mean soil moisture under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -23% and 34%

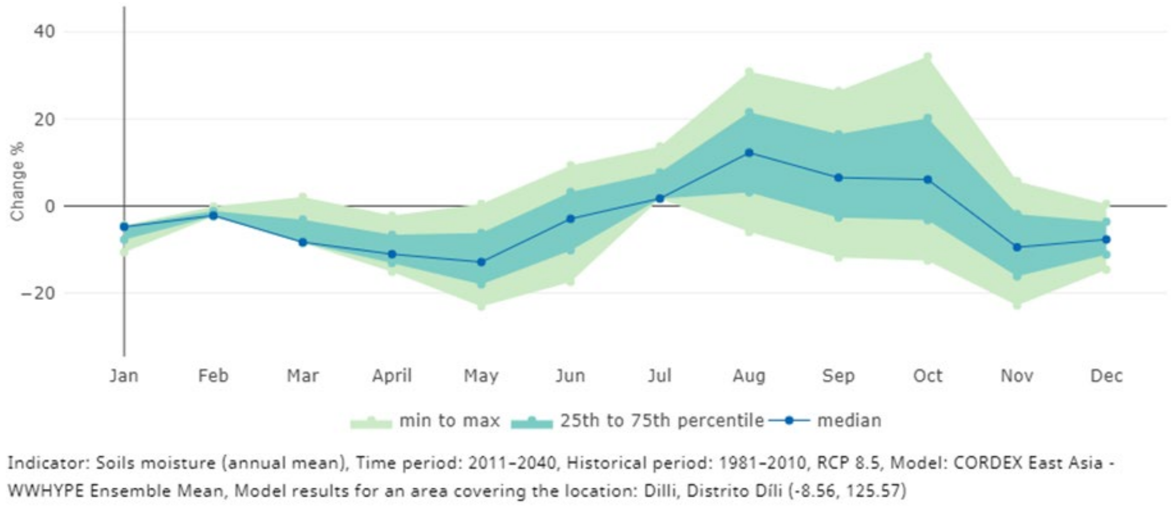


Figure 85: Projected change in monthly mean soil moisture under RCP 8.5 in the time period 2011 – 2040 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2041 – 2070 under RCP 8.5

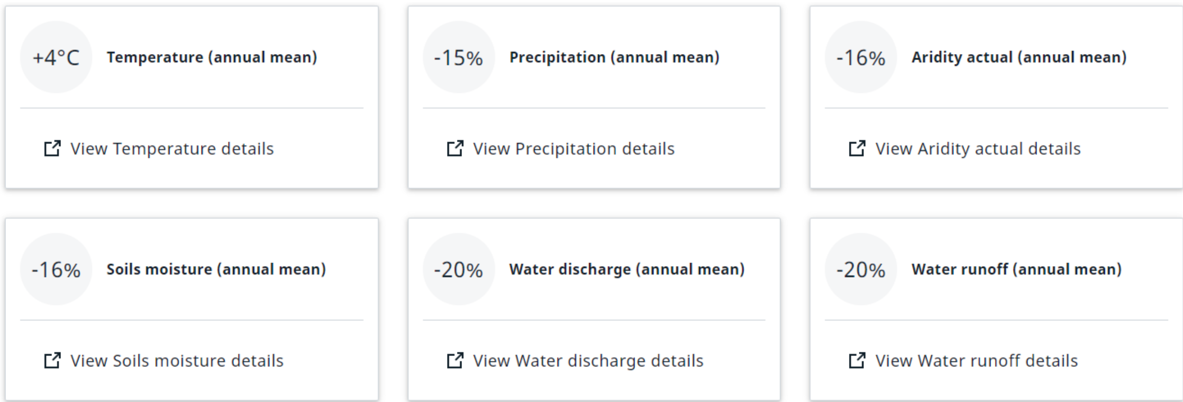
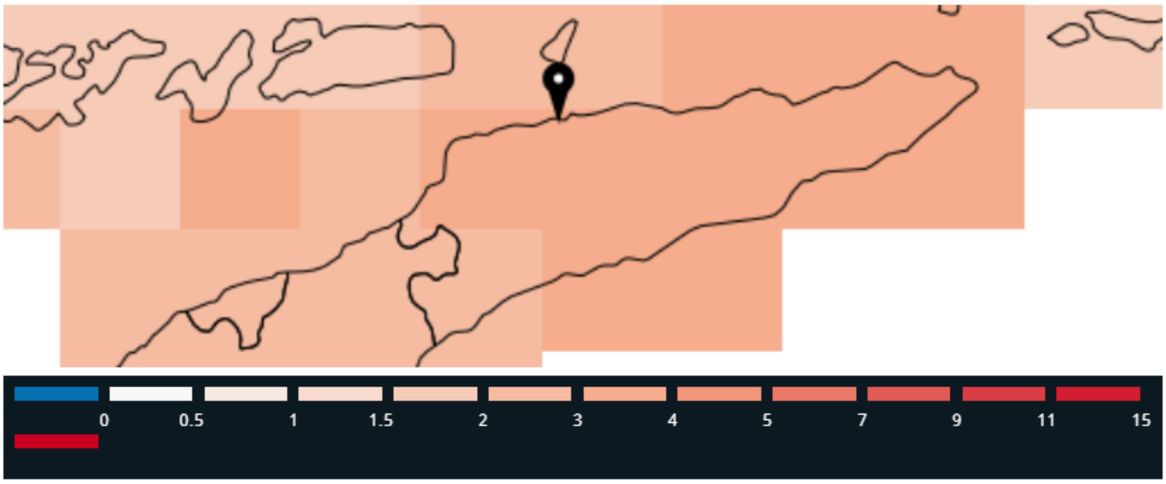


Figure 86: Future change in key indicators in the time period 2041 – 2070 under RCP 8.5 for Dilli, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is 3.5 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 3.4 °C and 3.5 °C



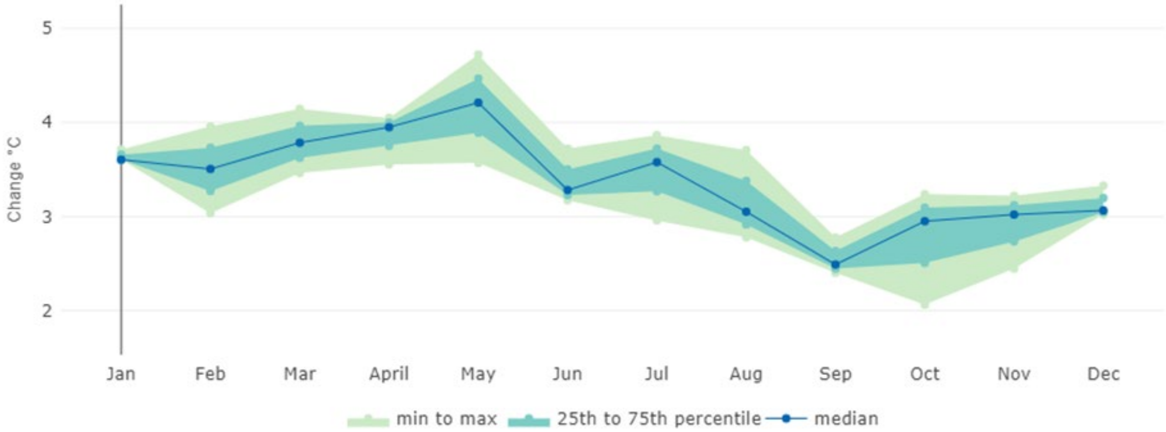
Indicator: Temperature (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 87: Projected change in annual mean temperature under RCP 8.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between 2.1 °C and 4.7 °C



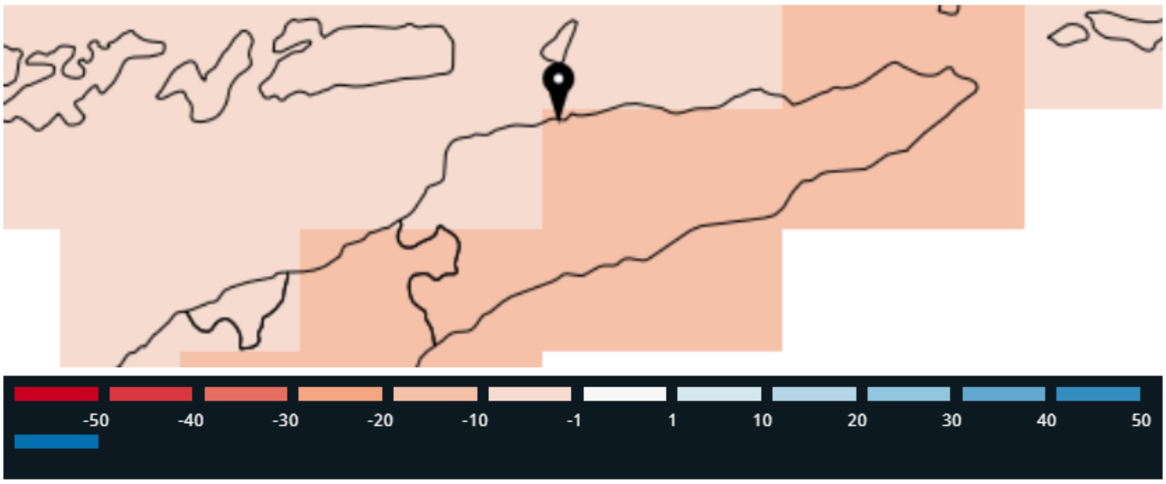
Indicator: Temperature (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 88: Projected change in monthly mean temperature under RCP 8.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is -15% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -16% and -12%



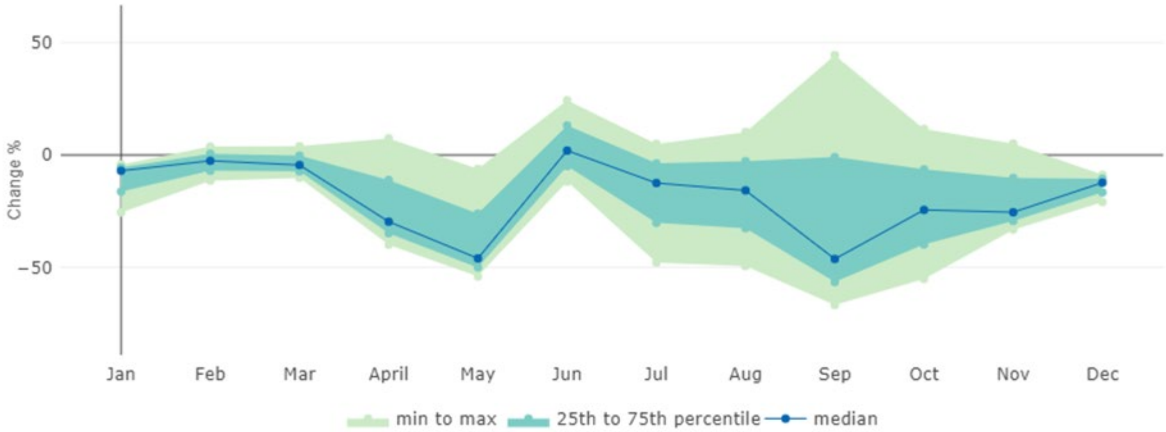
Indicator: Precipitation (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 89: Projected change in annual mean precipitation under RCP 8.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -67% and 44%



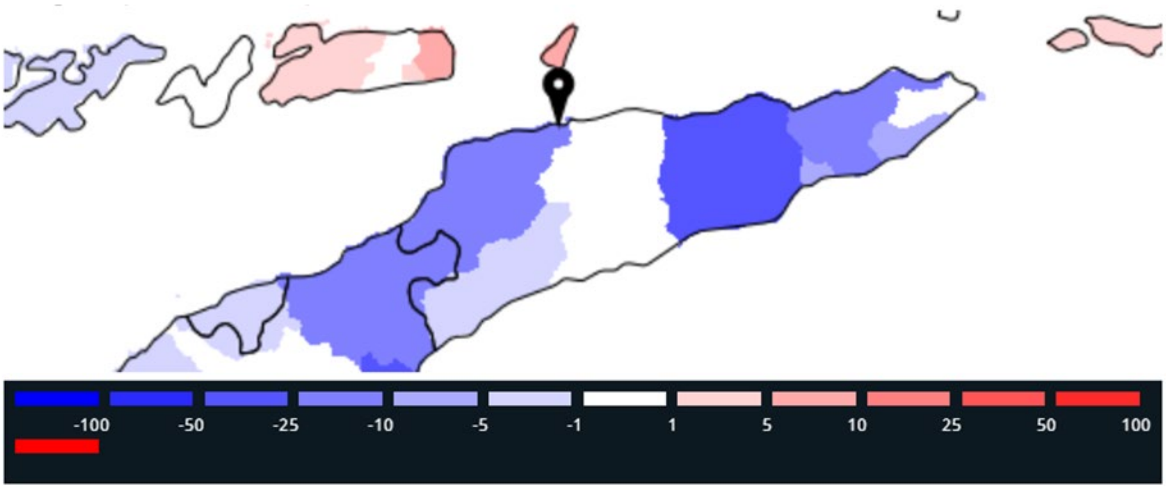
Indicator: Precipitation (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 90: Projected change in monthly mean precipitation under RCP 8.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is -16% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -29% and -13%



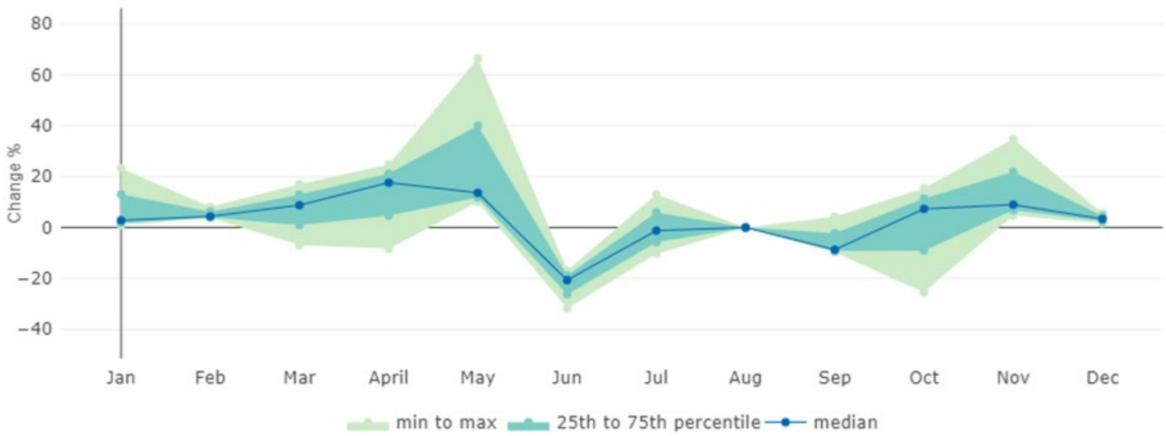
Indicator: Aridity actual (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 91: Projected change in annual mean actual aridity under RCP 8.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -32% and 66%



Indicator: Aridity actual (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 92: Projected change in monthly mean actual aridity under RCP 8.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is -16% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -16% and -12%

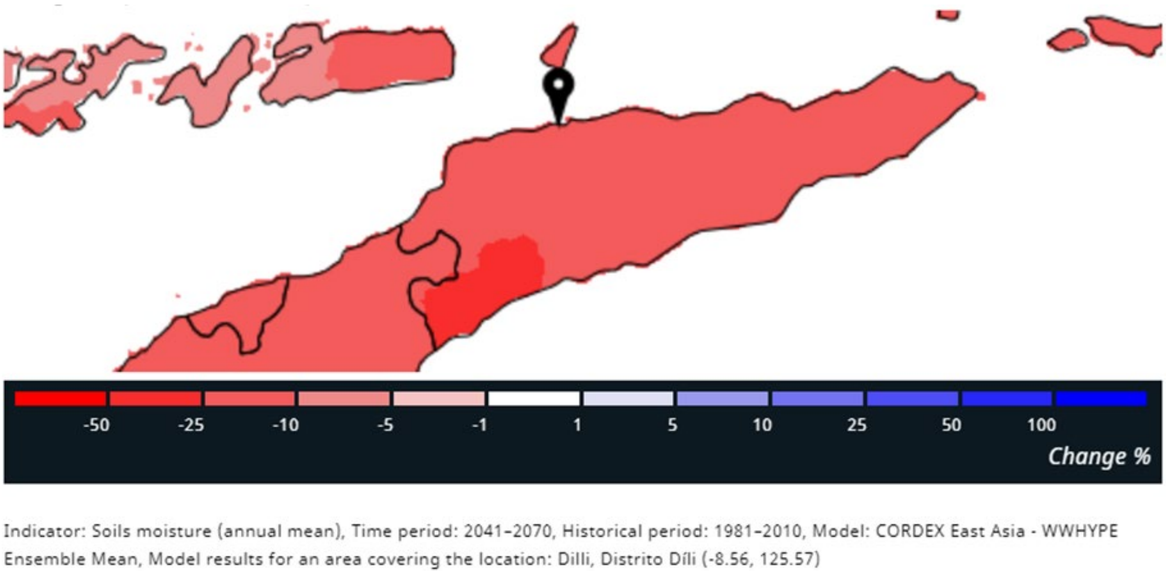


Figure 93: Projected change in annual mean soil moisture under RCP 8.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -54% and 40%

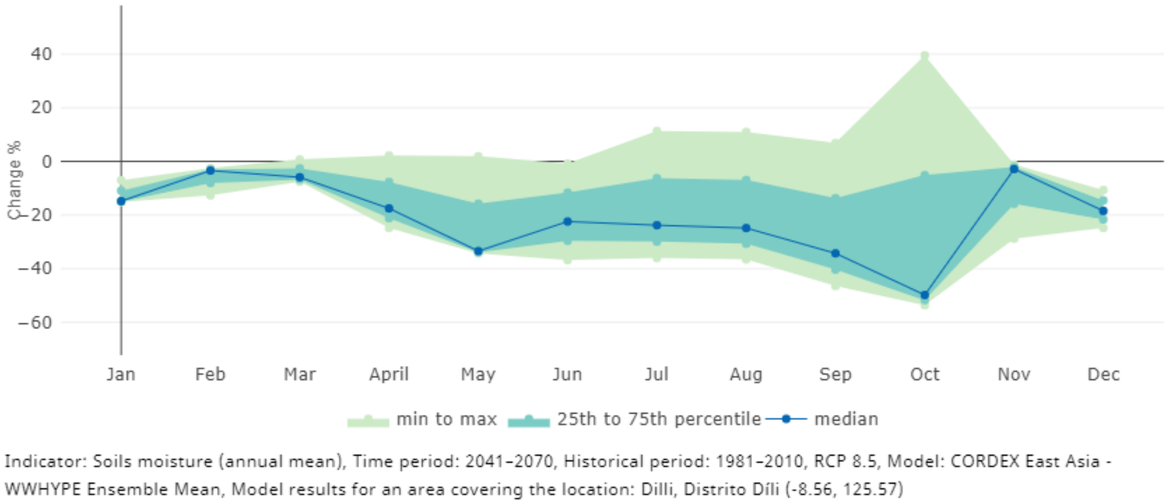


Figure 94: Projected change in monthly mean soil moisture under RCP 8.5 in the time period 2041 – 2070 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2071 – 2100 under RCP 8.5

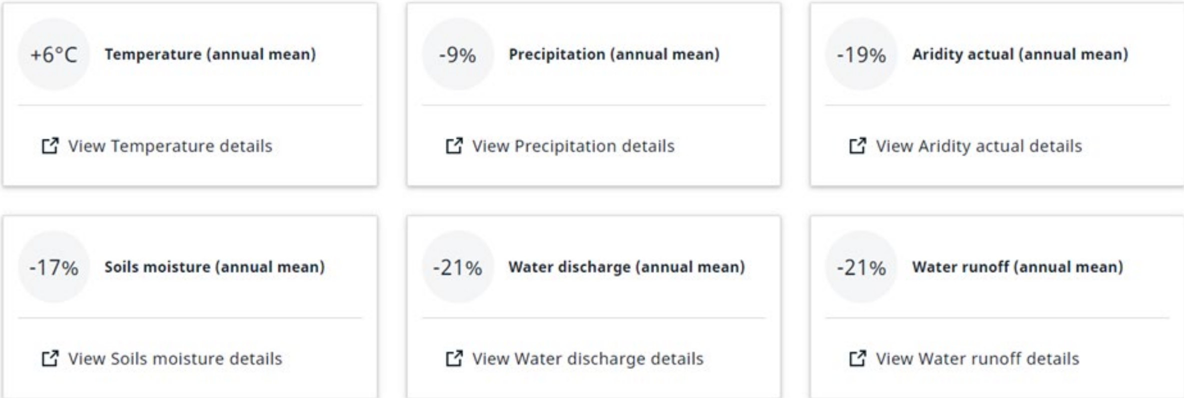
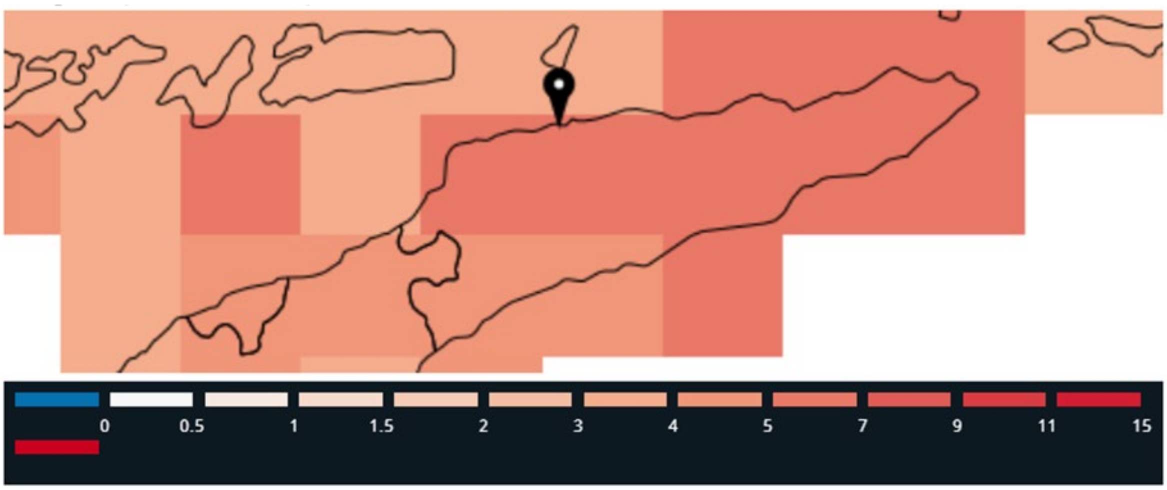


Figure 95: Future change in key indicators in the time period 2071 – 2100 under RCP 8.5 for Dilli, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is 5.8 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 5.7 °C and 5.8 °C



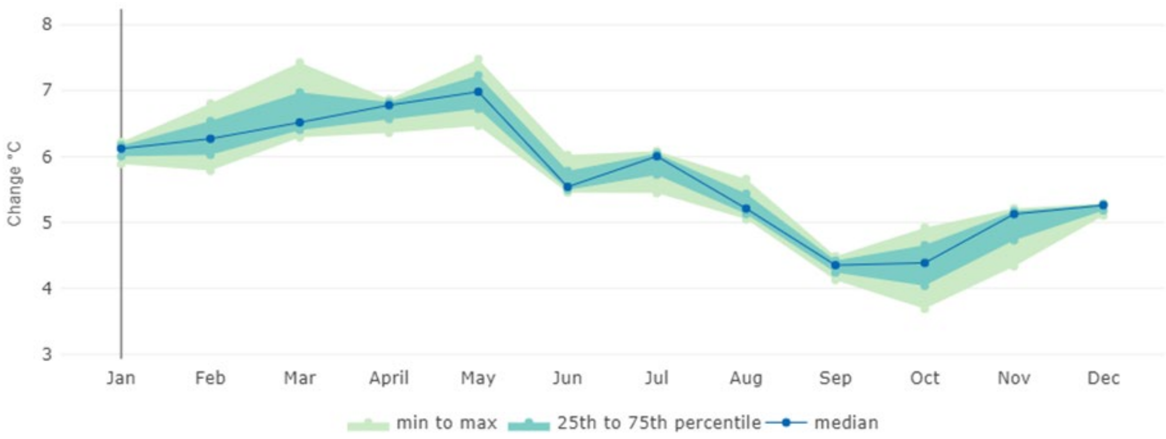
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 96: Projected change in annual mean temperature under RCP 8.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between 3.7 °C and 7.5 °C



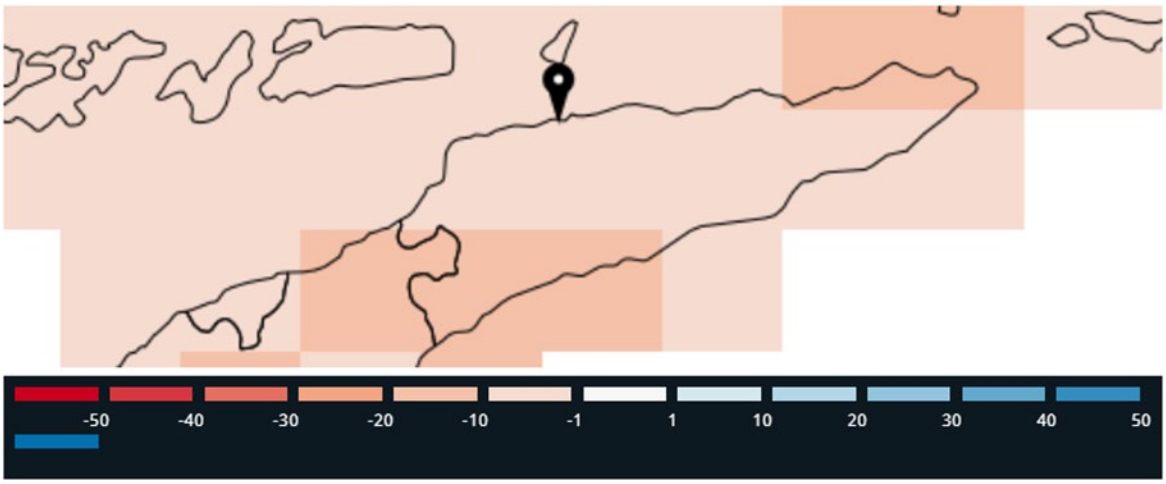
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 97: Projected change in monthly mean temperature under RCP 8.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is -9.5% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -15% and 9%



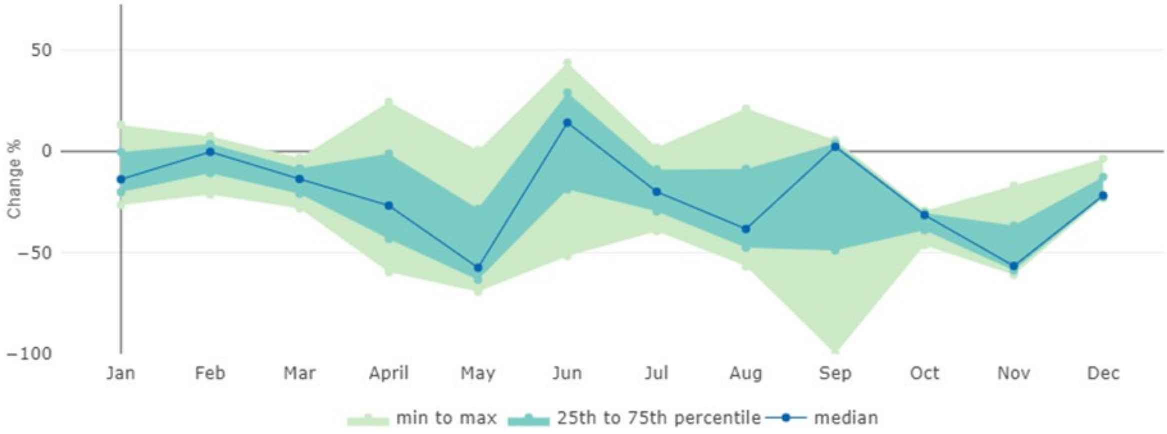
Indicator: Precipitation (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 98: Projected change in annual mean precipitation under RCP 8.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -100% and 44%



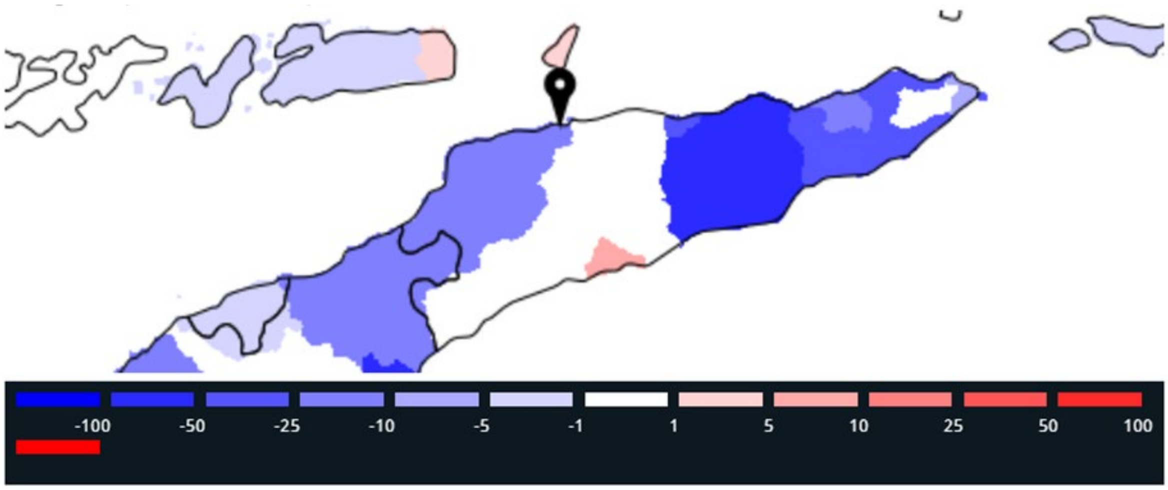
Indicator: Precipitation (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 99: Projected change in monthly mean precipitation under RCP 8.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is -19% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -35% and -16%



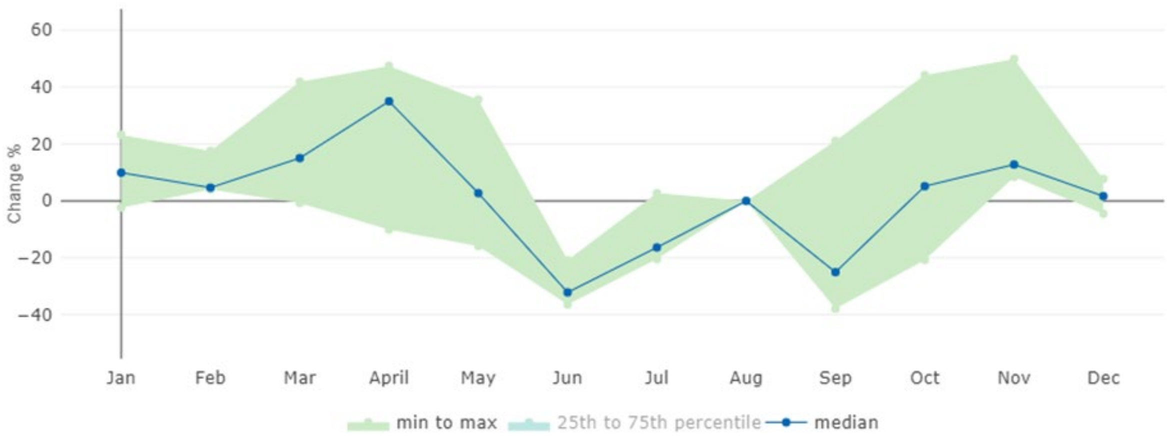
Indicator: Aridity actual (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 100: Projected change in annual mean actual aridity under RCP 8.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -38% and 50%



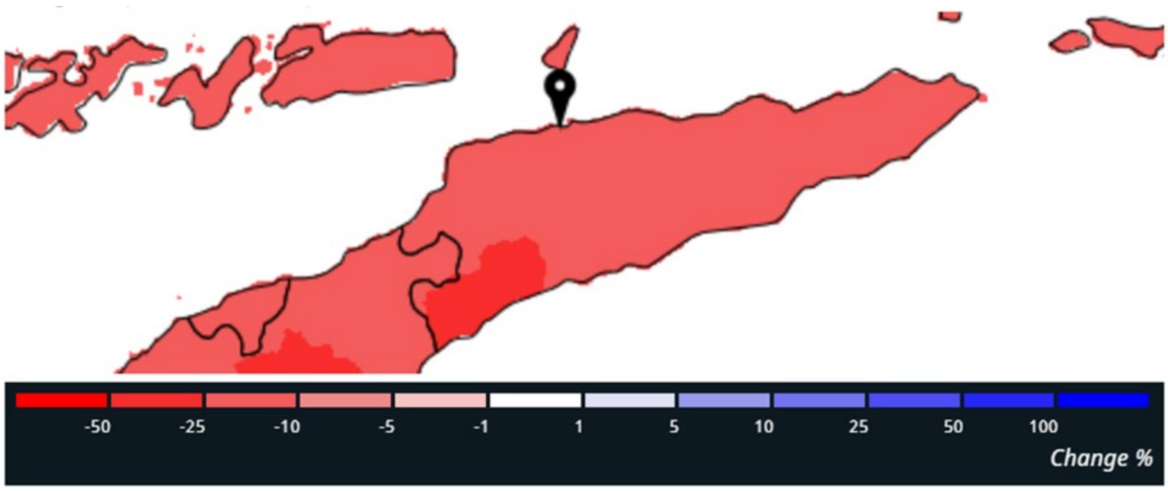
Indicator: Aridity actual (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 101: Projected change in monthly mean actual aridity under RCP 8.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is -17% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -20% and -16%



Indicator: Soils moisture (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Dilli, Distrito Díli (-8.56, 125.57)

Figure 102: Projected change in annual mean soil moisture under RCP 8.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -69% and 3.7%

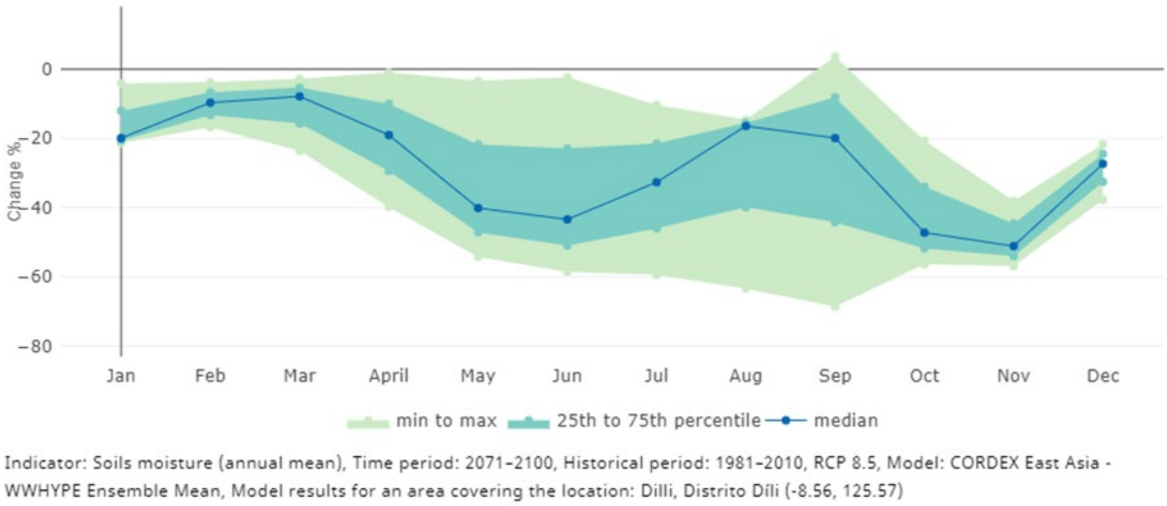


Figure 103: Projected change in monthly mean soil moisture under RCP 8.5 in the time period 2071 – 2100 for Dilli, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

3.5.2 Lospalos

Lospalos is located in the district of Lautém, Timor-Leste at 8.52°S, 127.00°E.

Figure 104: Location of Lospalos, Timor-Leste (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2011 – 2040 under RCP4.5

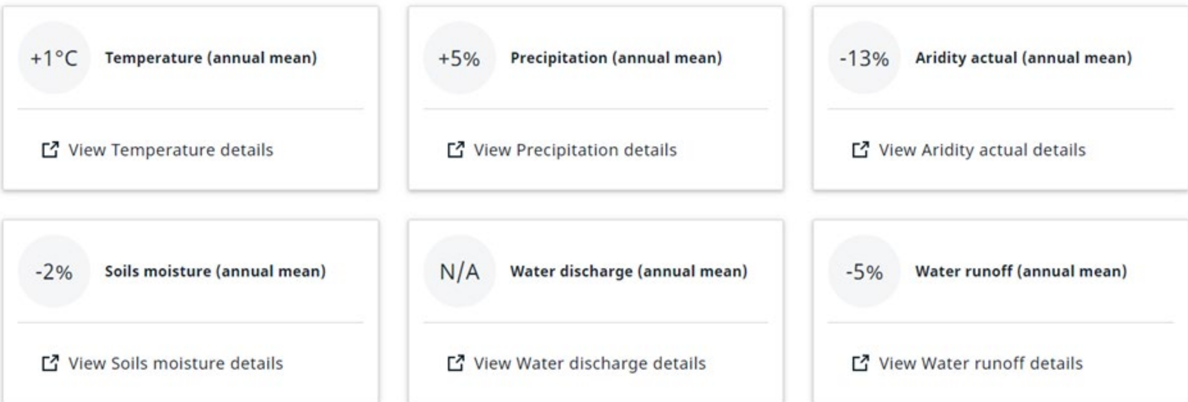


Figure 105: Future change in key indicators under RCP 4.5 in the time period 2011 – 2040 under RCP4.5 for Lospalos, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is 1.1 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 1.1 °C and 1.1 °C

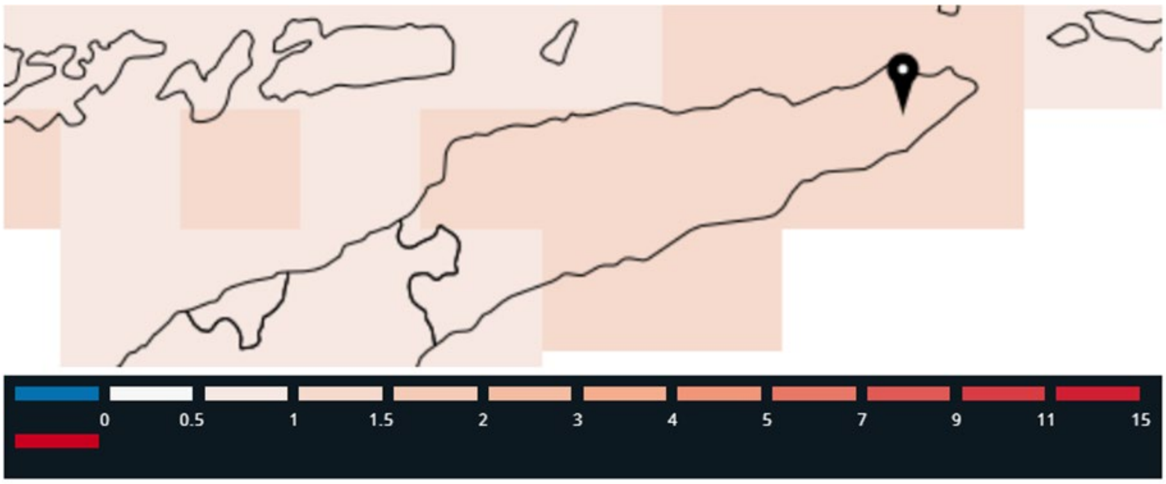


Figure 106: Projected change in annual mean temperature under RCP 4.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

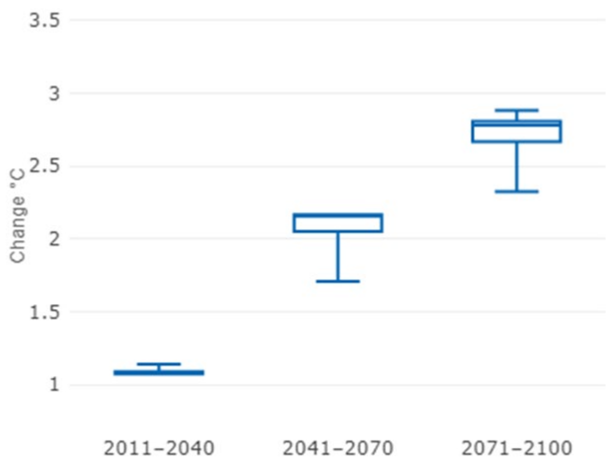


Figure 107: Projected change in annual mean temperature under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between 0.62 °C and 1.4 °C

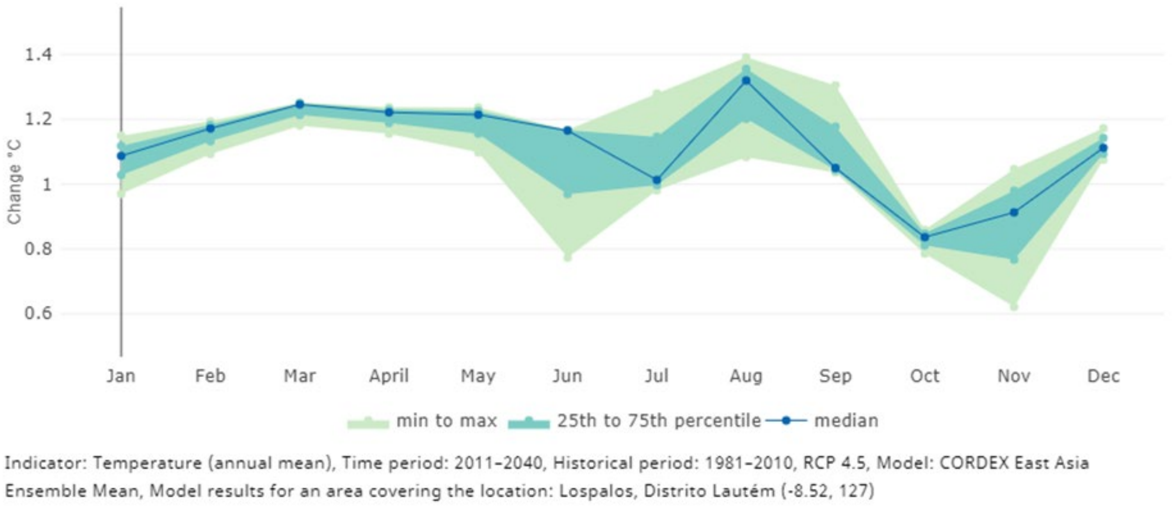


Figure 108: Projected change in monthly mean temperature under RCP 4.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is 4.9% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 2.1% and 4.9%

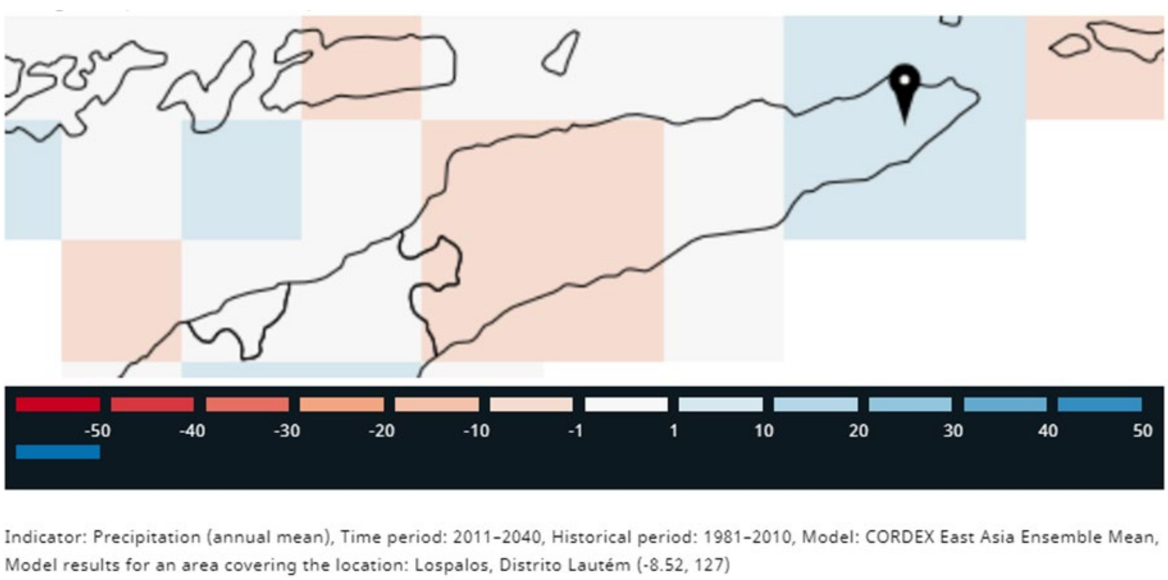


Figure 109: Projected change in annual mean precipitation in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

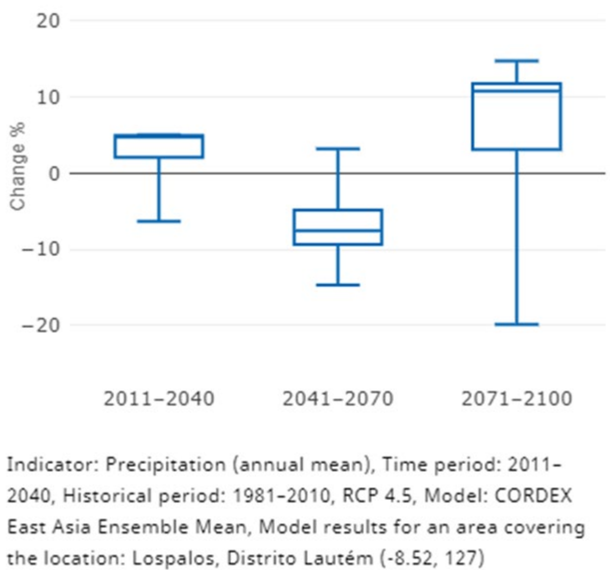


Figure 110: Projected change in annual mean precipitation under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -48% and 130%

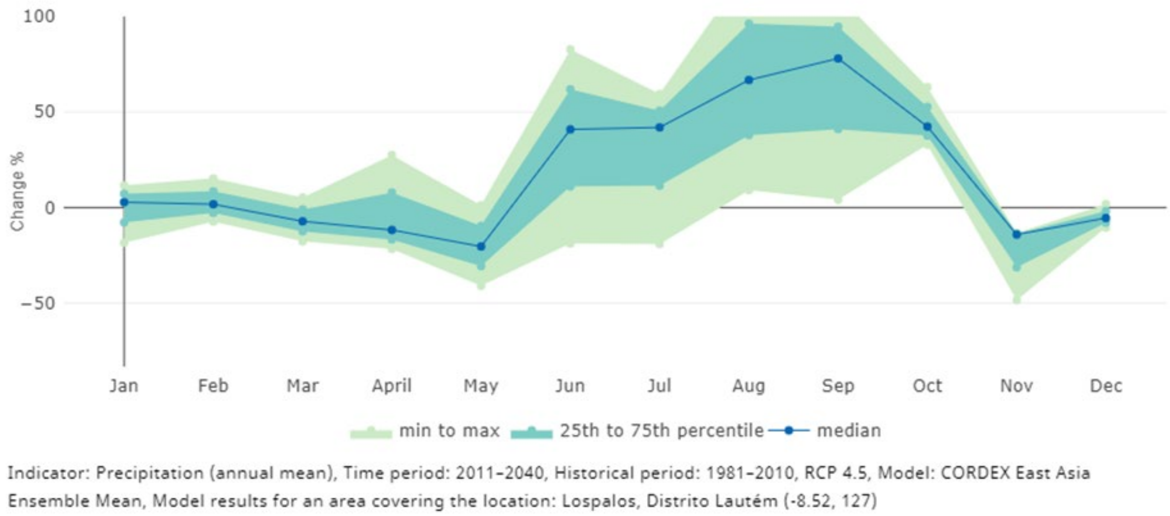
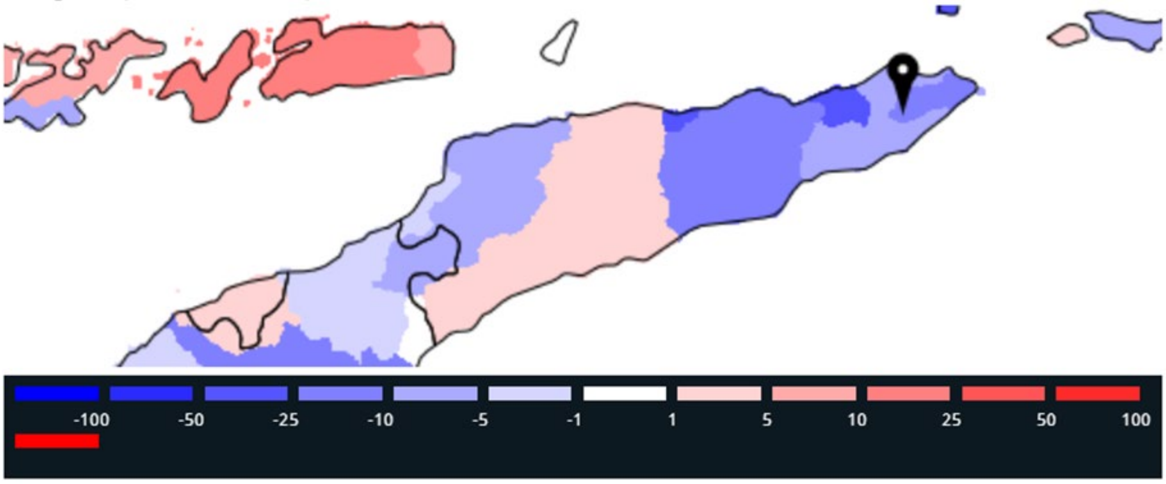


Figure 111: Projected change in monthly mean precipitation under RCP 4.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

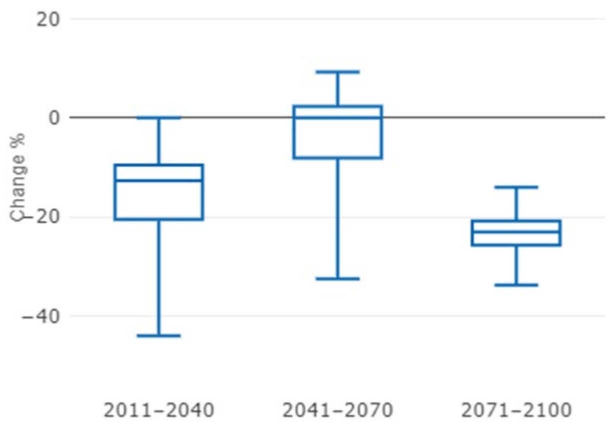
For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is -13% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -21% and -9.5%



Indicator: Aridity actual (annual mean), Time period: 2011–2040, Historical period: 1981–2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 112: Projected change in annual mean actual aridity under RCP 4.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



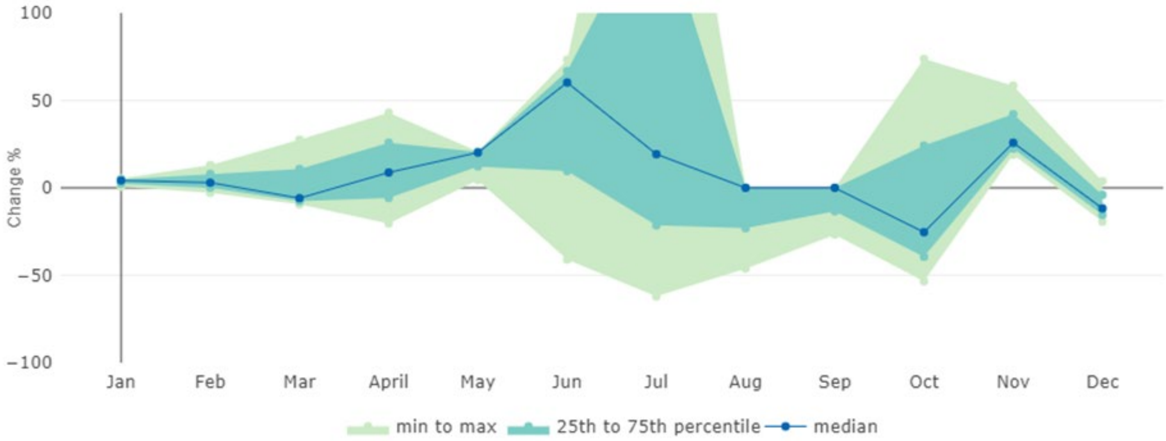
Indicator: Aridity actual (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 113: Projected change in annual mean actual aridity under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -62% and 310%



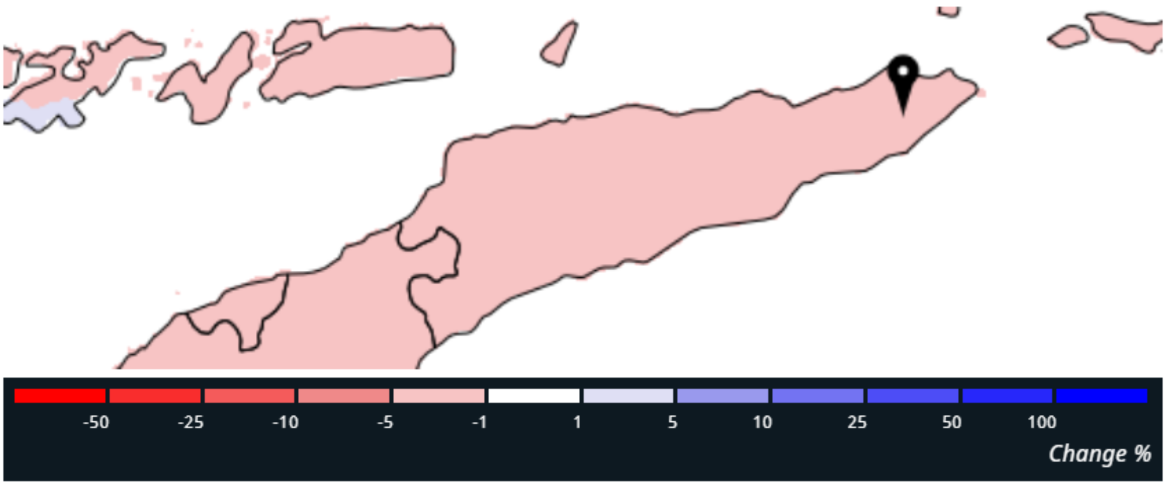
Indicator: Aridity actual (annual mean), Time period: 2011-2040, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 114: Projected change in monthly mean actual aridity under RCP 4.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is -2.1% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -2.4% and -0.67%



Indicator: Soils moisture (annual mean), Time period: 2011-2040, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 115: Projected change in annual mean soil moisture under RCP 4.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

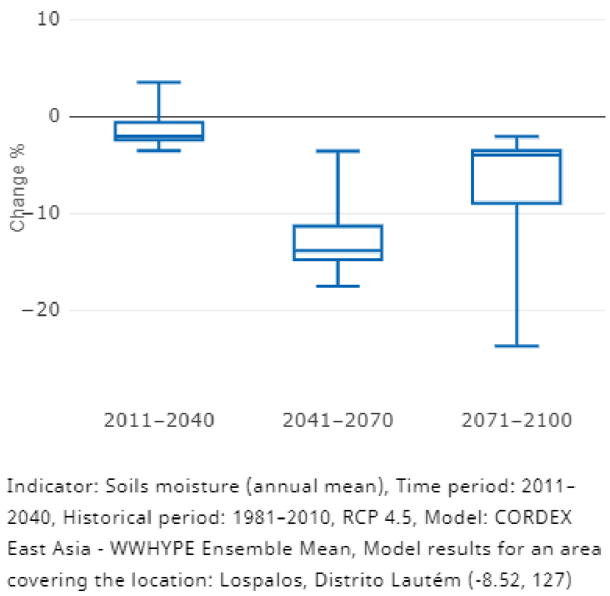


Figure 116: Projected change in annual mean soil moisture under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -28% and 40%

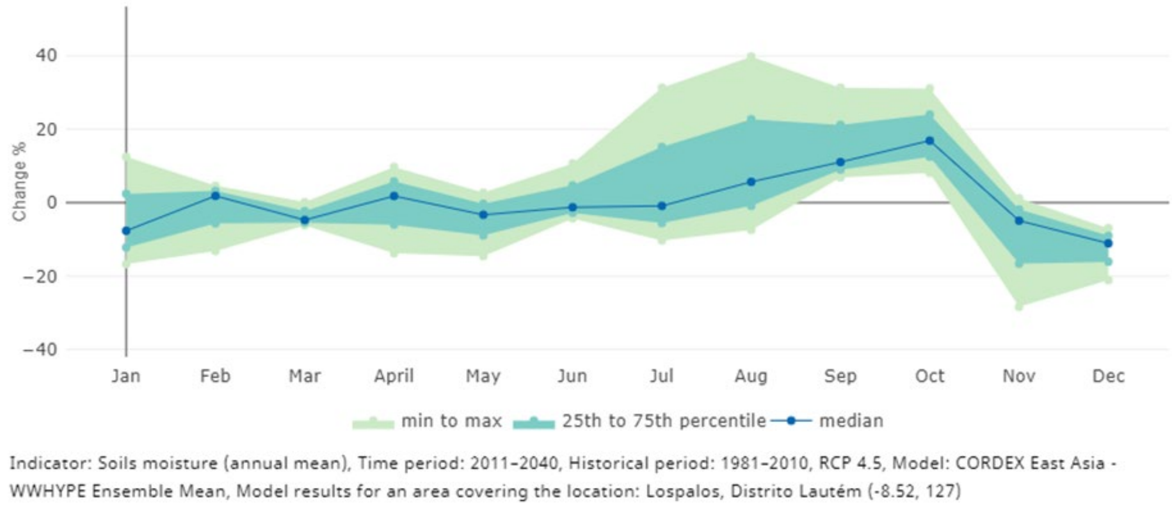


Figure 117: Projected change in monthly mean soil moisture under RCP 4.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2041 – 2070 under RCP4.5

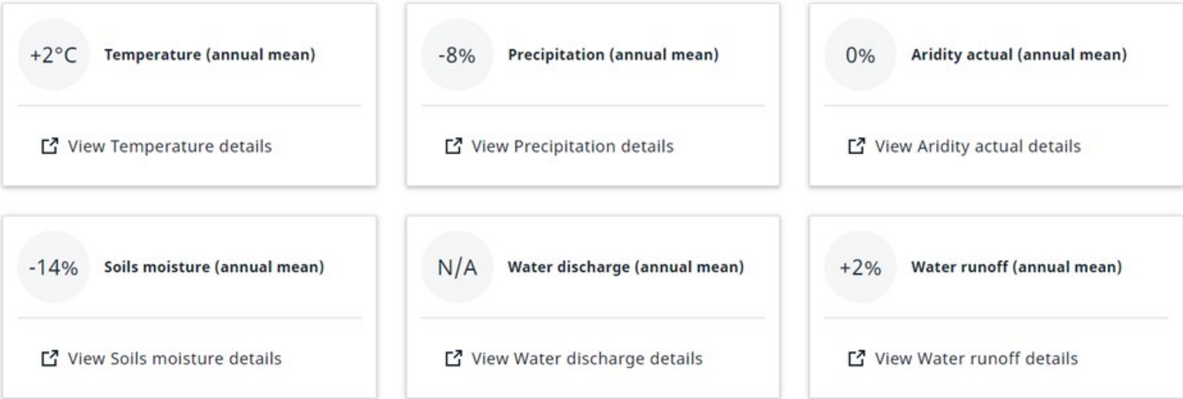


Figure 118: Future change in key indicators under RCP 4.5 in the time period 2041 – 2070 under RCP4.5 for Lospalos, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is 2.2 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 2.1 °C and 2.2 °C

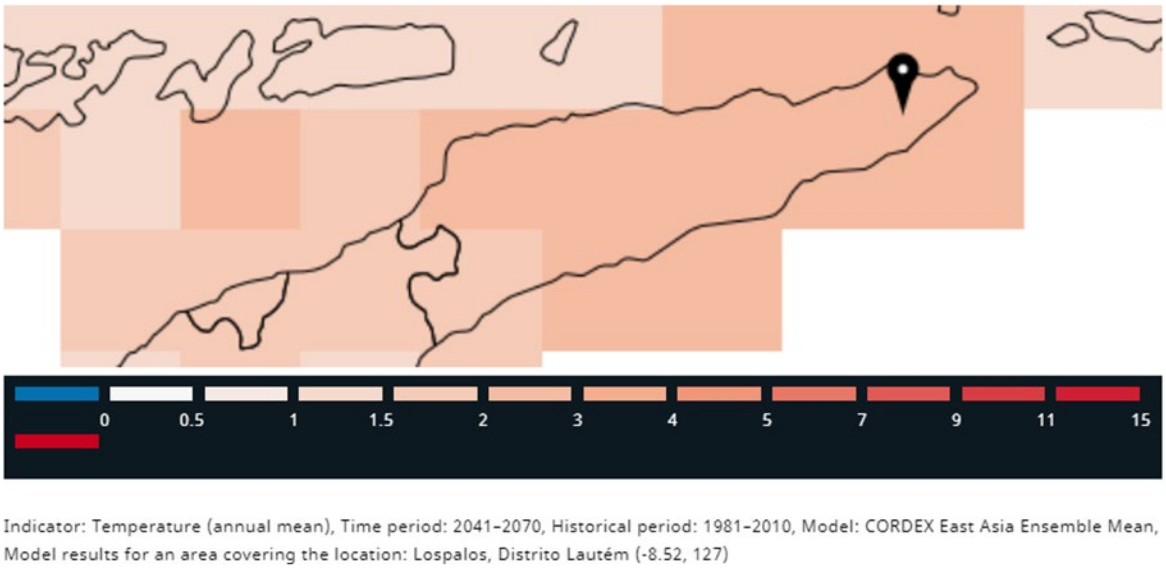


Figure 119: Projected change in annual mean temperature under RCP 4.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between 1.4 °C and 2.7 °C

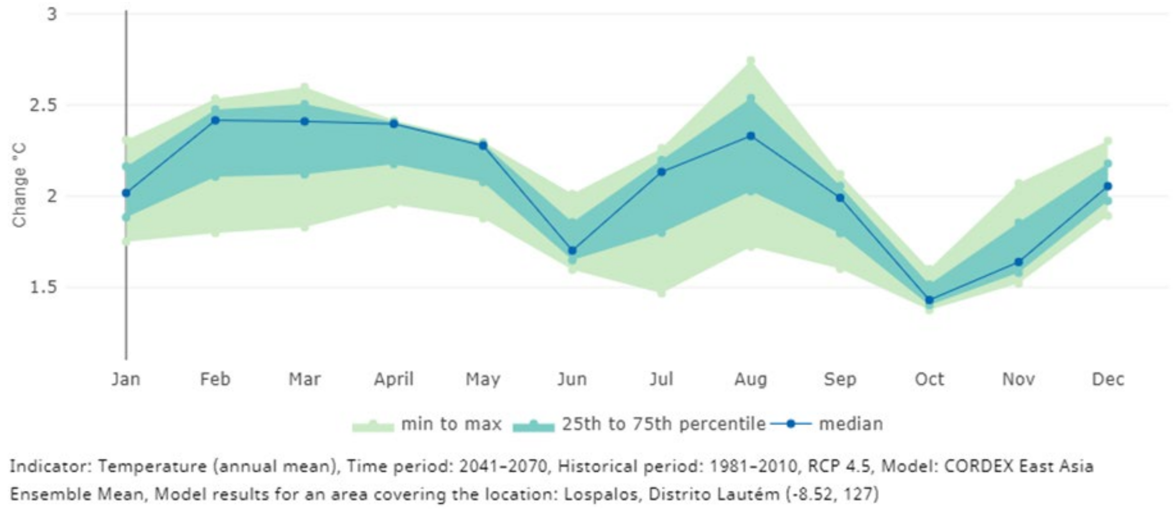


Figure 120: Projected change in monthly mean temperature under RCP 4.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is -7.5% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -9.3% and -4.9%

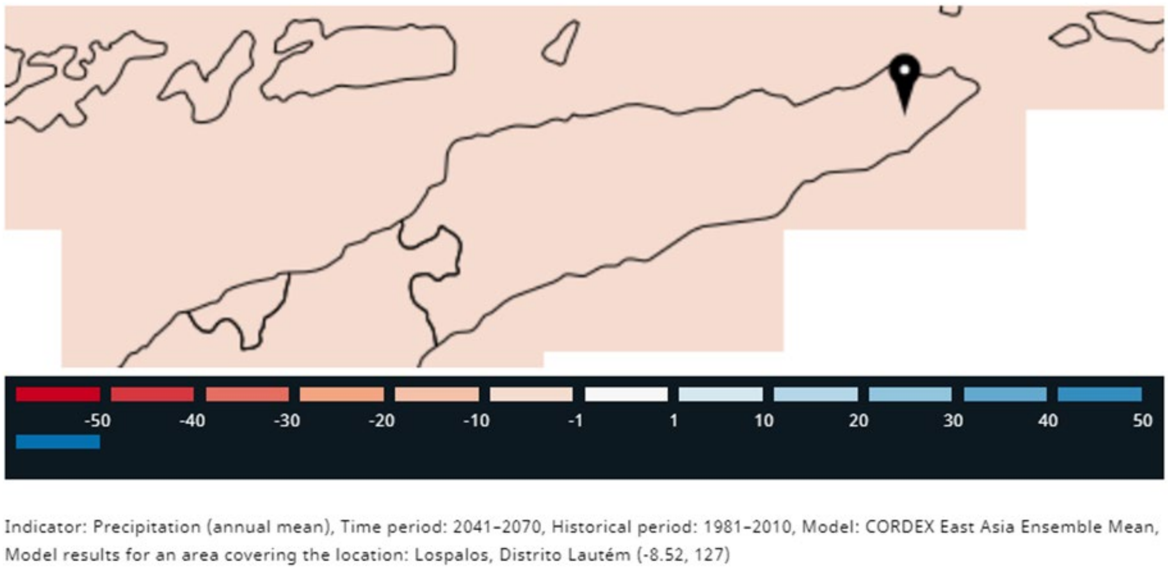


Figure 121: Projected change in annual mean precipitation under RCP 4.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -100% and 120%

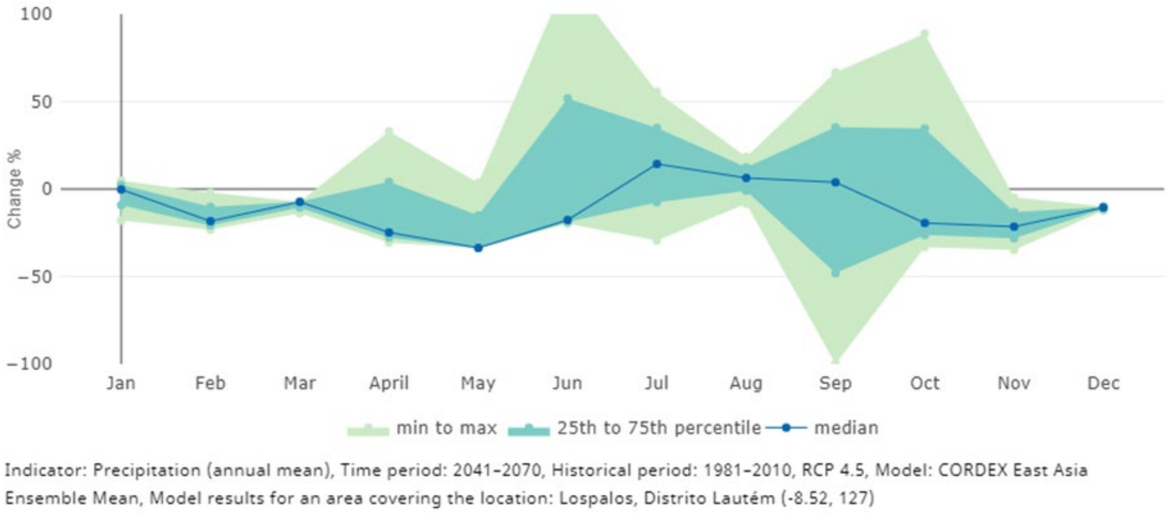


Figure 122: Projected change in monthly mean precipitation under RCP 4.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is -0% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -8.1% and 2.3%

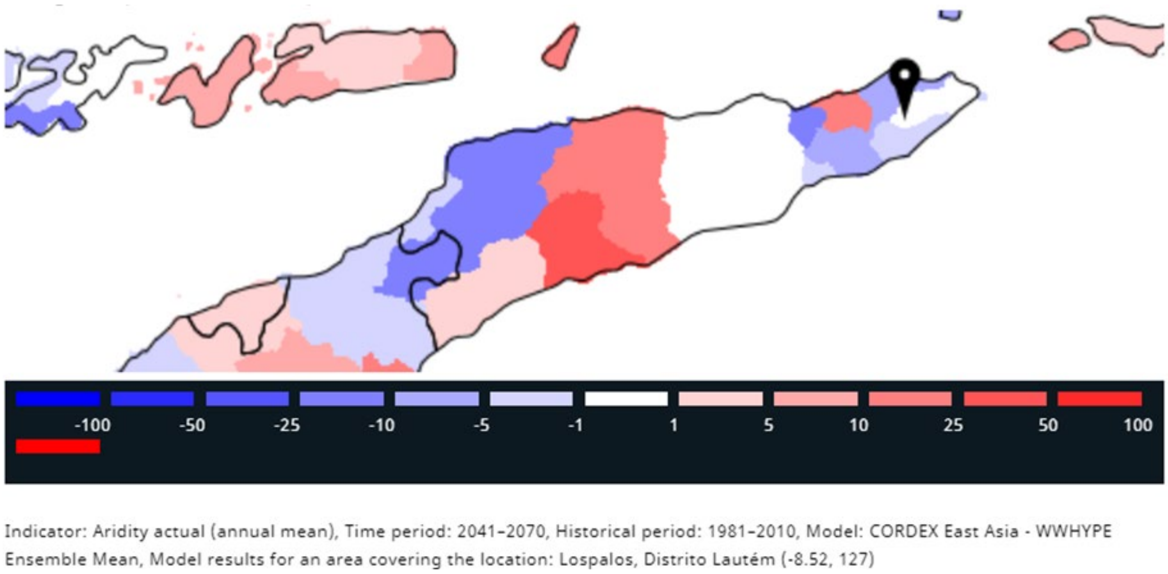


Figure 123: Projected change in annual mean actual aridity under RCP 4.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -62% and 180%

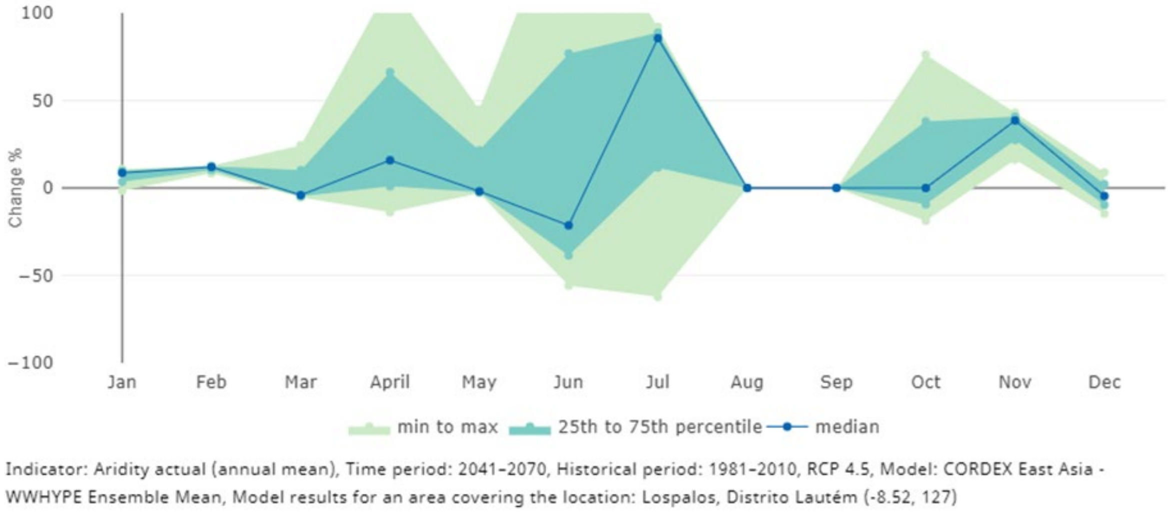


Figure 124: Projected change in monthly mean actual aridity under RCP 4.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is -14% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -15% and -11%

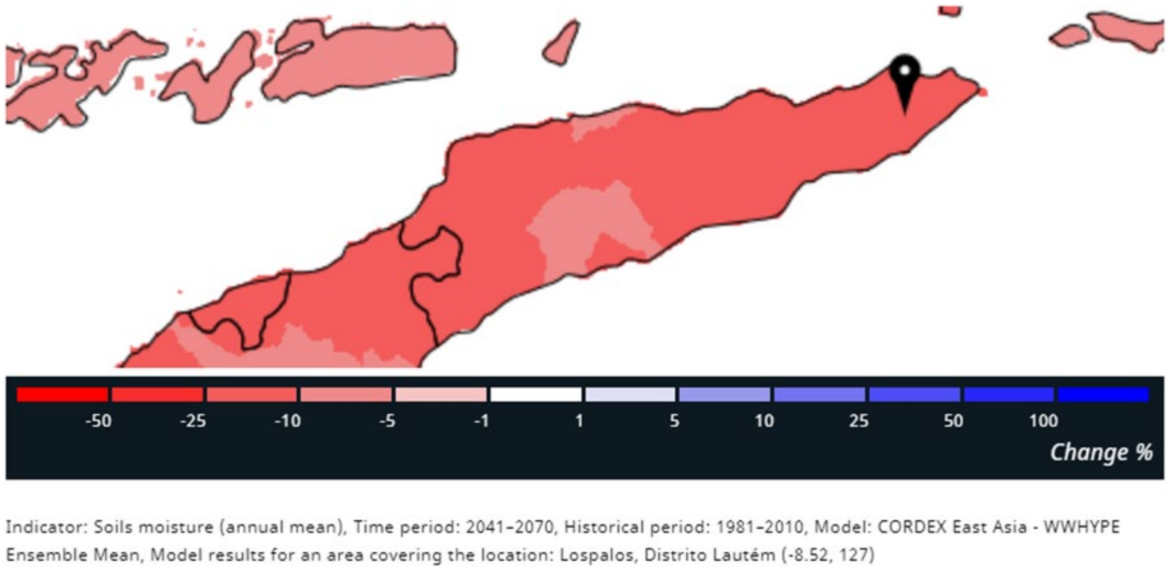


Figure 125: Projected change in annual mean soil moisture under RCP 4.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -31% and 30%

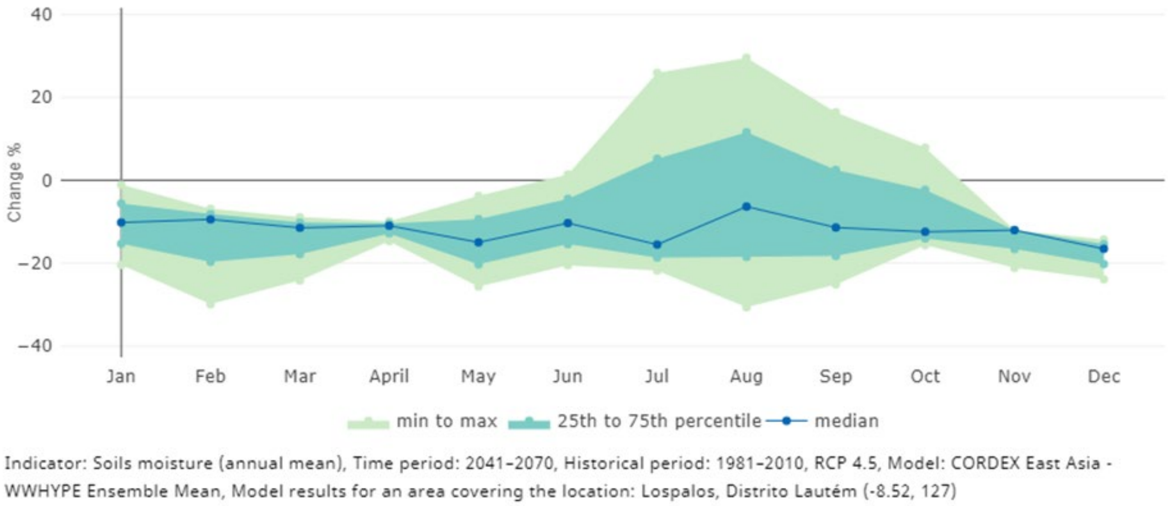


Figure 126: Projected change in monthly mean soil moisture under RCP 4.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2071 – 2100 under RCP4.5

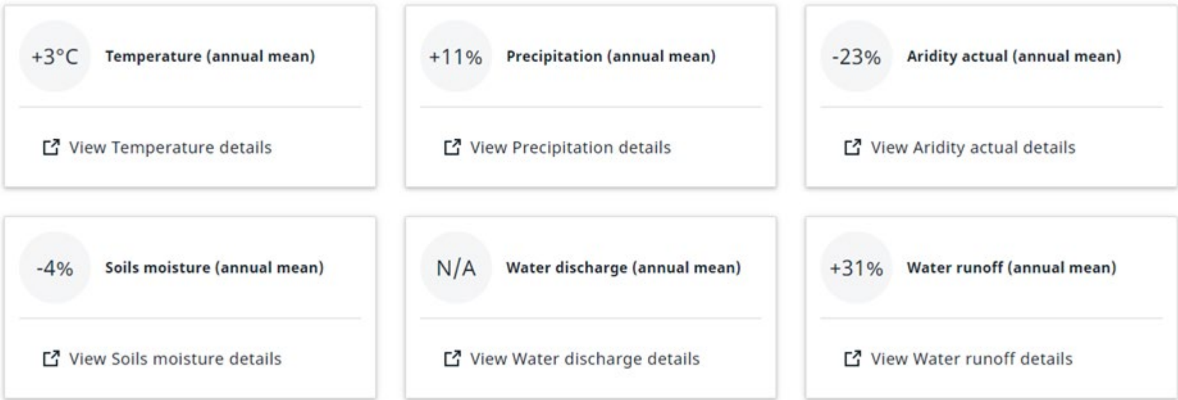
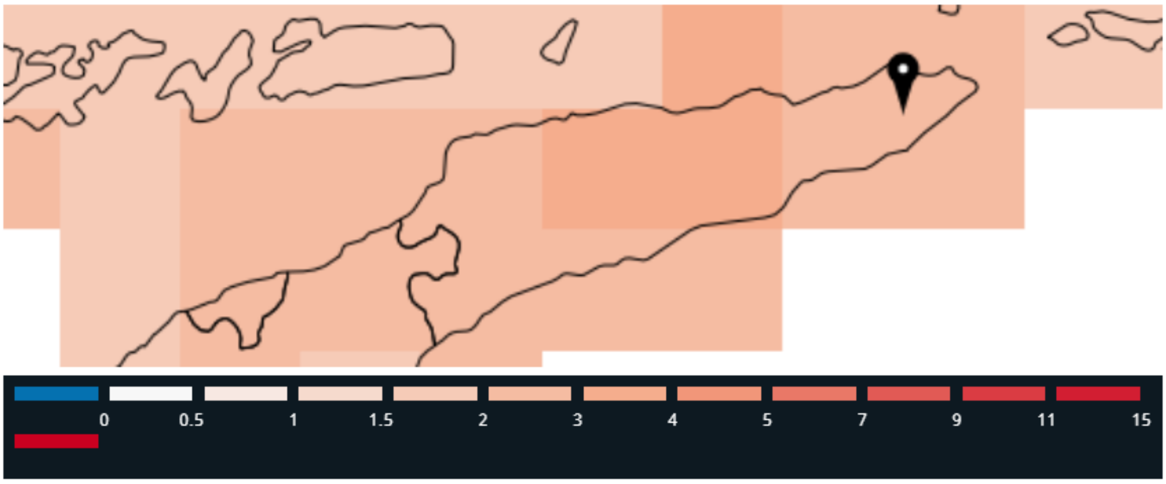


Figure 127: Future change in key indicators under RCP 4.5 in the time period 2071 – 2100 under RCP4.5 for Lospalos, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is 2.8 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 2.7 °C and 2.8 °C



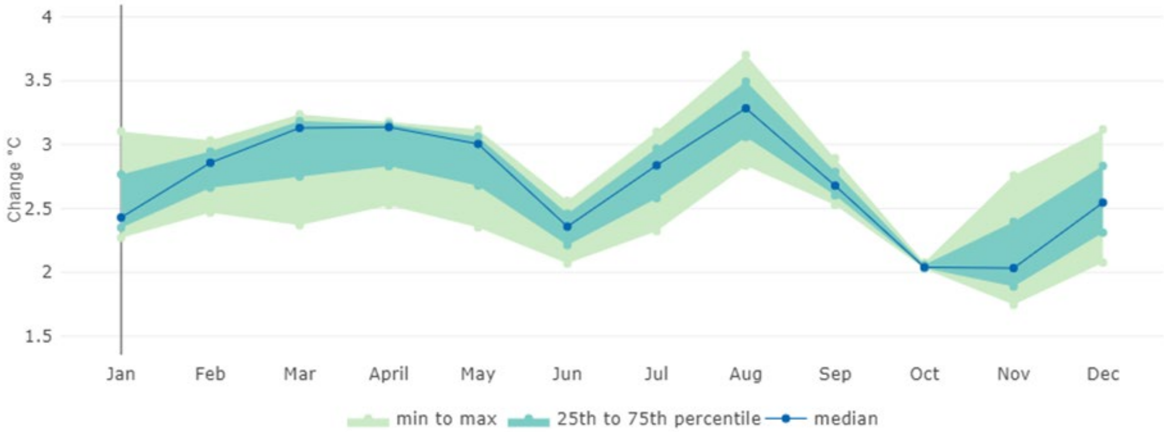
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 128: Projected change in annual mean temperature under RCP 4.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between 1.7 °C and 3.7 °C



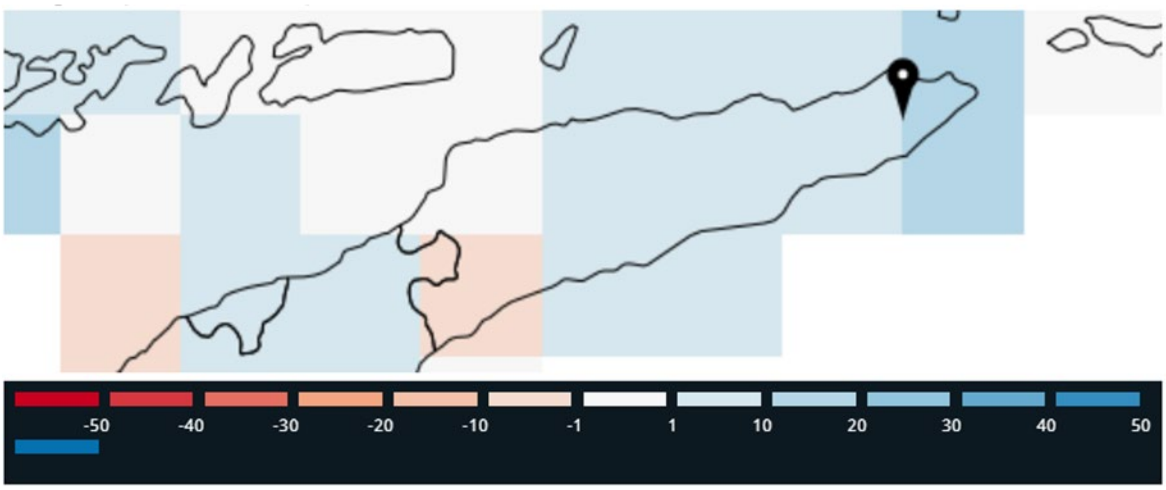
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 129: Projected change in monthly mean temperature under RCP 4.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is 11% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 3.1% and 12%



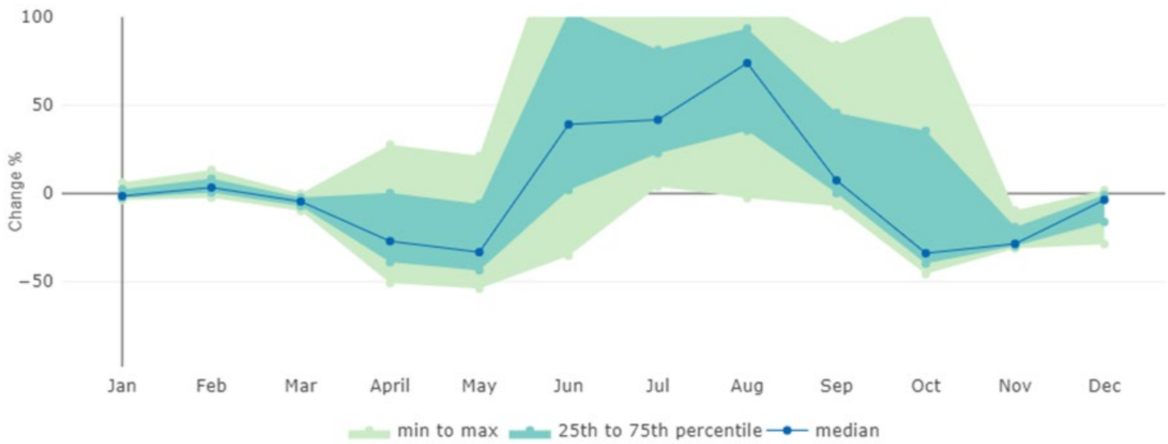
Indicator: Precipitation (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 130: Projected change in annual mean precipitation under RCP 4.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -54% and 170%



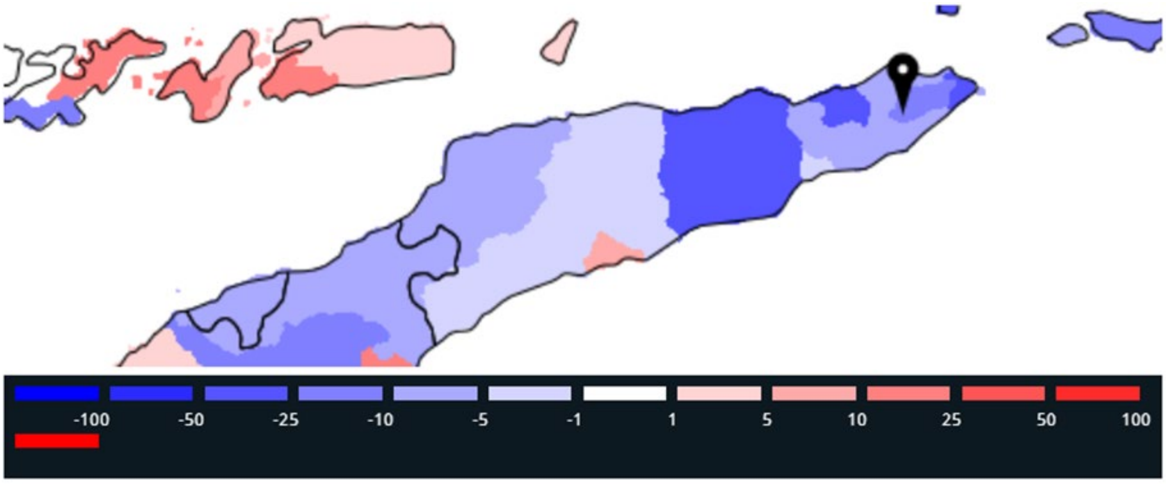
Indicator: Precipitation (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 131: Projected change in monthly mean precipitation under RCP 4.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is -23% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -26% and -21%



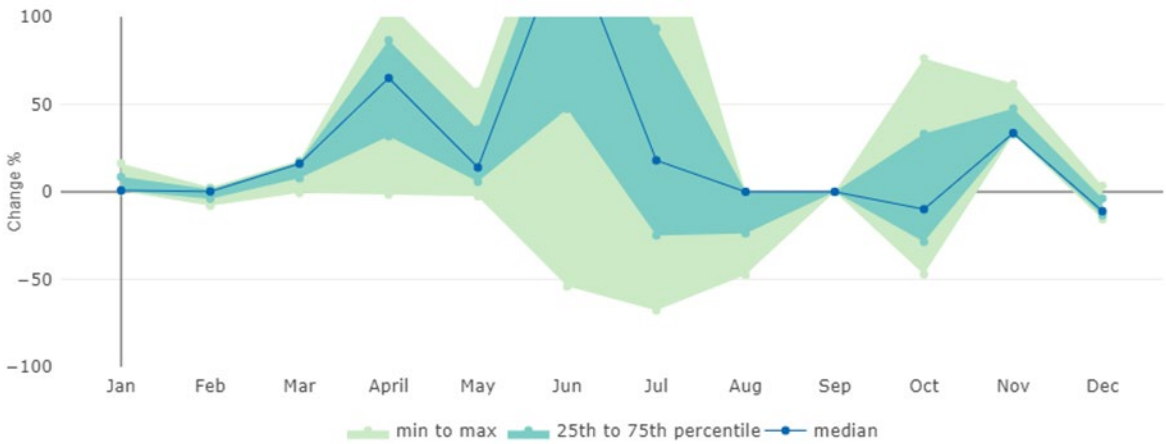
Indicator: Aridity actual (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 132: Projected change in annual mean actual aridity under RCP 4.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -68% and 200%



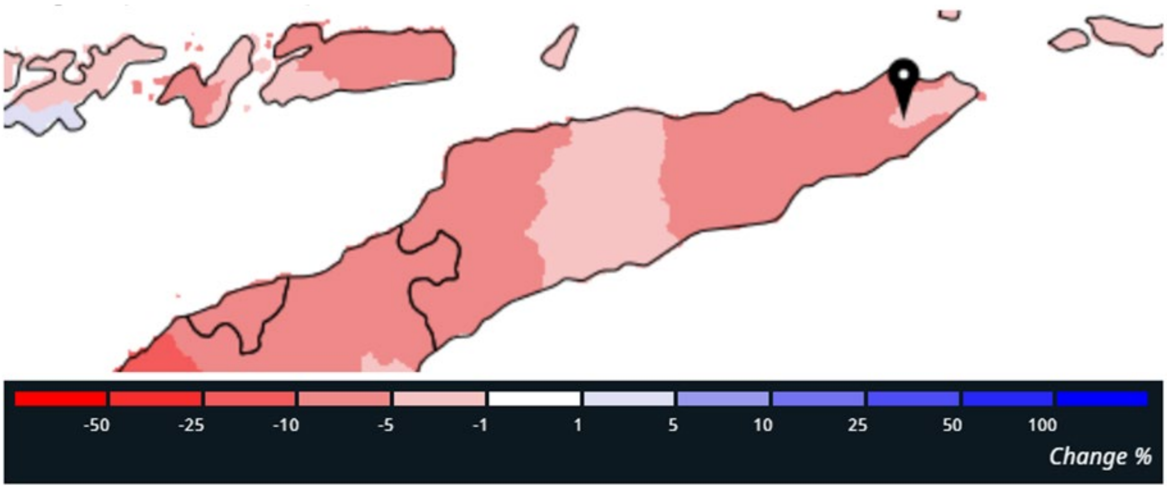
Indicator: Aridity actual (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 133: Projected change in monthly mean actual aridity under RCP 4.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is -4% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -9% and -3.5%



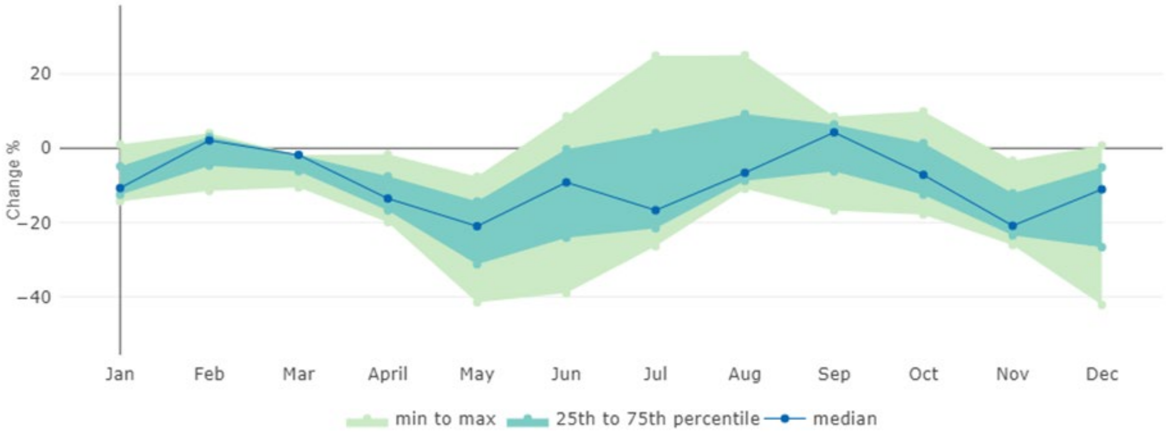
Indicator: Soils moisture (annual mean), Time period: 2071–2100, Historical period: 1981–2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 134: Projected change in annual mean soil moisture under RCP 4.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -59% and 41%



Indicator: Soils moisture (annual mean), Time period: 2071–2100, Historical period: 1981–2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 135: Projected change in monthly mean soil moisture under RCP 4.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2011 – 2040 under RCP 8.5

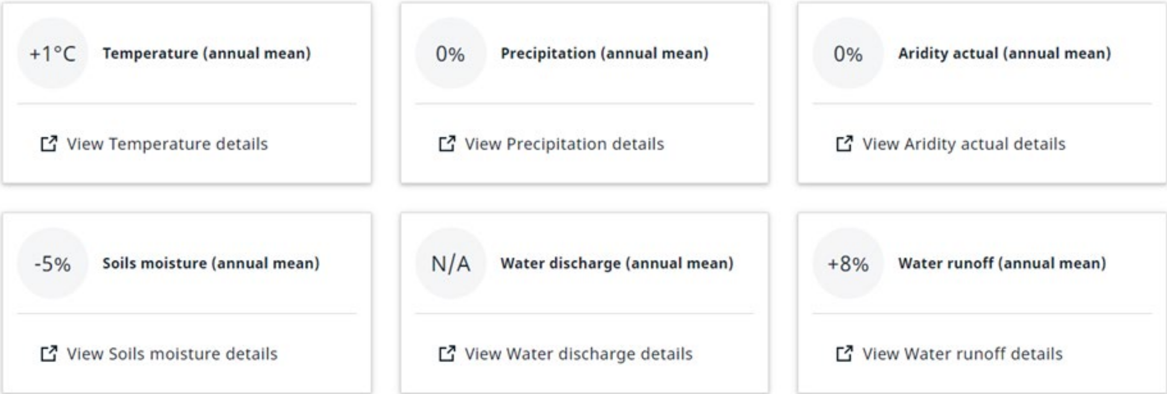


Figure 136: Future change in key indicators under RCP 8.5 in the time period 2011 – 2040 under RCP8.5 for Lospalos, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is 1.3 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 1.3 °C and 1.3 °C

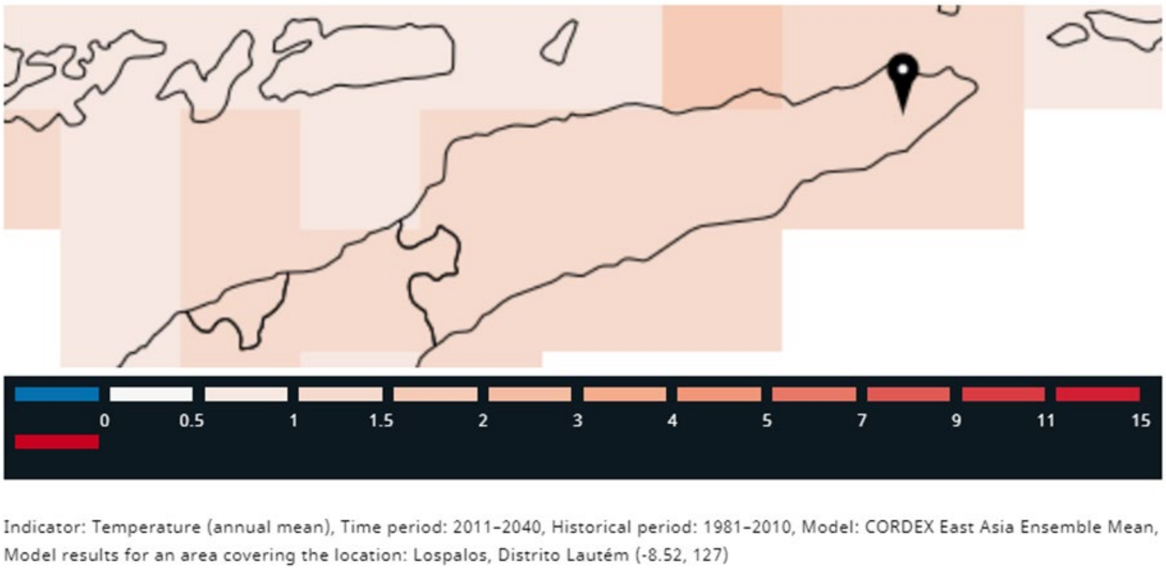
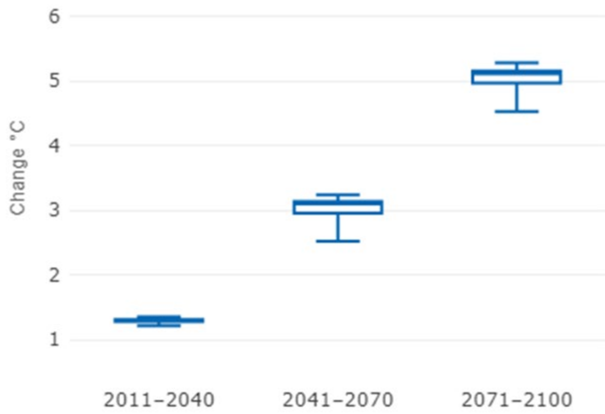


Figure 137: Projected change in annual mean temperature under RCP 8.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



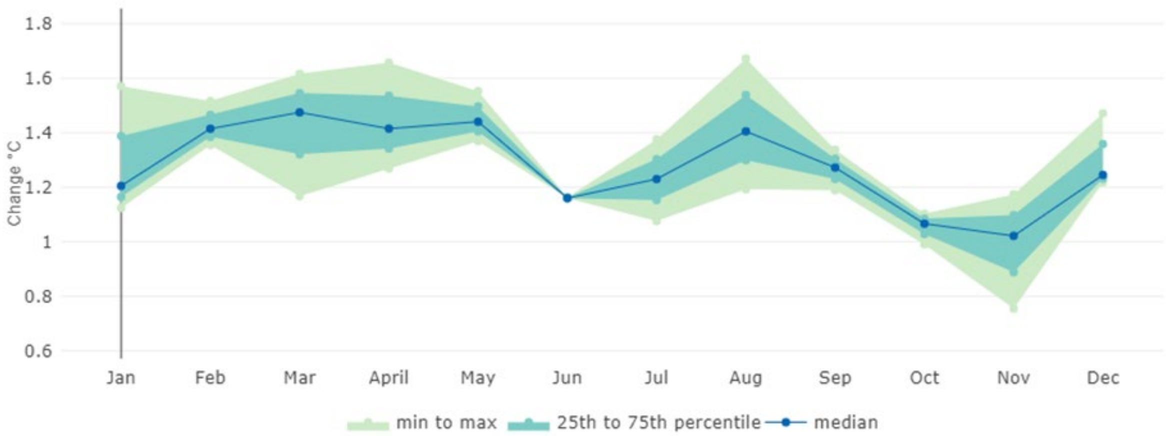
Indicator: Temperature (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 138: Projected change in annual mean temperature under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between 0.75 °C and 1.7 °C



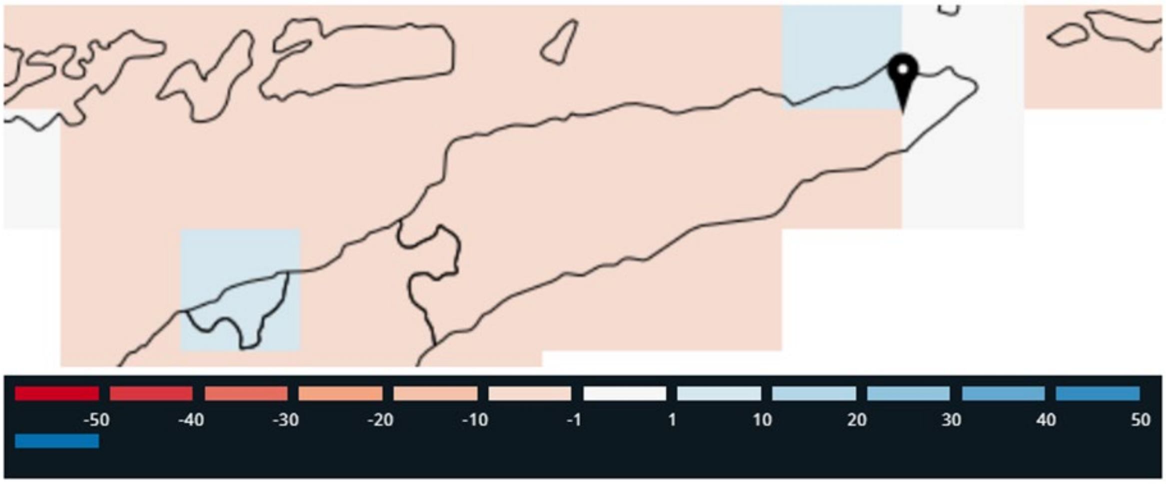
Indicator: Temperature (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 139: Projected change in monthly mean temperature under RCP 8.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

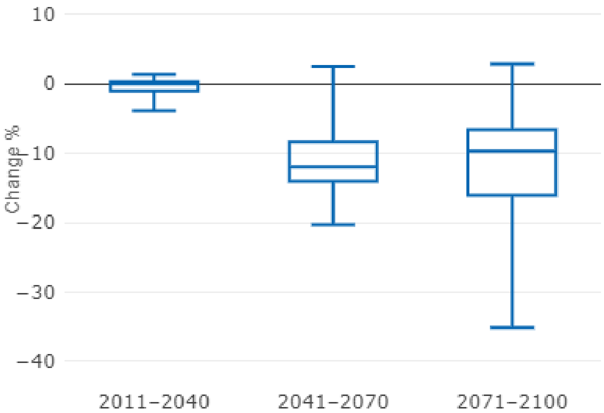
For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is -0.026% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -0.99% and -0.32%



Indicator: Precipitation (annual mean), Time period: 2011-2040, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 140: Projected change in annual mean precipitation under RCP 8.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



Indicator: Precipitation (annual mean), Time period: 2011-2040, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 141: Projected change in annual mean precipitation under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -24% and 110%

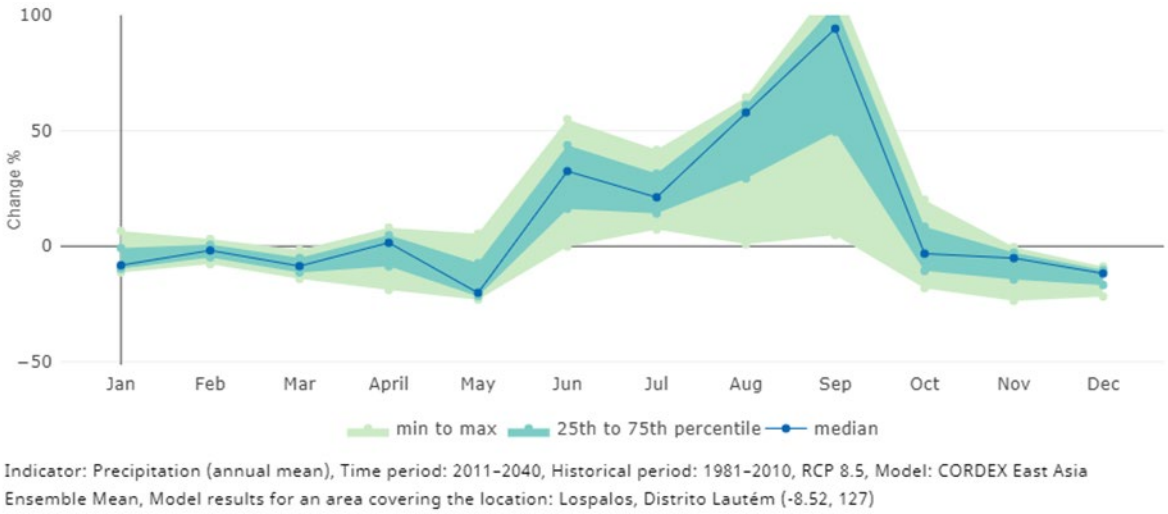


Figure 142: Projected change in monthly mean precipitation under RCP 8.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is 0% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -0.91% and 22%

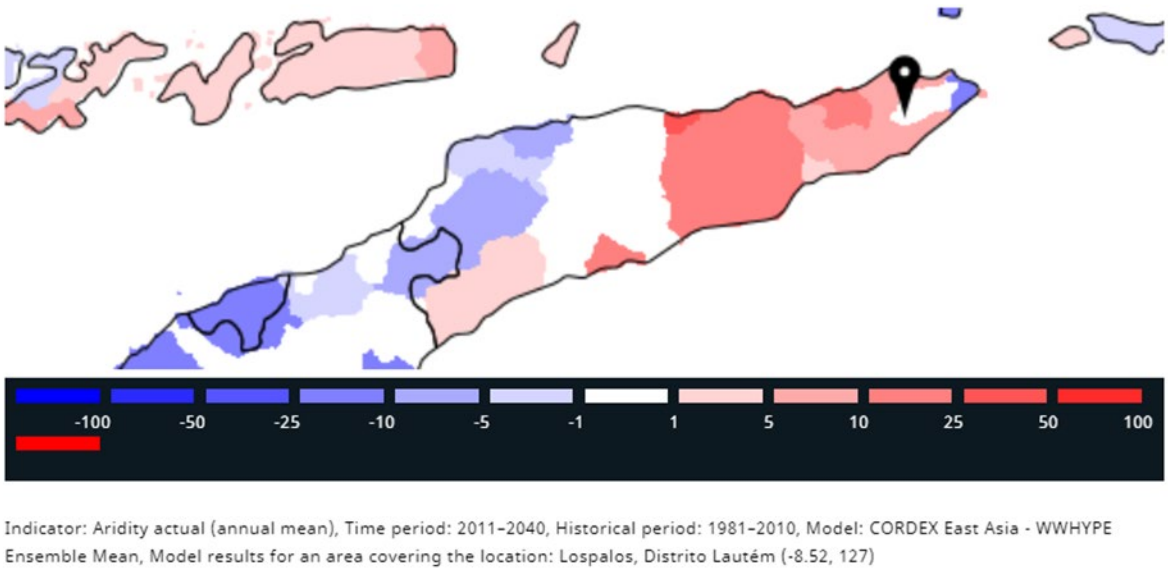
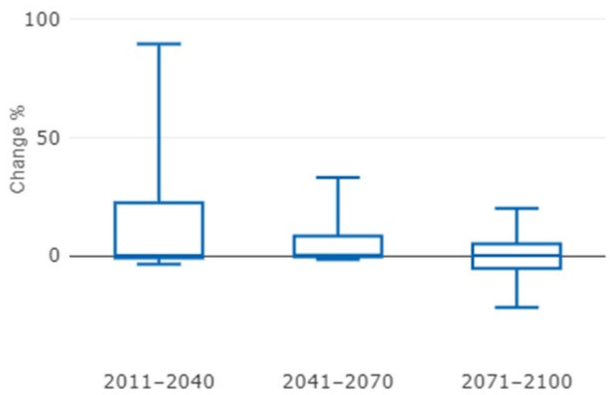


Figure 143: Projected change in annual mean actual aridity under RCP 8.5 in the time period 2011 – 2040 for Lospalos Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



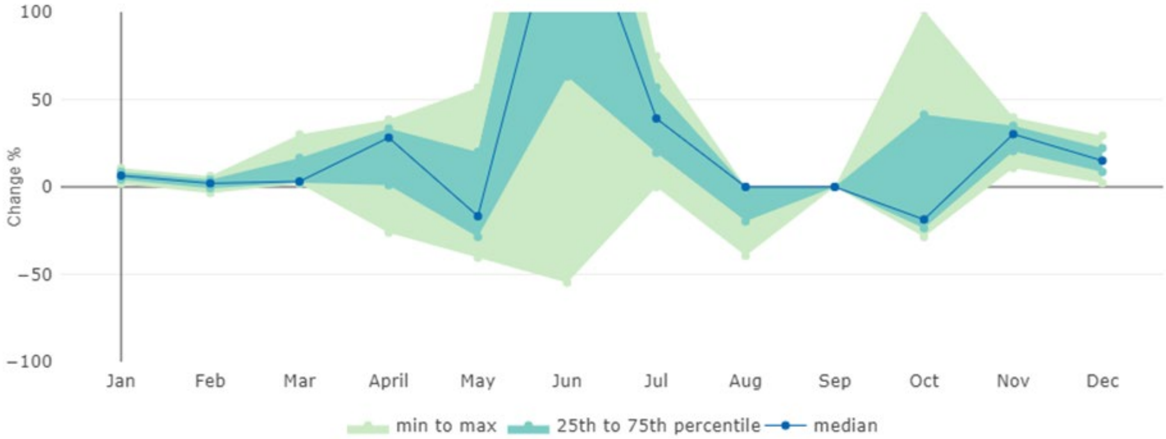
Indicator: Aridity actual (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 144: Projected change in annual mean actual aridity under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -55% and 310%



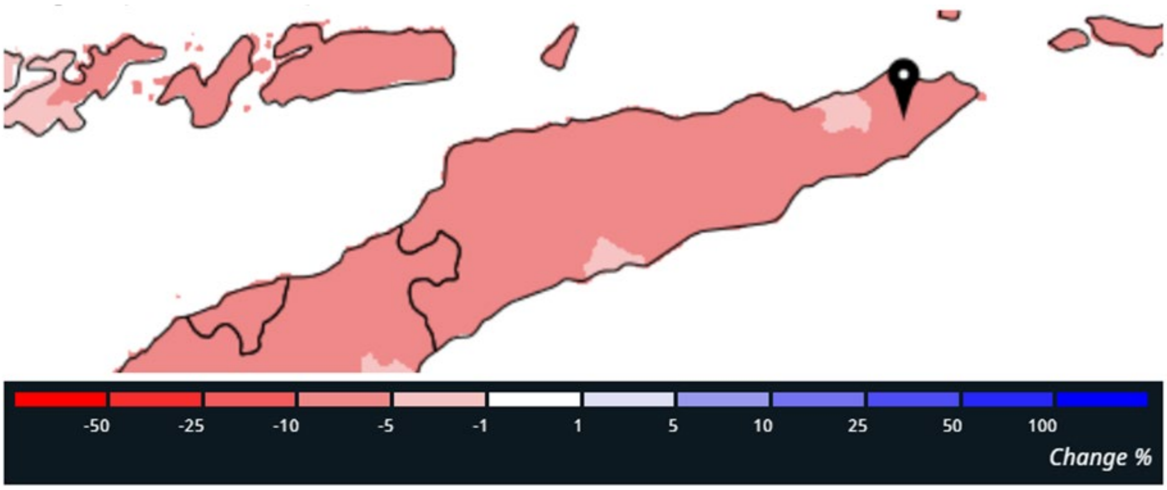
Indicator: Aridity actual (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 145: Projected change in monthly mean actual aridity under RCP 8.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

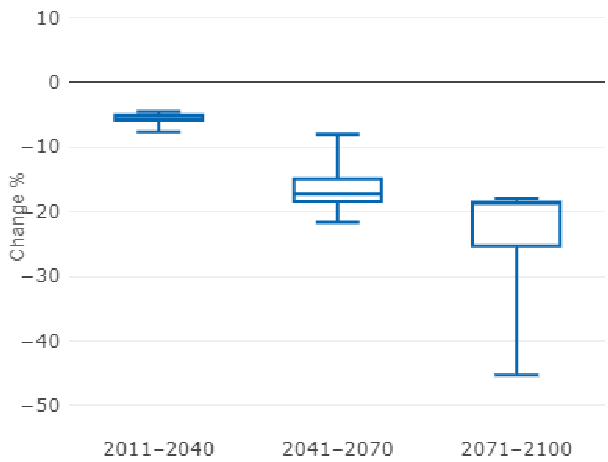
For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is -5.2% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -5.9% and -5.1%



Indicator: Soils moisture (annual mean), Time period: 2011-2040, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 146: Projected change in annual mean soil moisture under RCP 8.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



Indicator: Soils moisture (annual mean), Time period: 2011-2040, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 147: Projected change in annual mean soil moisture under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -20% and 9.6%

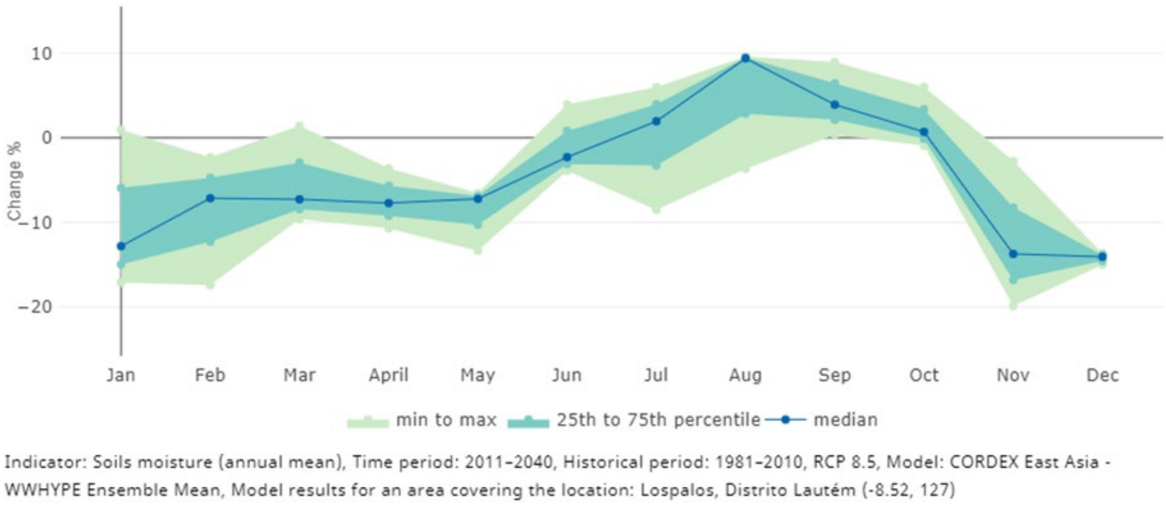


Figure 148: Projected change in monthly mean soil moisture under RCP 8.5 in the time period 2011 – 2040 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2041 – 2070 under RCP 8.5

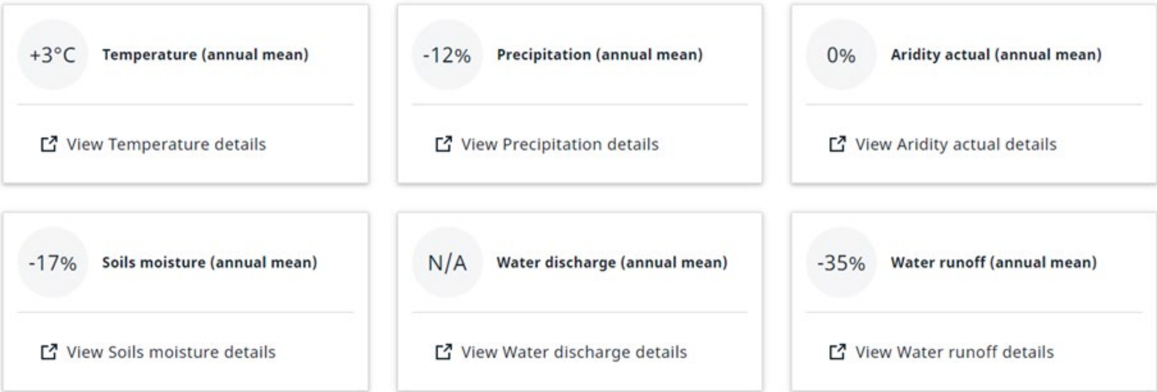
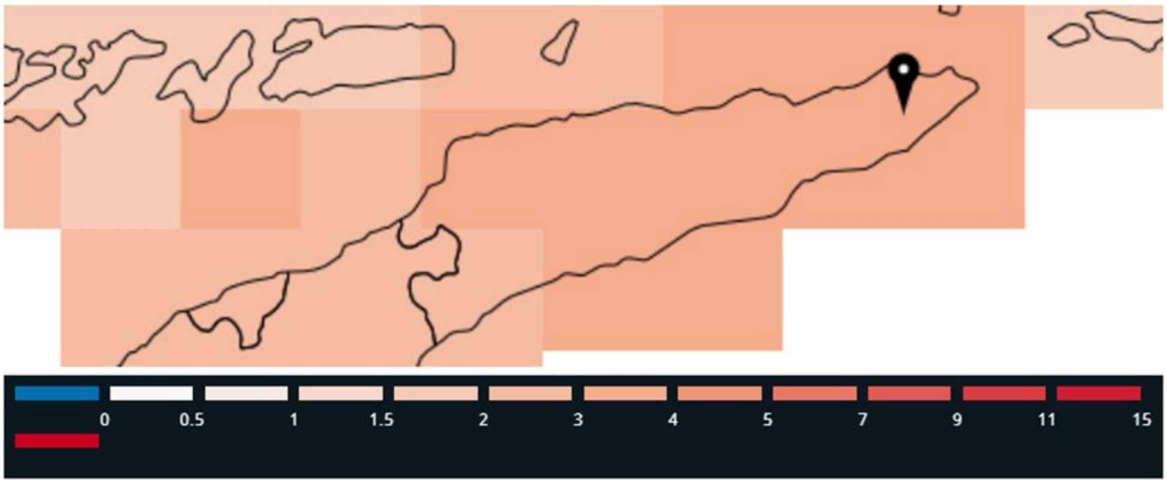


Figure 149: Future change in key indicators in the time period 2041 – 2070 under RCP 8.5 for Lospalos, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is 3.1 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 3 °C and 3.1 °C



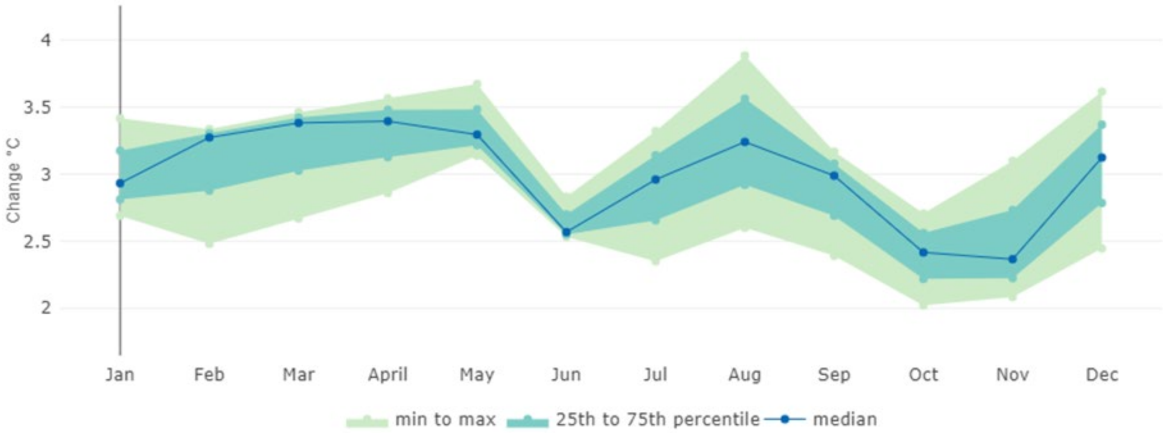
Indicator: Temperature (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 150: Projected change in annual mean temperature under RCP 8.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between 2 °C and 3.9 °C



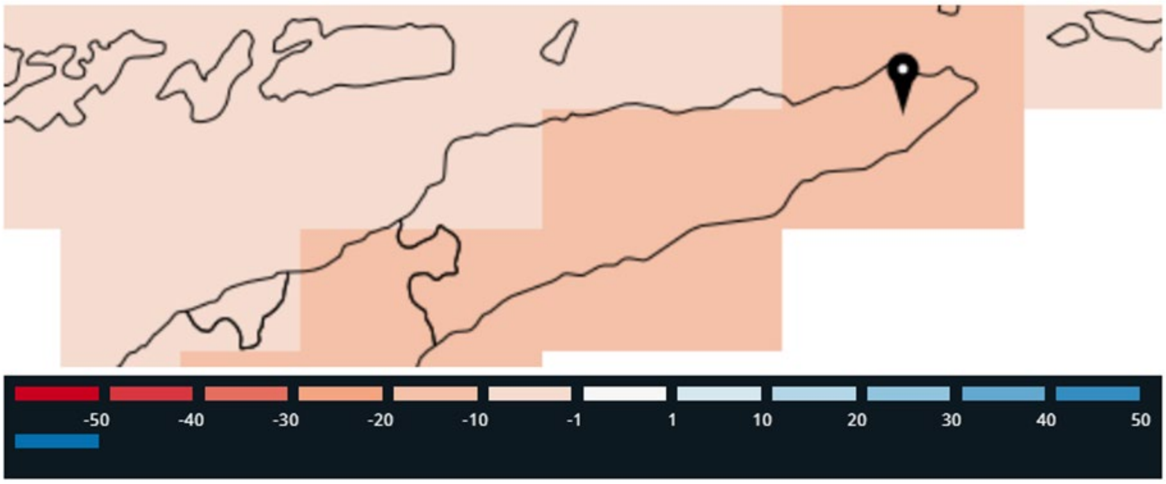
Indicator: Temperature (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 151: Projected change in monthly mean temperature under RCP 8.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is -12% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -14% and -8.3%



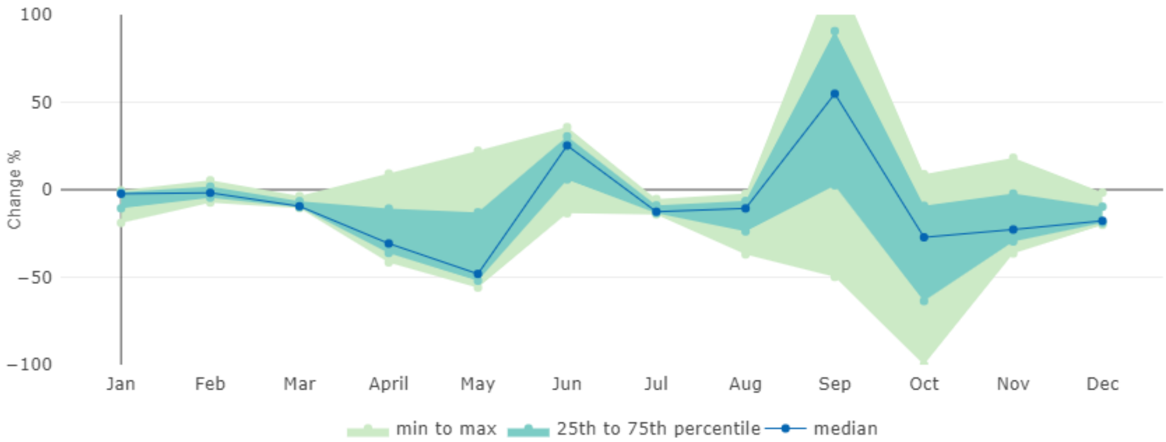
Indicator: Precipitation (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 152: Projected change in annual mean precipitation under RCP 8.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -100% and 130%



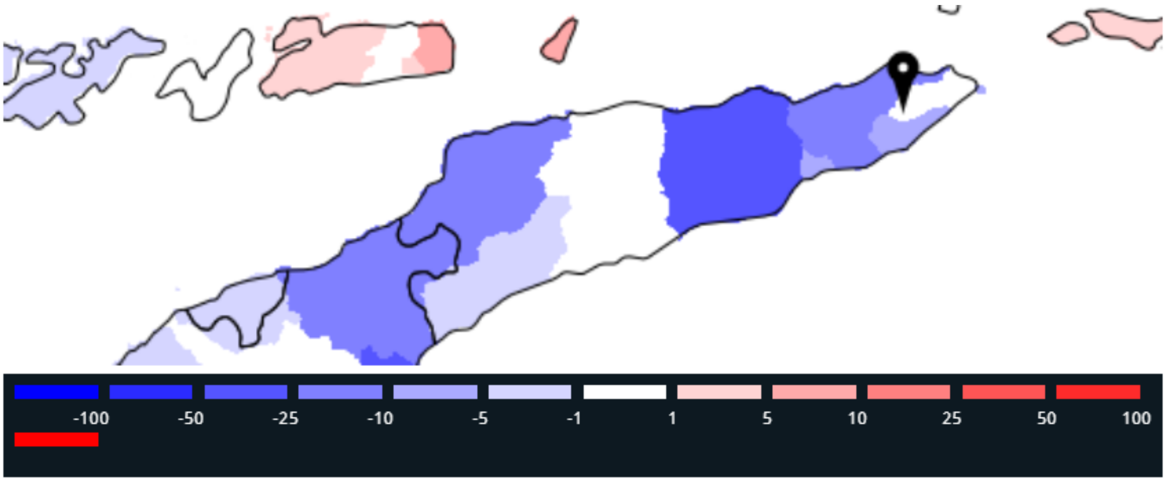
Indicator: Precipitation (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 153: Projected change in monthly mean precipitation under RCP 8.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is 0% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -0.4% and 8.3%



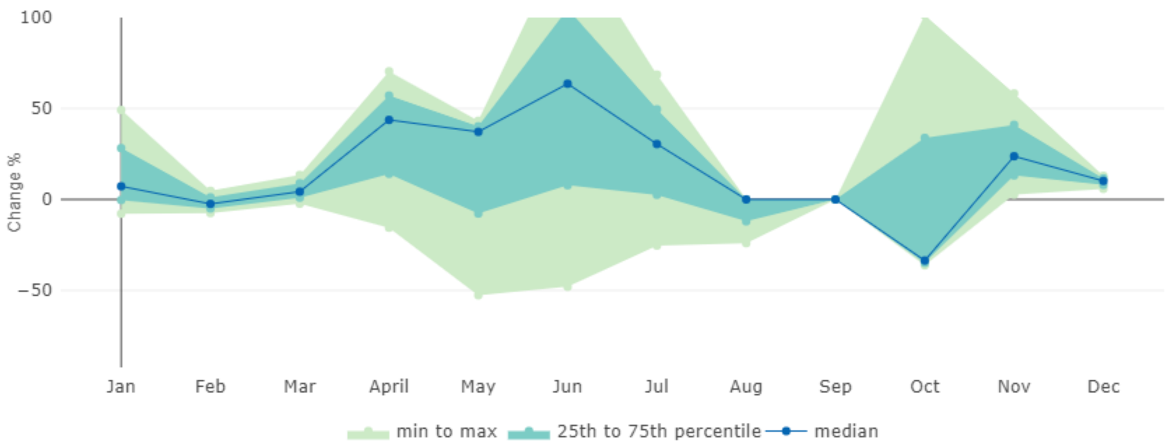
Indicator: Aridity actual (annual mean), Time period: 2041–2070, Historical period: 1981–2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 154: Projected change in annual mean actual aridity under RCP 8.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -53% and 150%



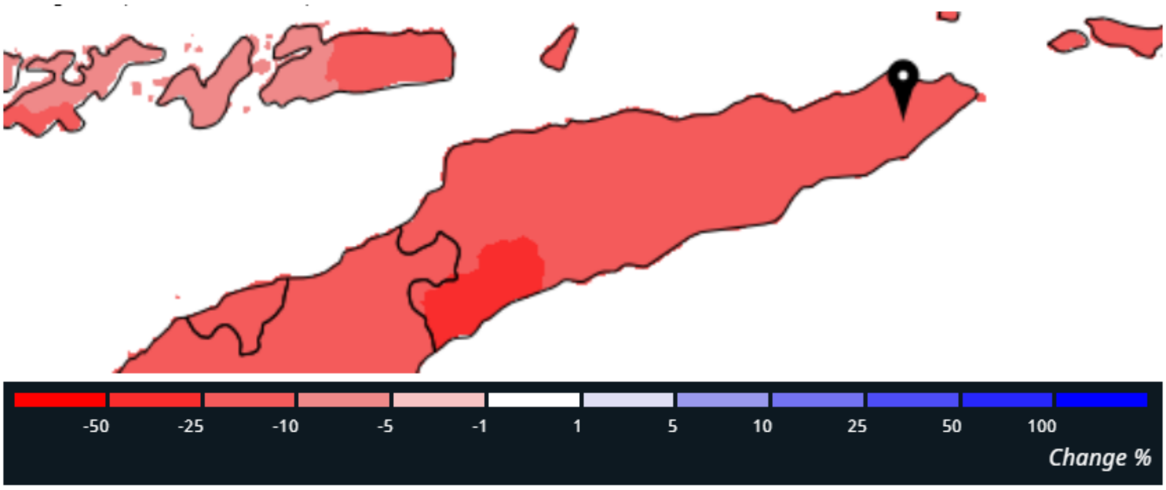
Indicator: Aridity actual (annual mean), Time period: 2041–2070, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 155: Projected change in monthly mean actual aridity under RCP 8.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is -17% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -18% and -15%



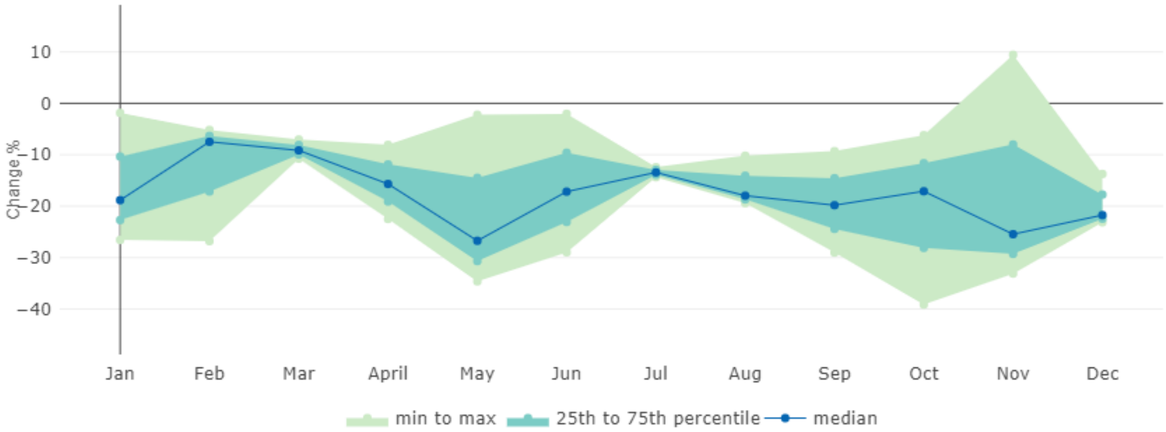
Indicator: Soils moisture (annual mean), Time period: 2041–2070, Historical period: 1981–2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 156: Projected change in annual mean soil moisture under RCP 8.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -39% and 9.4%



Indicator: Soils moisture (annual mean), Time period: 2041–2070, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 157: Projected change in monthly mean soil moisture under RCP 8.5 in the time period 2041 – 2070 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2071 – 2100 under RCP 8.5

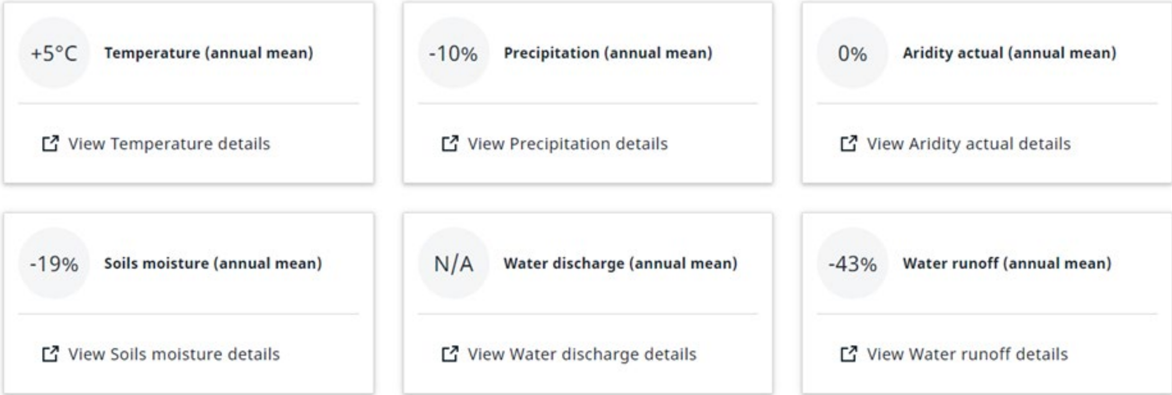
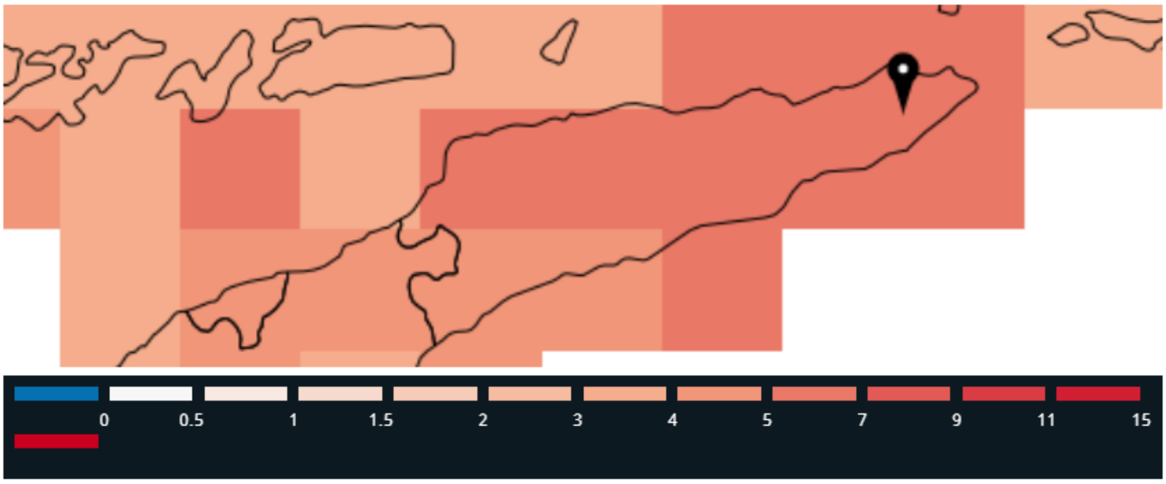


Figure 158: Future change in key indicators in the time period 2071 – 2100 under RCP 8.5 for Lospalos, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is 5.1 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 5 °C and 5.2 °C



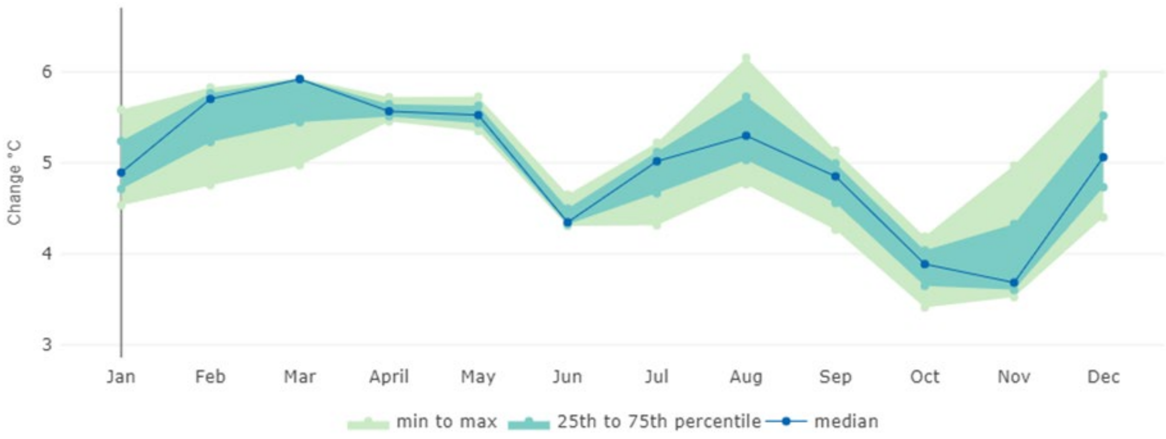
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 159: Projected change in annual mean temperature under RCP 8.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between 3.4 °C and 6.2 °C



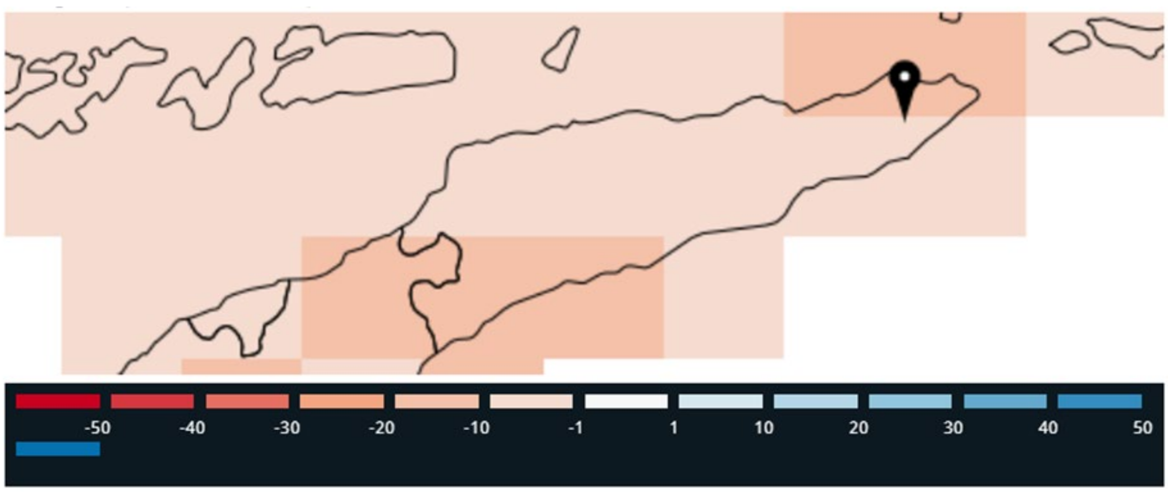
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 160: Projected change in monthly mean temperature under RCP 8.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is -9.7% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -16% and -6.6%



Indicator: Precipitation (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Lospalos, Distrito Lautém (-8.52, 127)

Figure 161: Projected change in annual mean precipitation under RCP 8.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -69% and 85%

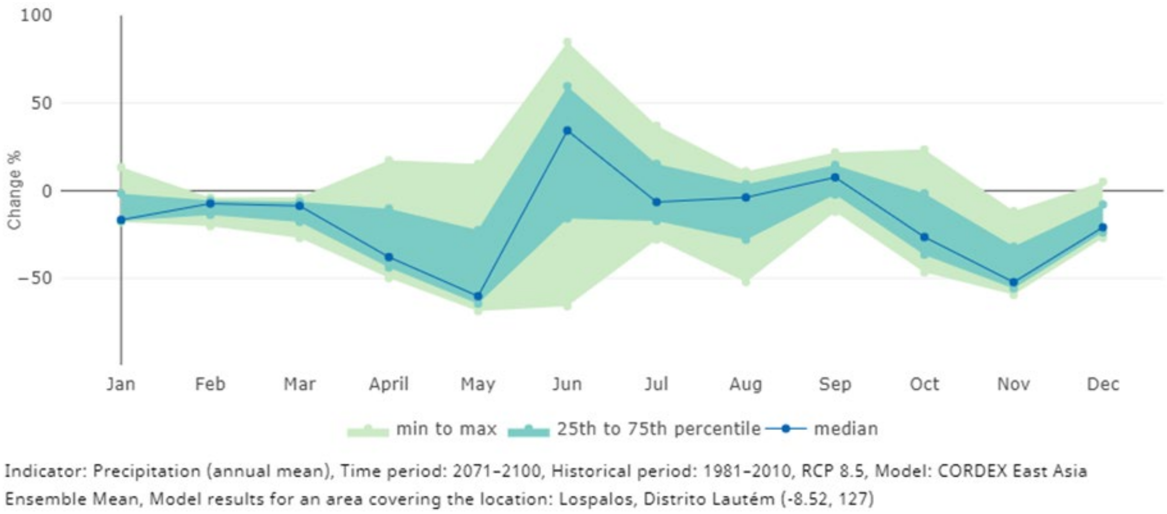


Figure 162: Projected change in monthly mean precipitation under RCP 8.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is 0% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -5.5% and 5%

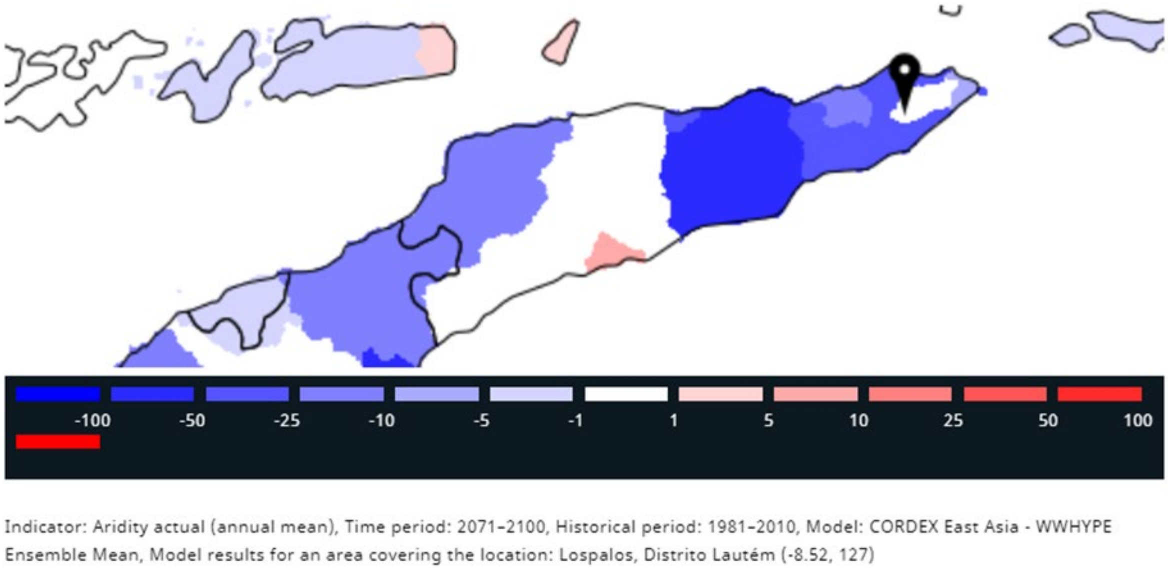


Figure 163: Projected change in annual mean actual aridity under RCP 8.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -65% and 140%

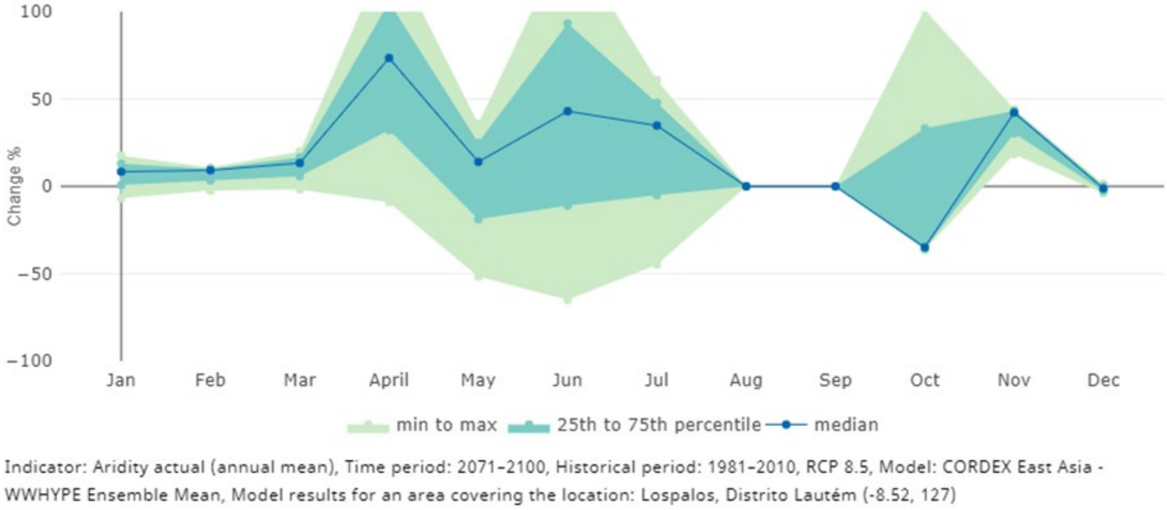


Figure 164: Projected change in monthly mean actual aridity under RCP 8.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is -19% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -25% and -19%

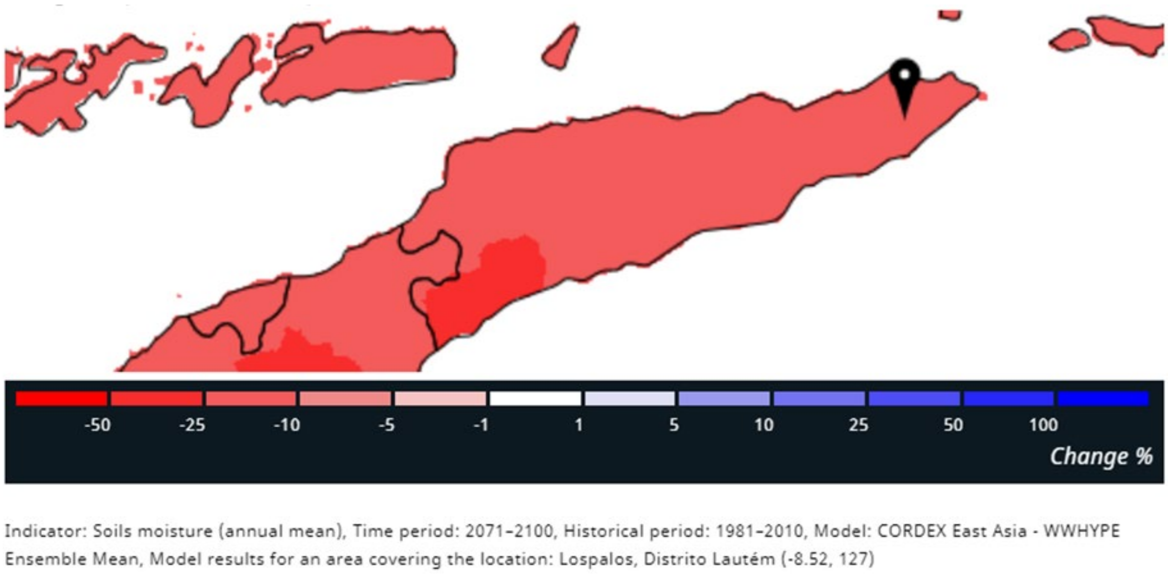


Figure 165: Projected change in annual mean soil moisture under RCP 8.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -60% and -1.6%

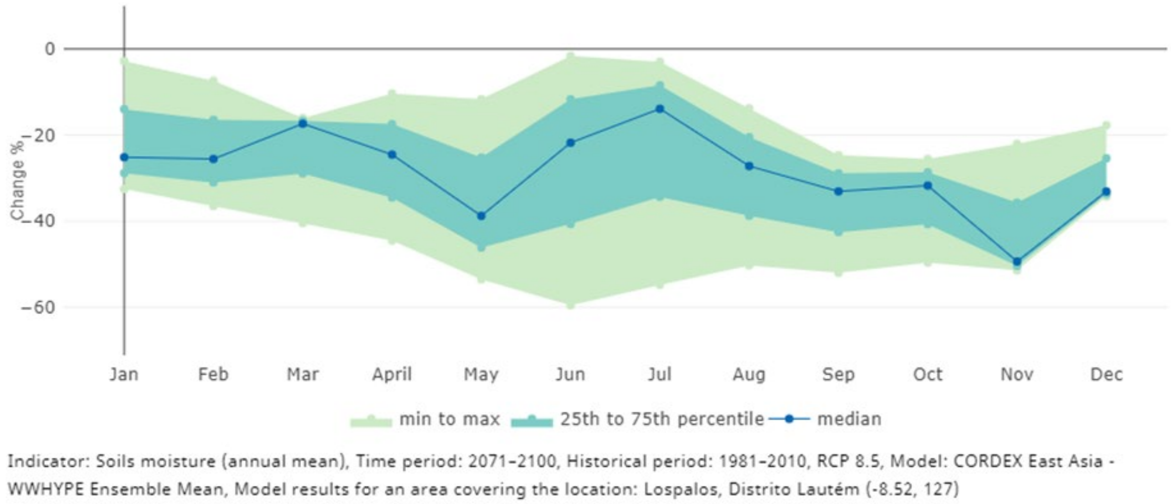


Figure 166: Projected change in monthly mean soil moisture under RCP 8.5 in the time period 2071 – 2100 for Lospalos, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

3.5.3 Manufahi

Manufahi is a municipality of Timor-Leste located at 9.00°S, 125.65°E.

Figure 167: Location of Manufahi, Timor-Leste (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2011 – 2040 under RCP4.5

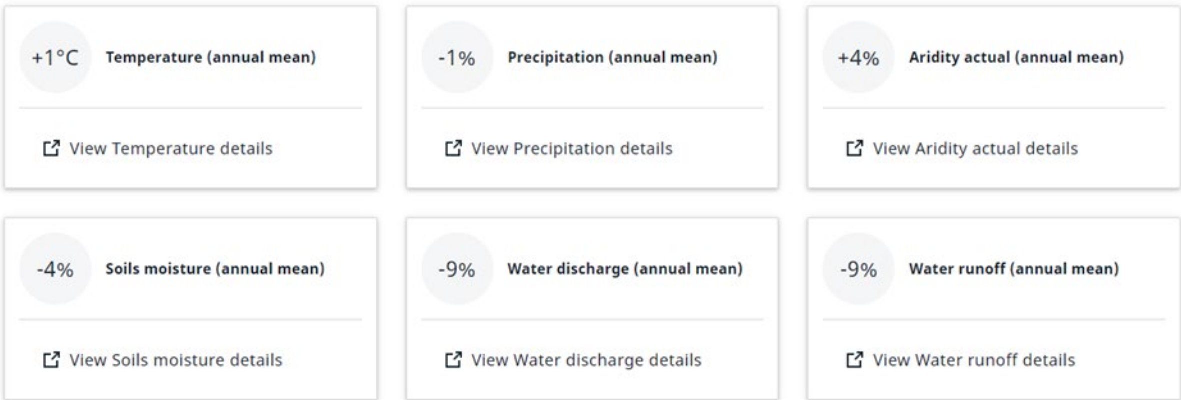


Figure 168: Future change in key indicators under RCP 4.5 in the time period 2011 – 2040 under RCP4.5 for Manufahi, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is 1.2 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 1.2 °C and 1.2 °C

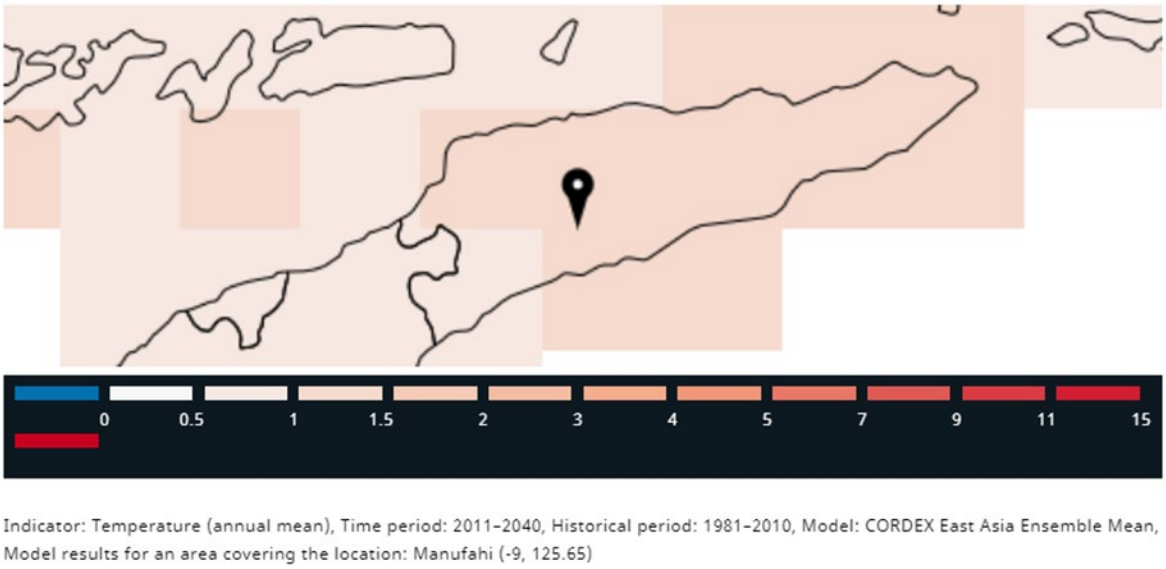


Figure 169: Projected change in annual mean temperature under RCP 4.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

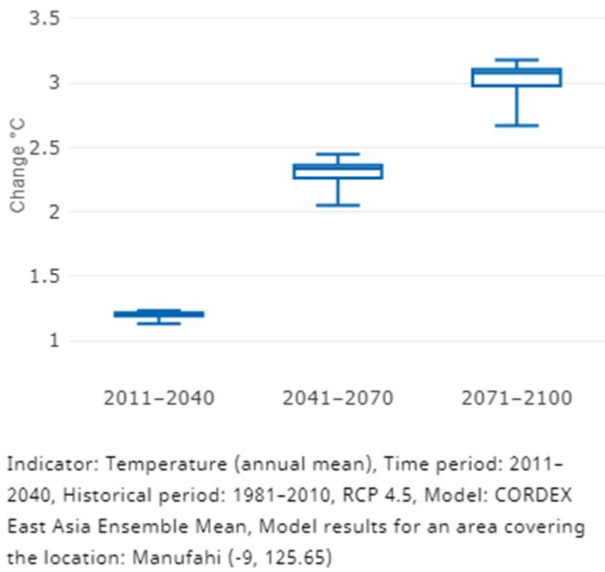


Figure 170: Projected change in annual mean temperature under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between 0.64 °C and 1.7 °C

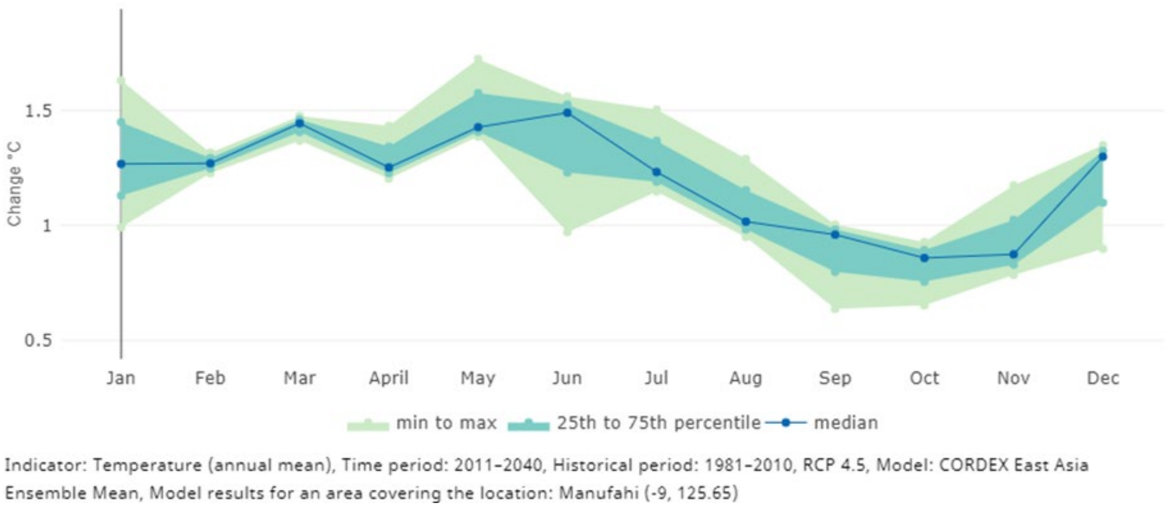


Figure 171: Projected change in monthly mean temperature under RCP 4.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is -1.4% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -3.4% and -0.67%

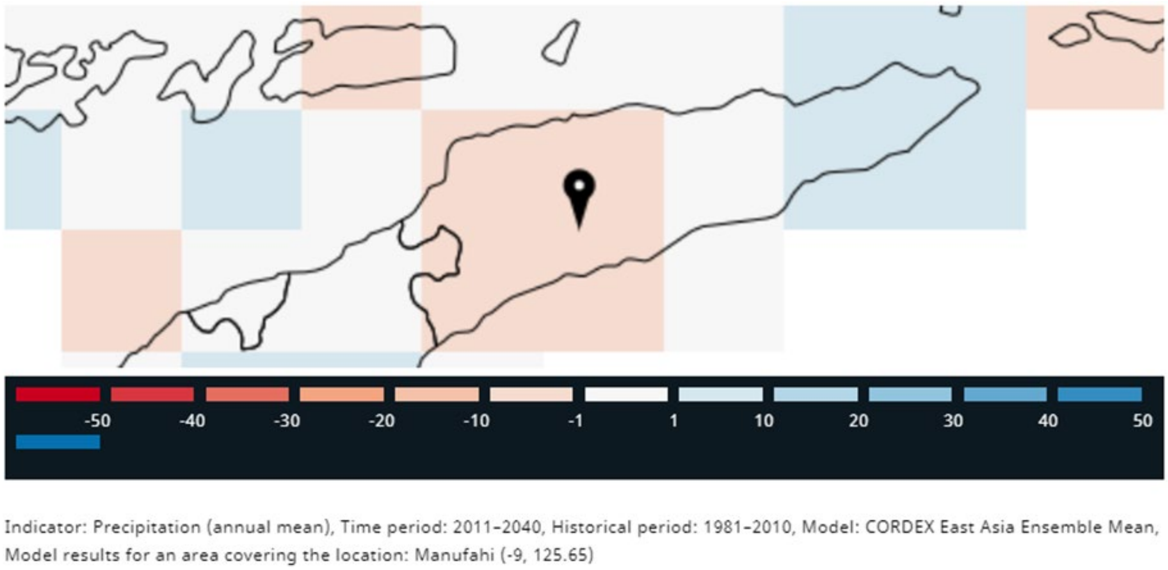


Figure 172: Projected change in annual mean precipitation in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

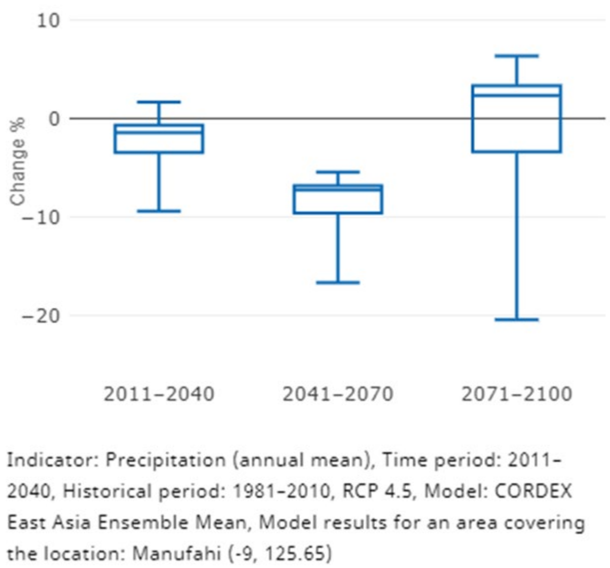


Figure 173: Projected change in annual mean precipitation under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -46% and 91%

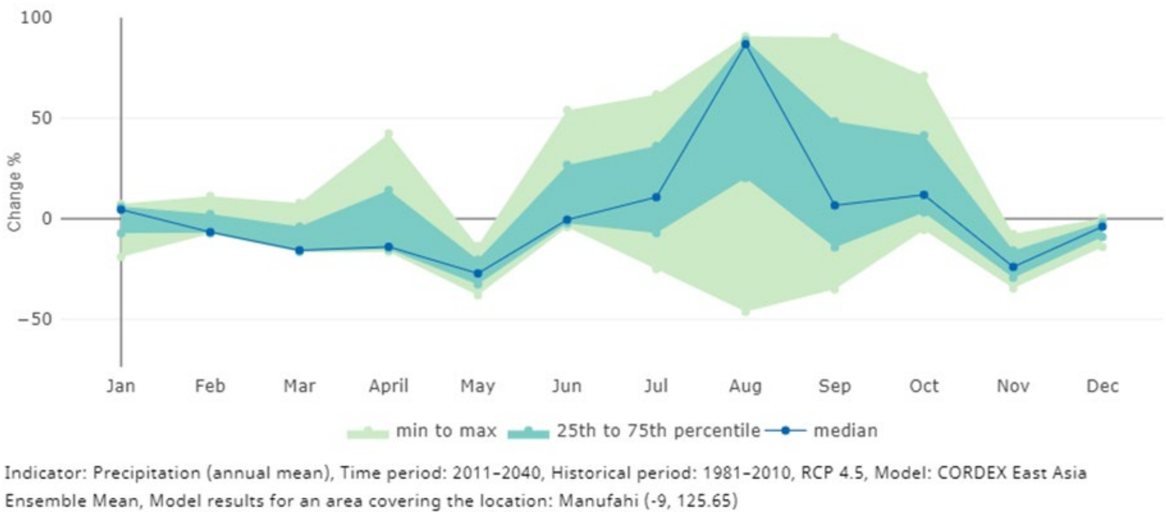


Figure 174: Projected change in monthly mean precipitation under RCP 4.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is 4.2% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -6.9% and 6.7%

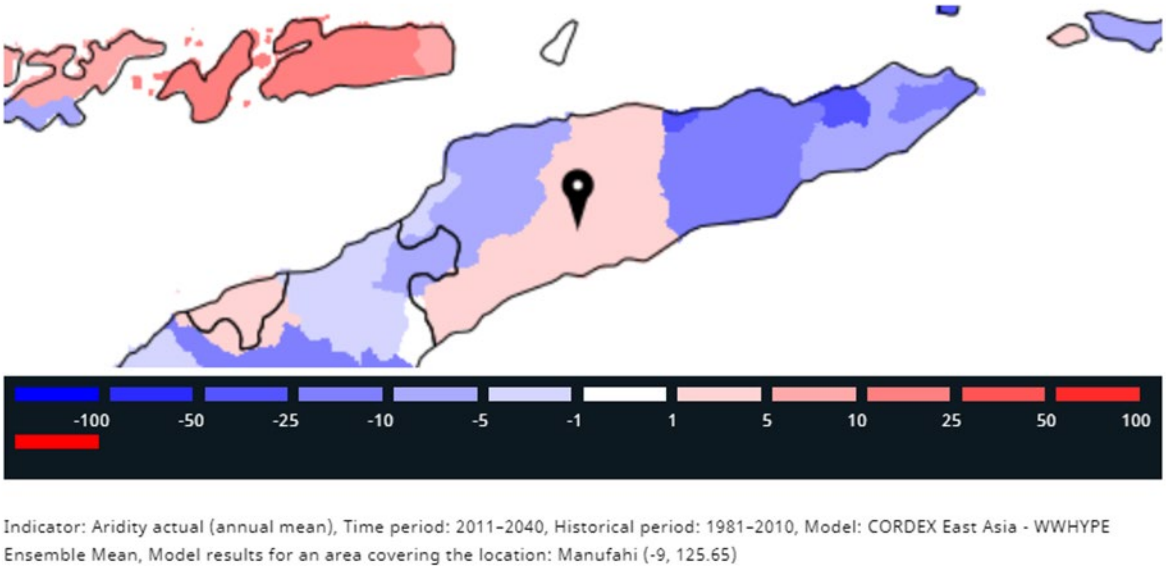


Figure 175: Projected change in annual mean actual aridity under RCP 4.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

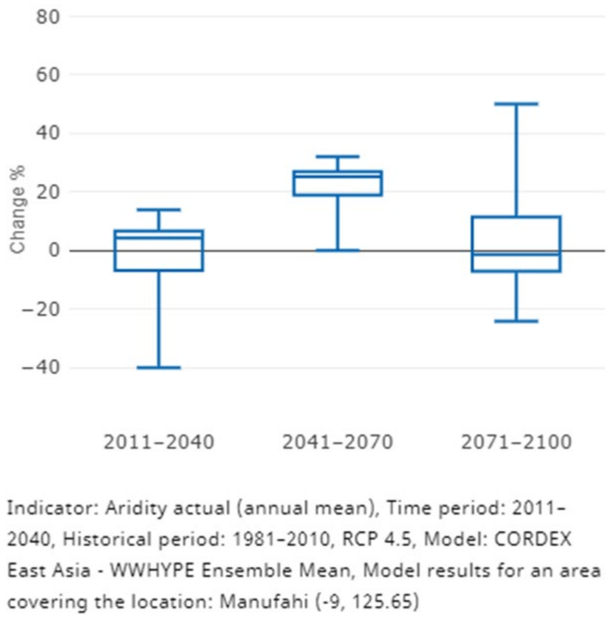


Figure 176: Projected change in annual mean actual aridity under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -49% and 220%

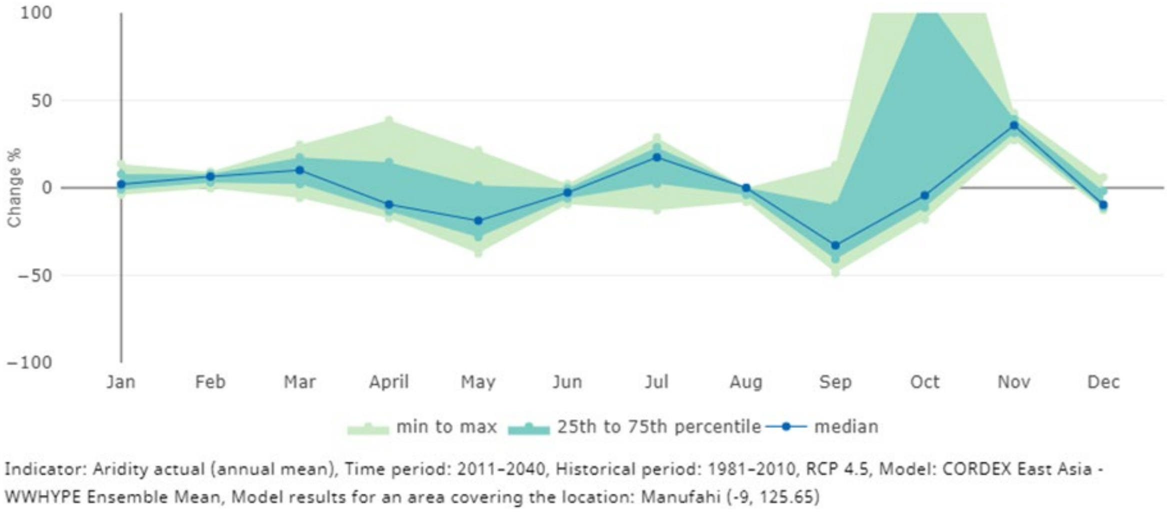


Figure 177: Projected change in monthly mean actual aridity under RCP 4.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Median change is -4.4% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -5% and -3.7%

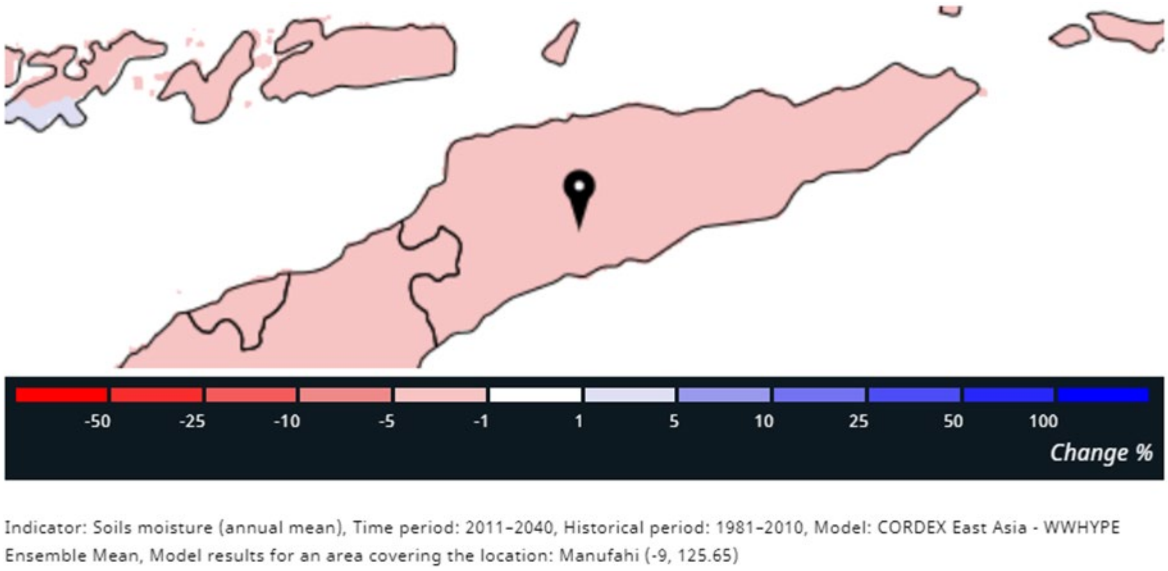
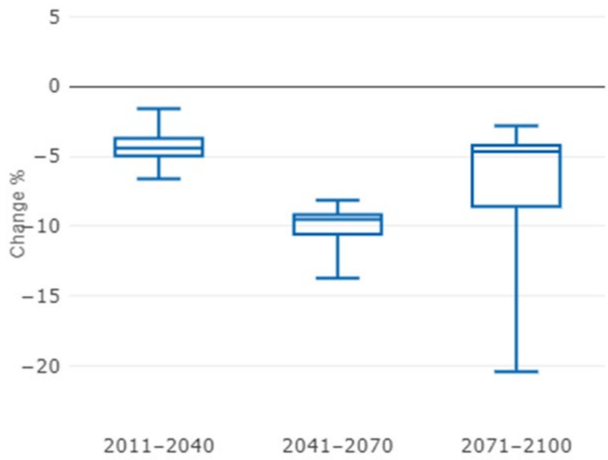


Figure 178: Projected change in annual mean soil moisture under RCP 4.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



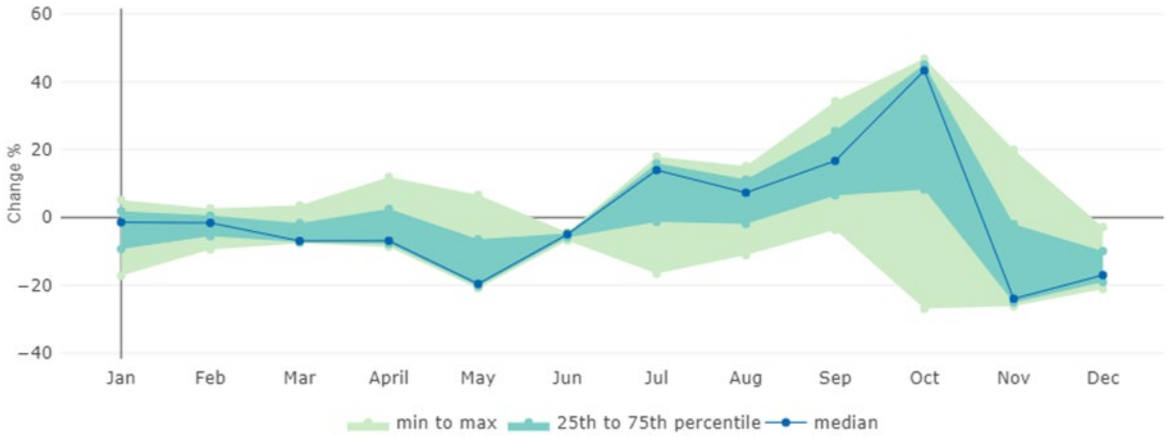
Indicator: Soils moisture (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 179: Projected change in annual mean soil moisture under RCP 4.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -27% and 47%



Indicator: Soils moisture (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 180: Projected change in monthly mean soil moisture under RCP 4.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2041 – 2070 under RCP4.5

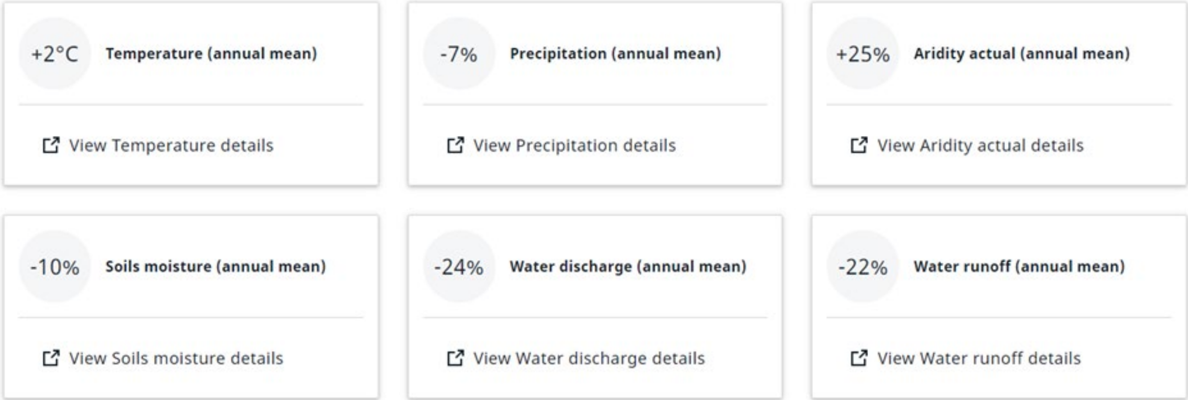


Figure 181: Future change in key indicators under RCP 4.5 in the time period 2041 – 2070 under RCP4.5 for Manufahi, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is 2.3 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 2.3 °C and 2.4 °C

Indicator: Temperature (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 182: Projected change in annual mean temperature under RCP 4.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between 1.4 °C and 3.1 °C

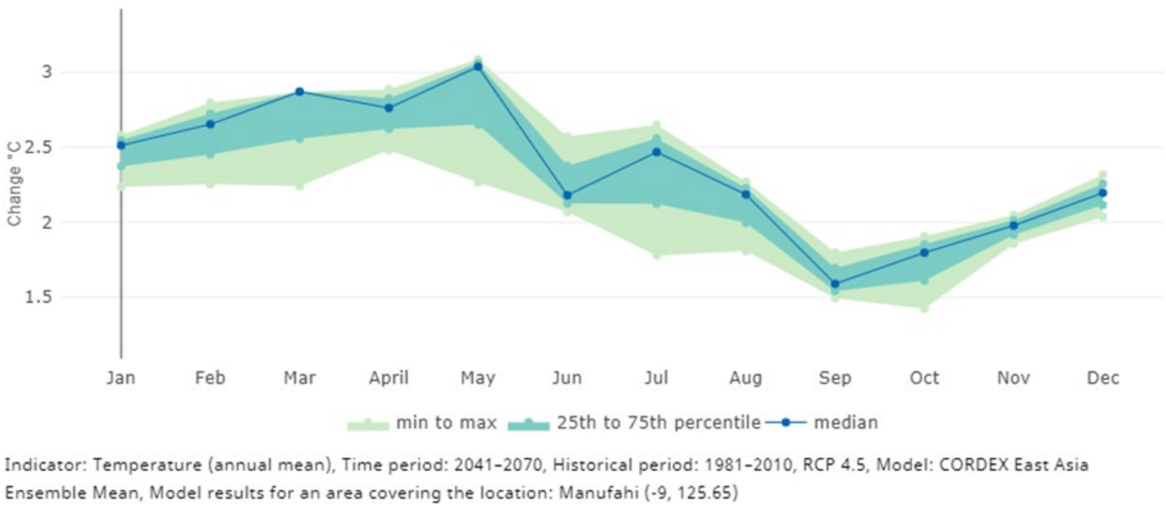


Figure 183: Projected change in monthly mean temperature under RCP 4.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is -7.3% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -9.6% and -6.8%

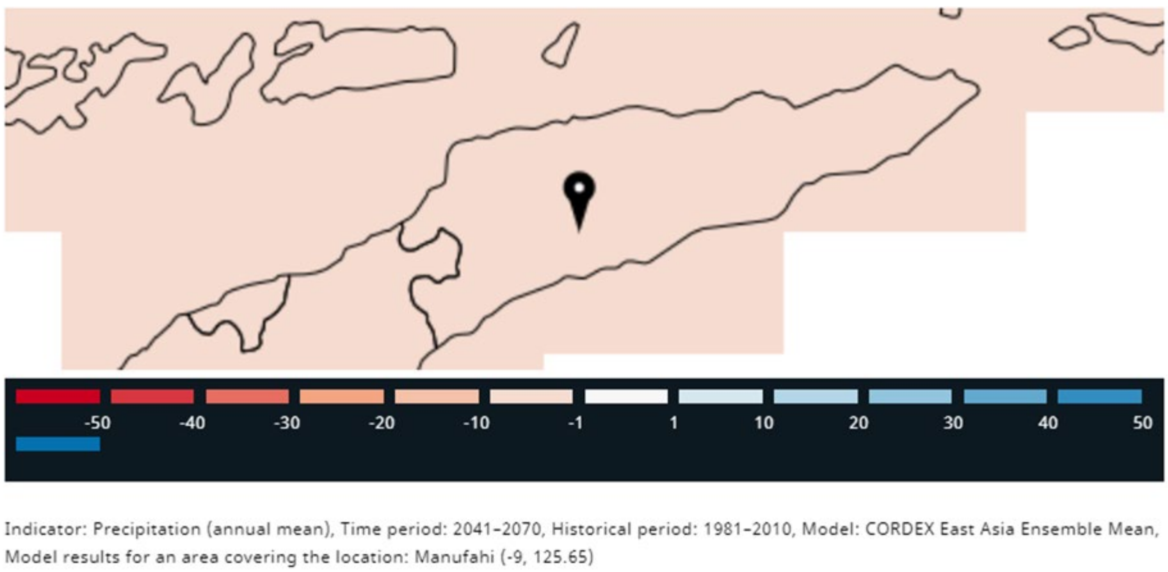


Figure 184: Projected change in annual mean precipitation under RCP 4.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -66% and 94%

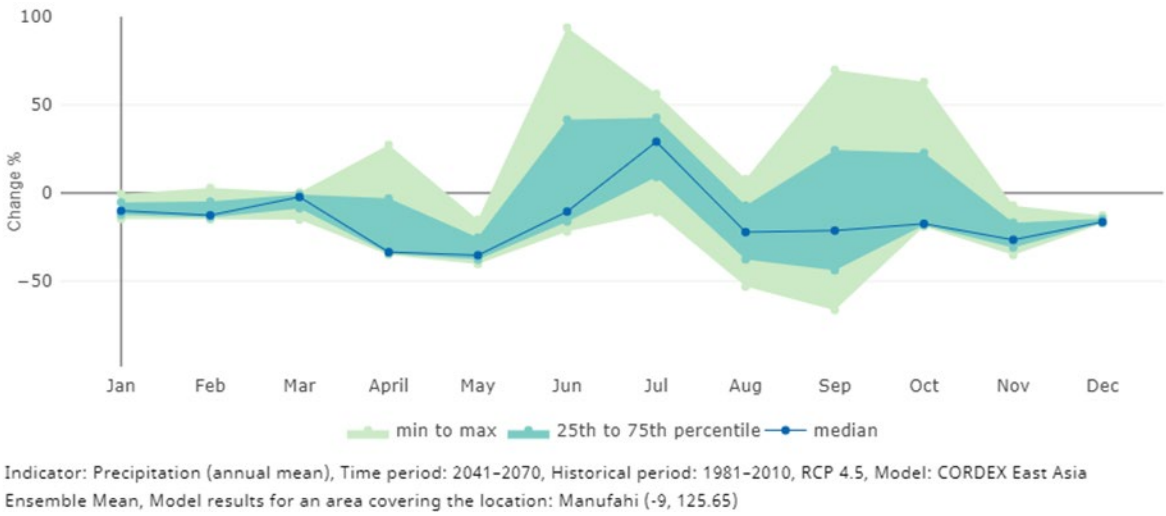


Figure 185: Projected change in monthly mean precipitation under RCP 4.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is 35% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 19% and 27%

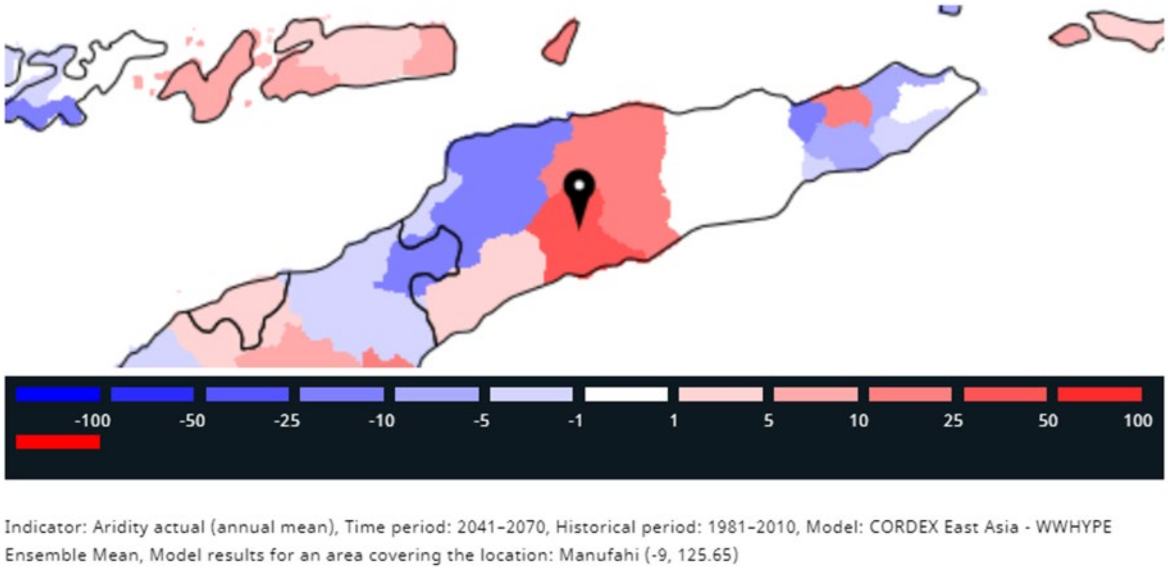


Figure 186: Projected change in annual mean actual aridity under RCP 4.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -43% and 170%

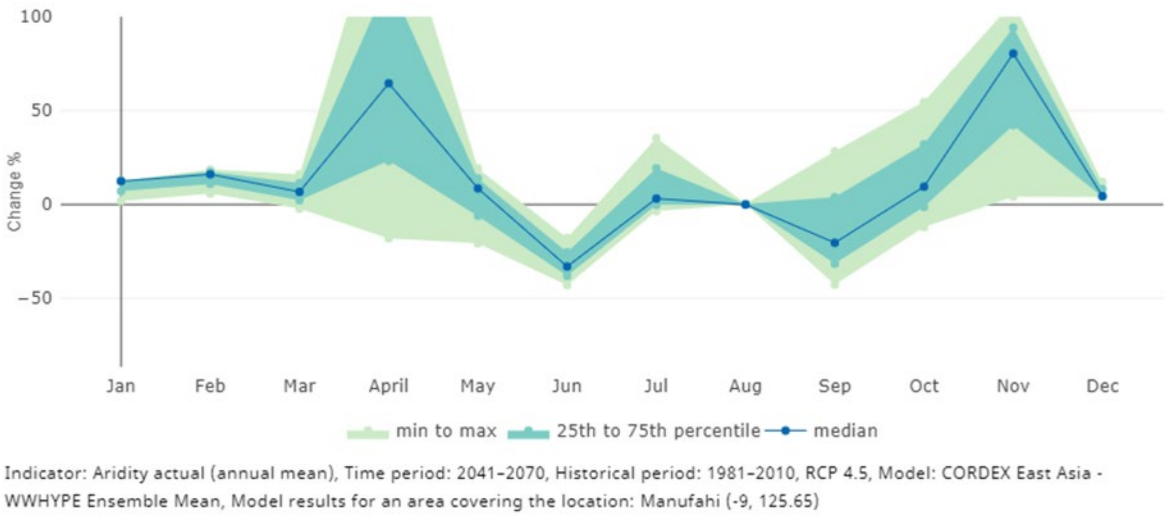


Figure 187: Projected change in monthly mean actual aridity under RCP 4.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Median change is -9.5% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -11% and -9.2%

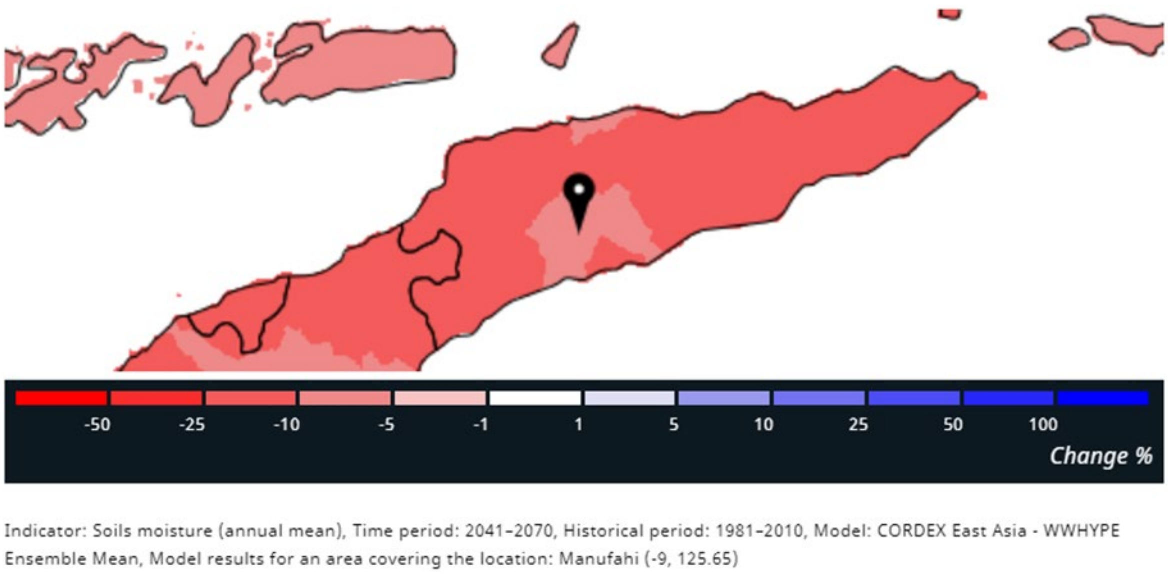


Figure 188: Projected change in annual mean soil moisture under RCP 4.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -30% and 59%

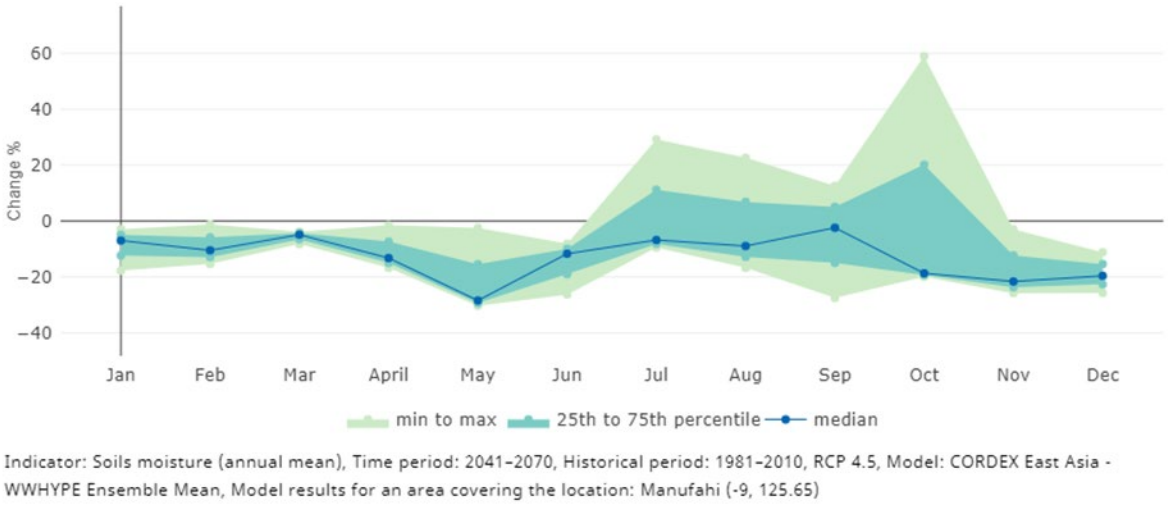


Figure 189: Projected change in monthly mean soil moisture under RCP 4.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2071 – 2100 under RCP4.5

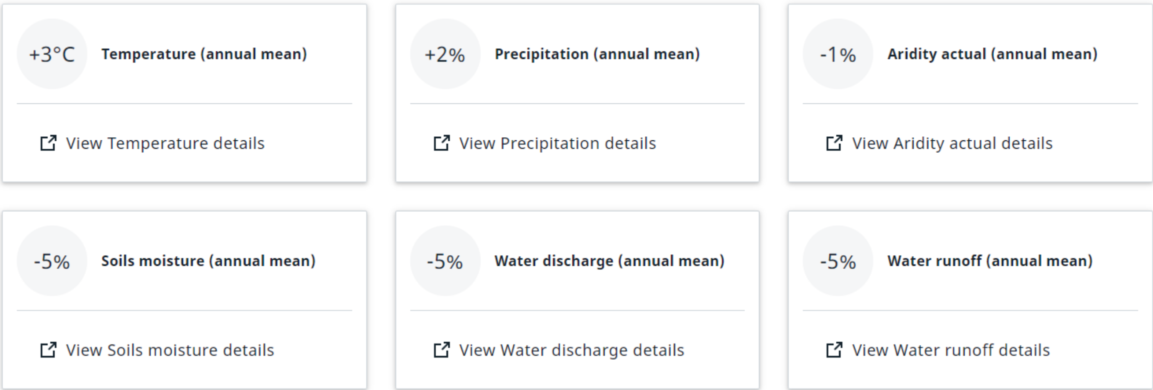
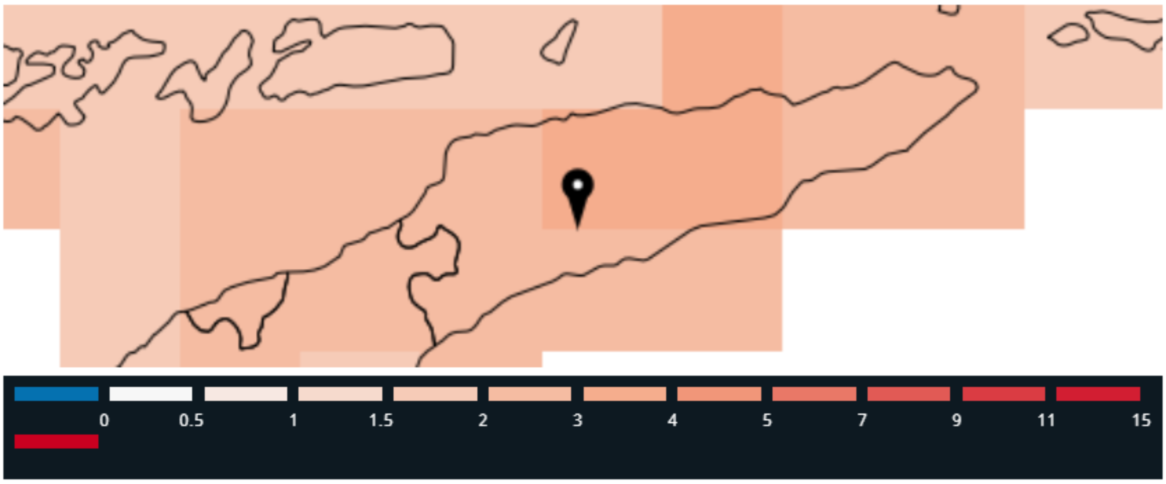


Figure 190: Future change in key indicators under RCP 4.5 in the time period 2071 – 2100 under RCP4.5 for Manufahi, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is 3.1 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 3 °C and 3.1 °C



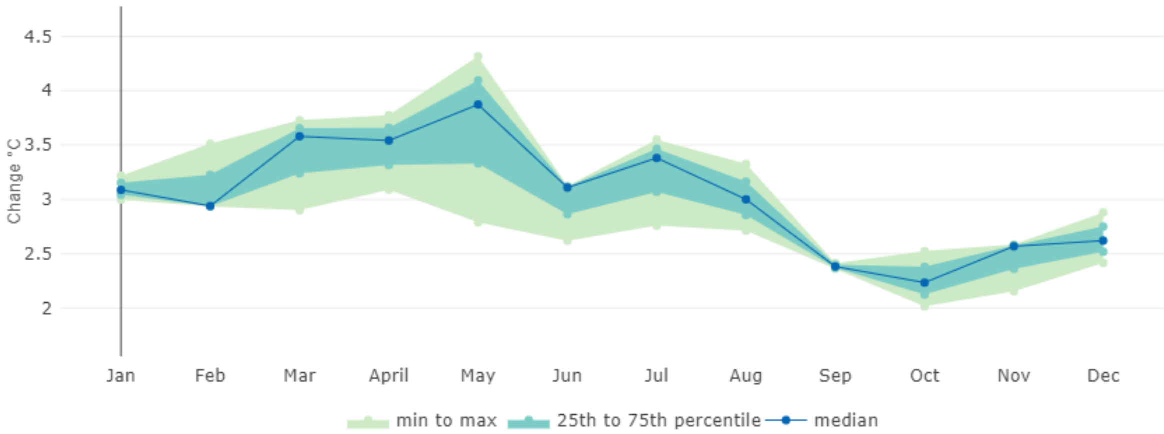
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 191: Projected change in annual mean temperature under RCP 4.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between 2 °C and 4.3 °C



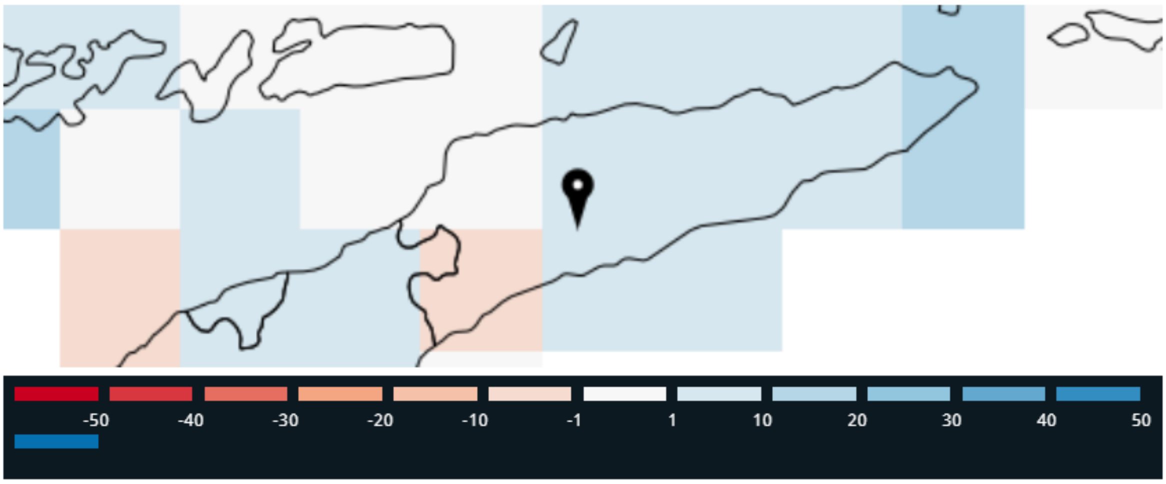
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 192: Projected change in monthly mean temperature under RCP 4.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is 2.3% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -3.4% and 3.3%



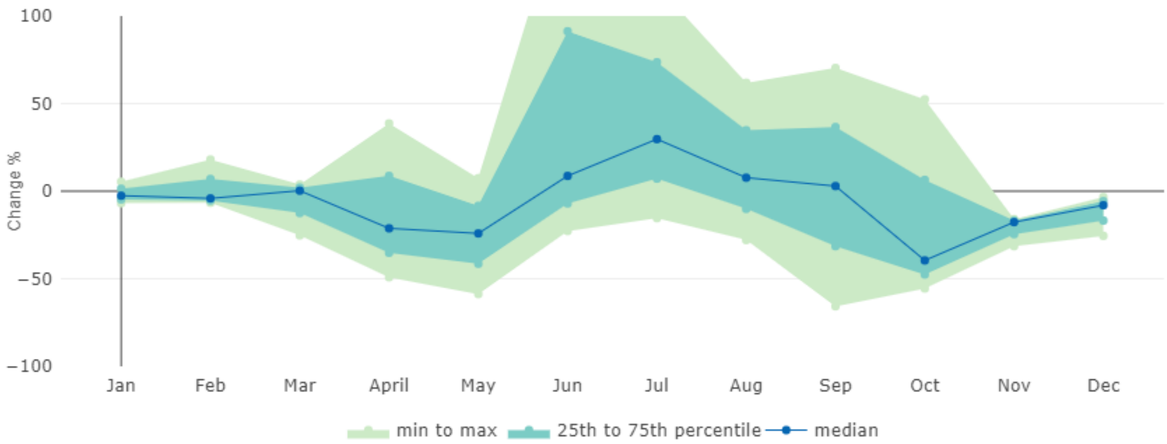
Indicator: Precipitation (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 193: Projected change in annual mean precipitation under RCP 4.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -66% and 170%



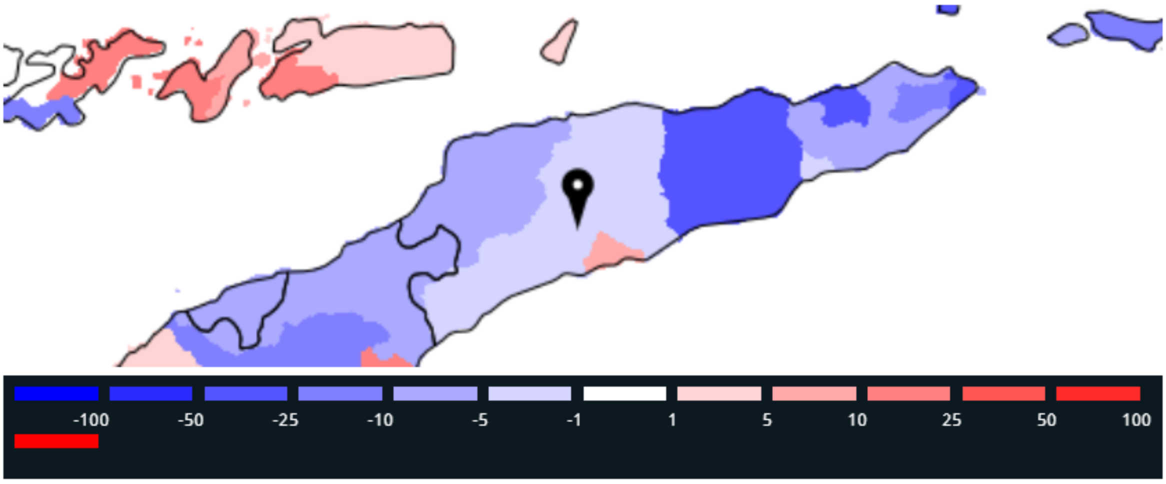
Indicator: Precipitation (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 194: Projected change in monthly mean precipitation under RCP 4.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is -1.4% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -7.2% and 11%



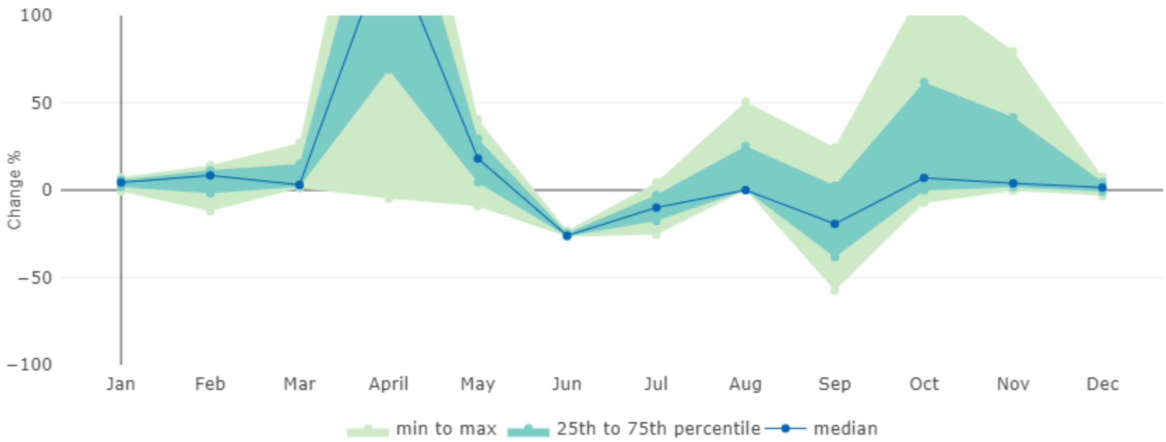
Indicator: Aridity actual (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 195: Projected change in annual mean actual aridity under RCP 4.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -57% and 260%



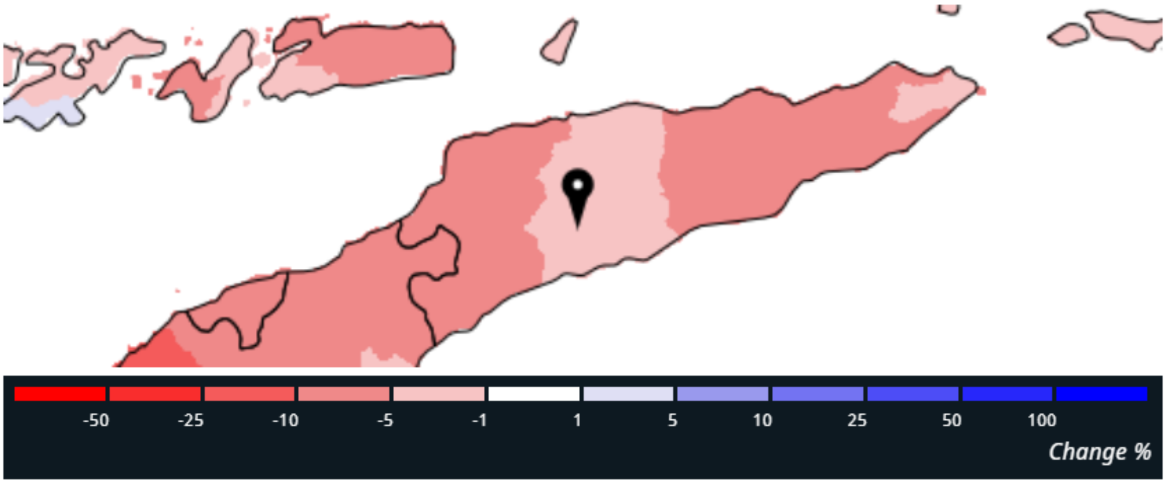
Indicator: Aridity actual (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 196: Projected change in monthly mean actual aridity under RCP 4.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Median change is -4.7% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -8.6% and -4.2%



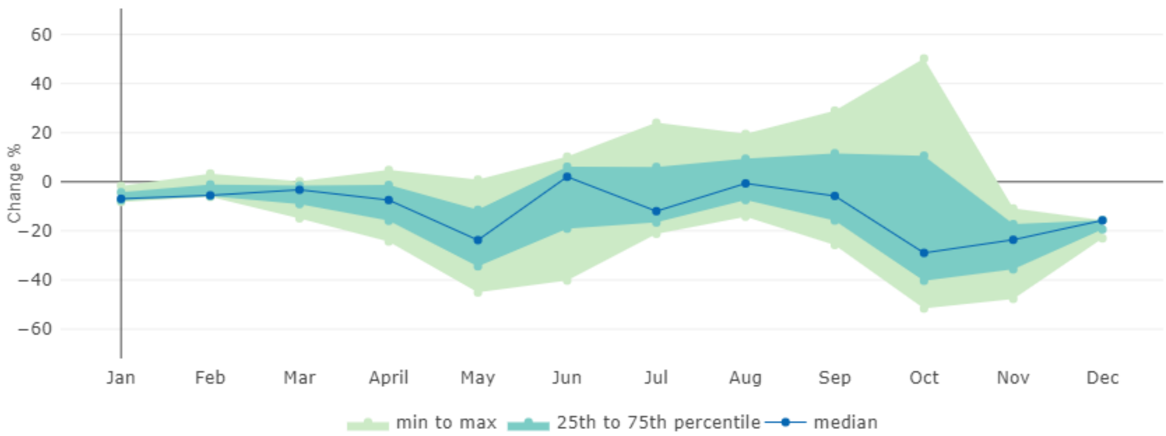
Indicator: Soils moisture (annual mean), Time period: 2071–2100, Historical period: 1981–2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 197: Projected change in annual mean soil moisture under RCP 4.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 4.5):

- Monthly mean change lies between -52% and 50%



Indicator: Soils moisture (annual mean), Time period: 2071–2100, Historical period: 1981–2010, RCP 4.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 198: Projected change in monthly mean soil moisture under RCP 4.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2011 – 2040 under RCP 8.5

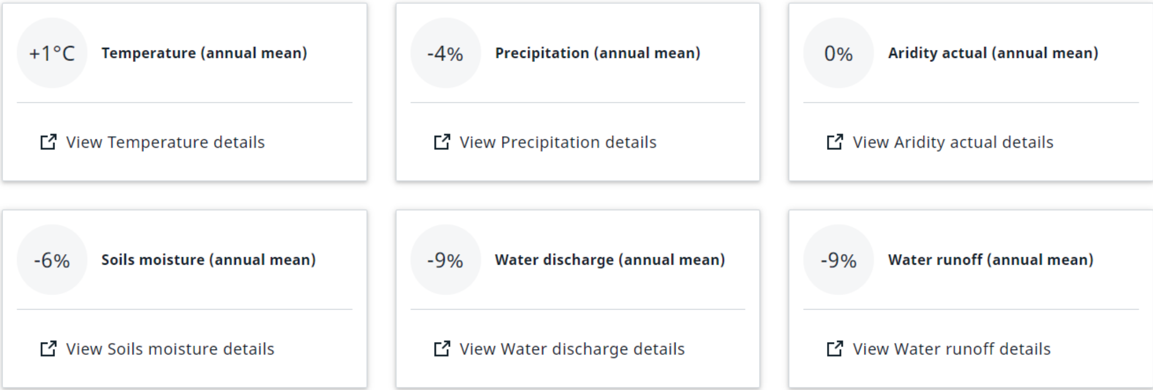


Figure 199: Future change in key indicators under RCP 8.5 in the time period 2011 – 2040 under RCP8.5 for Manufahi, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is 1.4 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 1.4 °C and 1.4 °C

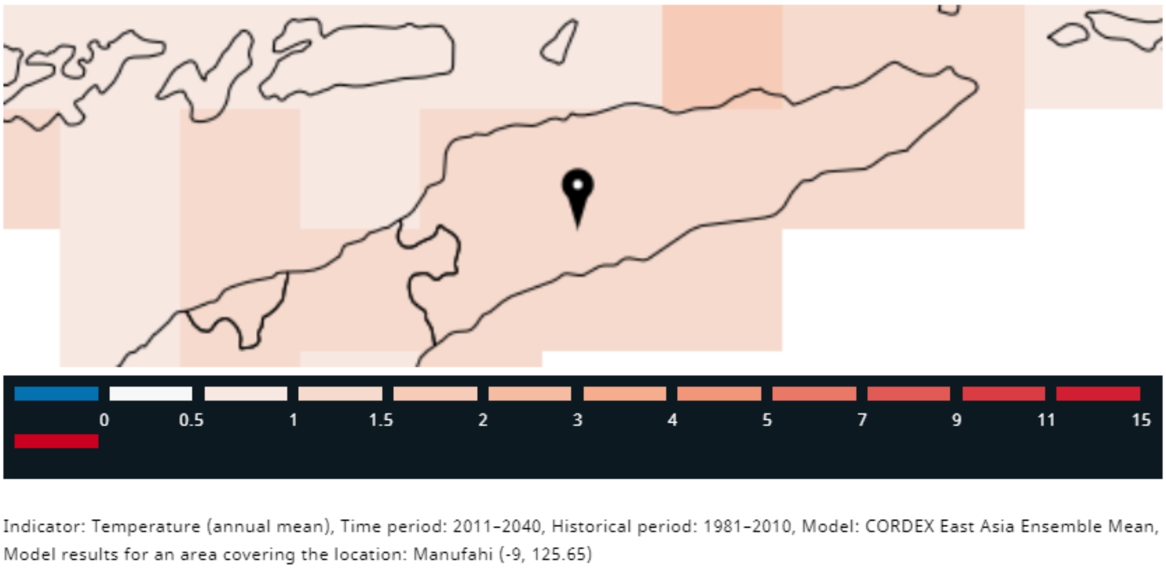


Figure 200: Projected change in annual mean temperature under RCP 8.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

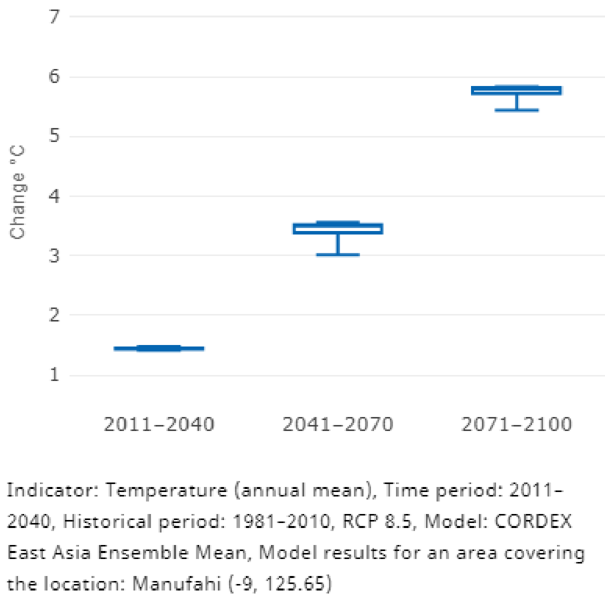


Figure 201: Projected change in annual mean temperature under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between 0.84 °C and 2.1 °C

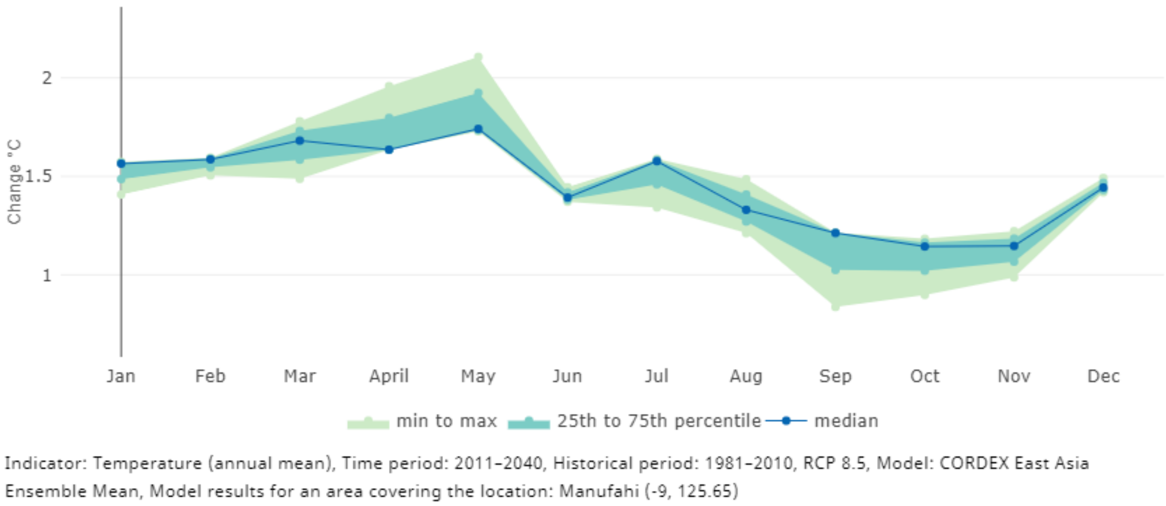


Figure 202: Projected change in monthly mean temperature under RCP 8.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is -3.7% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -5.2% and -2.7%

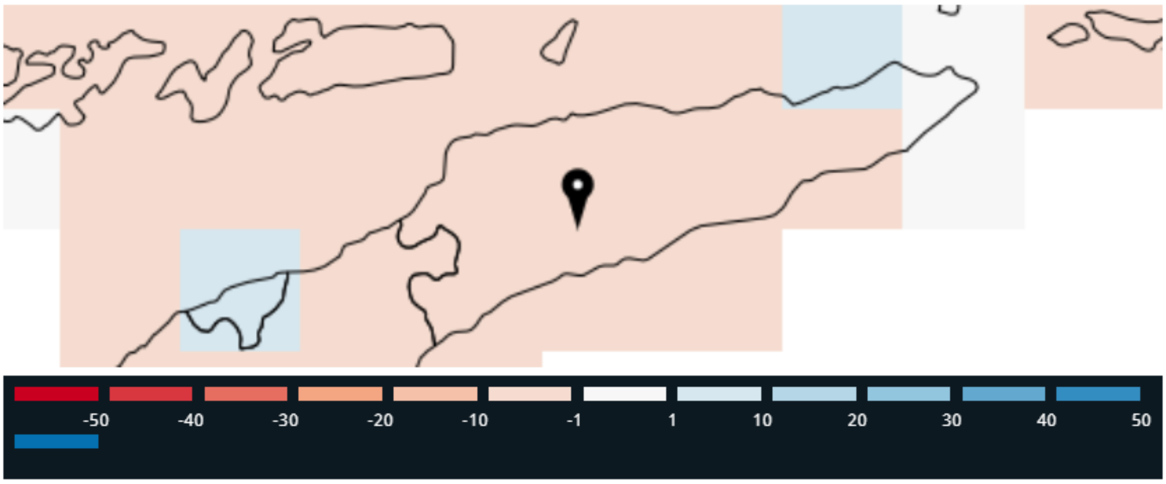


Figure 203: Projected change in annual mean precipitation under RCP 8.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

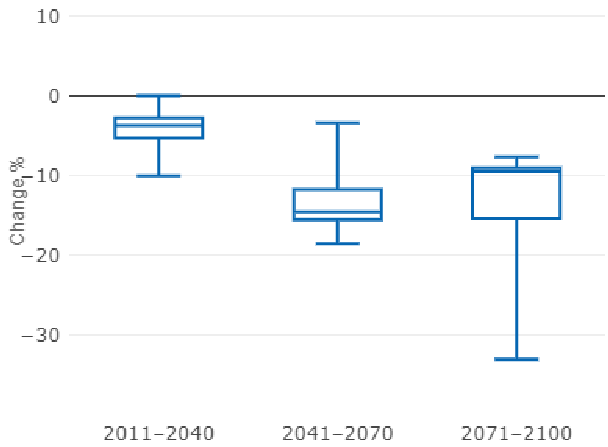
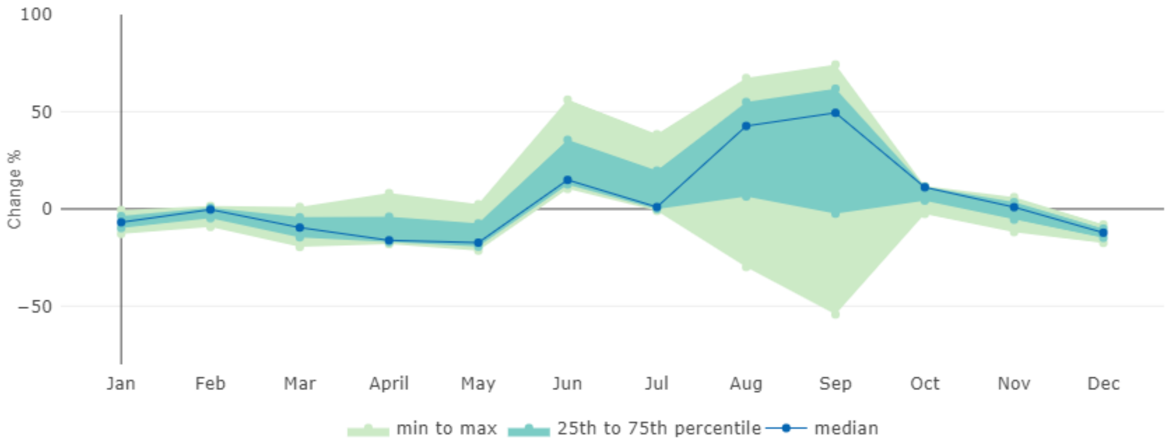


Figure 204: Projected change in annual mean precipitation under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -54% and 74%



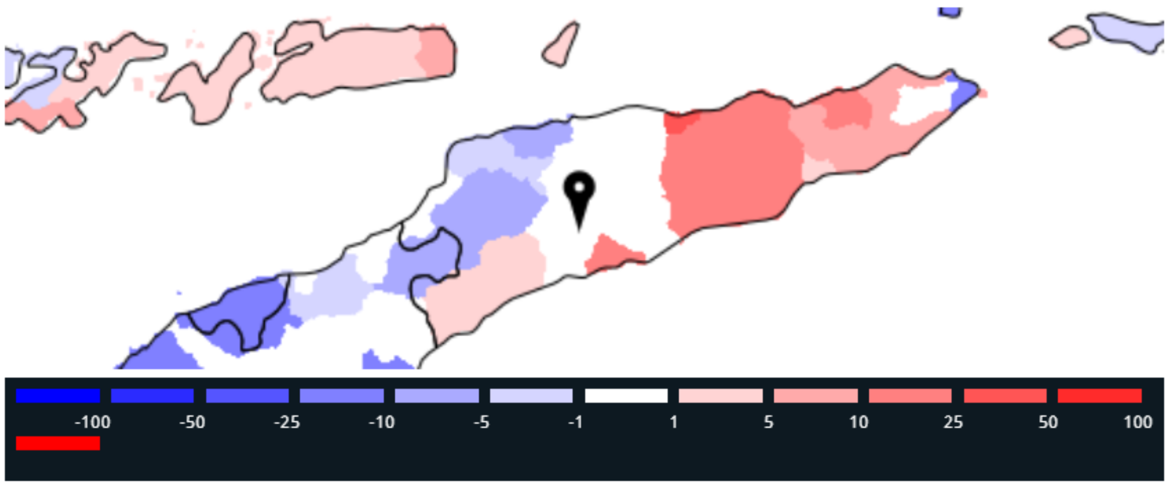
Indicator: Precipitation (annual mean), Time period: 2011-2040, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 205: Projected change in monthly mean precipitation under RCP 8.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is 0% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -7.8% and 35%



Indicator: Aridity actual (annual mean), Time period: 2011-2040, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 206: Projected change in annual mean actual aridity under RCP 8.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

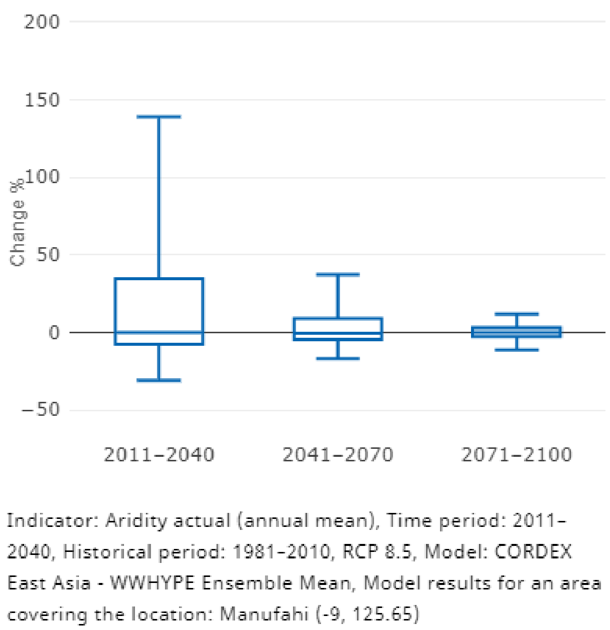


Figure 207: Projected change in annual mean actual aridity under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -67% and 390%

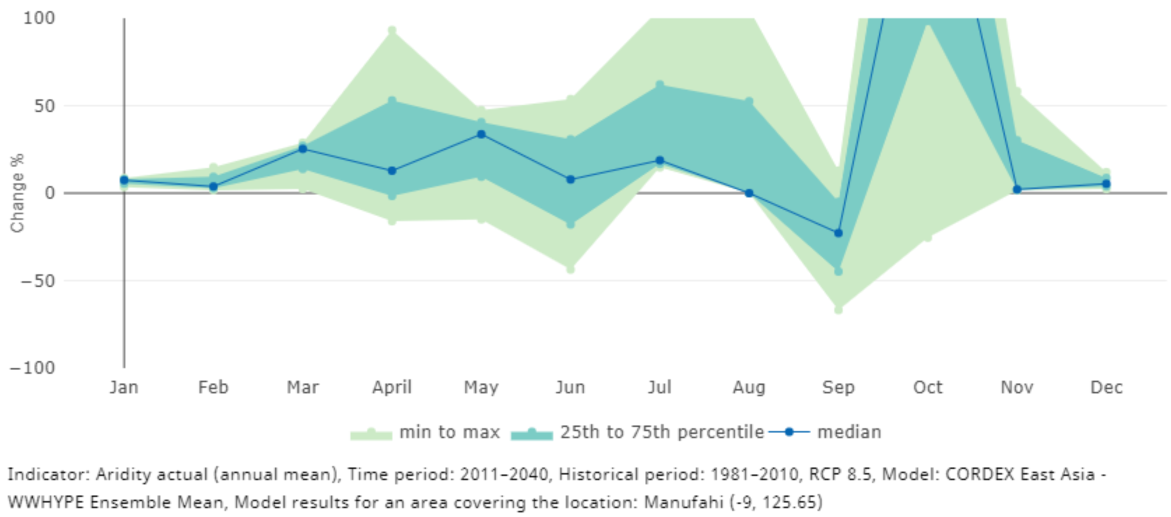
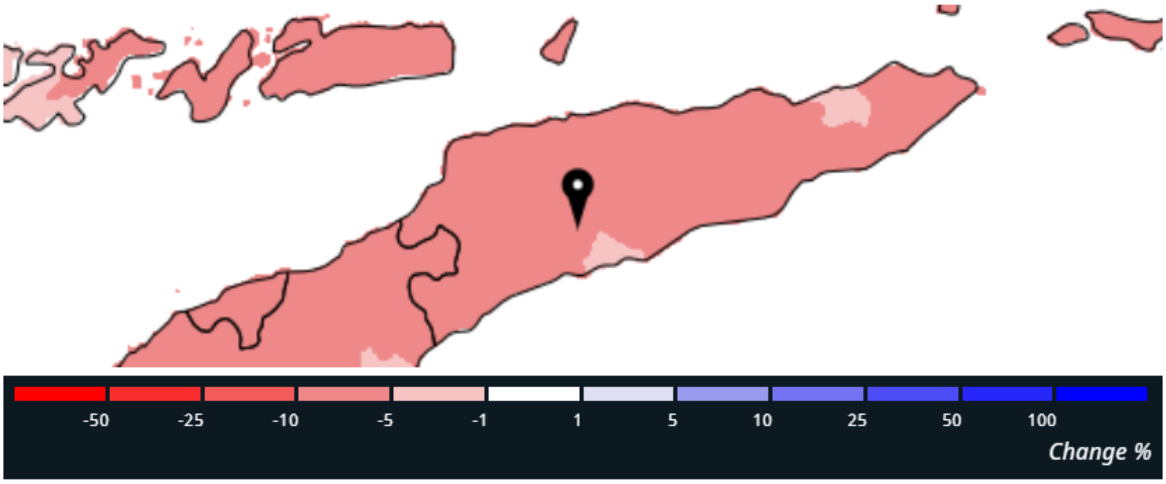


Figure 208: Projected change in monthly mean actual aridity under RCP 8.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

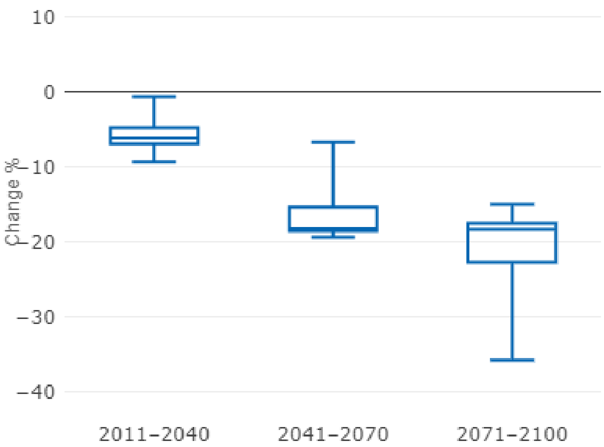
For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Median change is -6.1% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -6.9% and -4.7%



Indicator: Soils moisture (annual mean), Time period: 2011–2040, Historical period: 1981–2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 209: Projected change in annual mean soil moisture under RCP 8.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)



Indicator: Soils moisture (annual mean), Time period: 2011–2040, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 210: Projected change in annual mean soil moisture under RCP 8.5 in the time periods 2011- 2040, 2041 – 2070 and 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2011 – 2040 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -27% and 42%

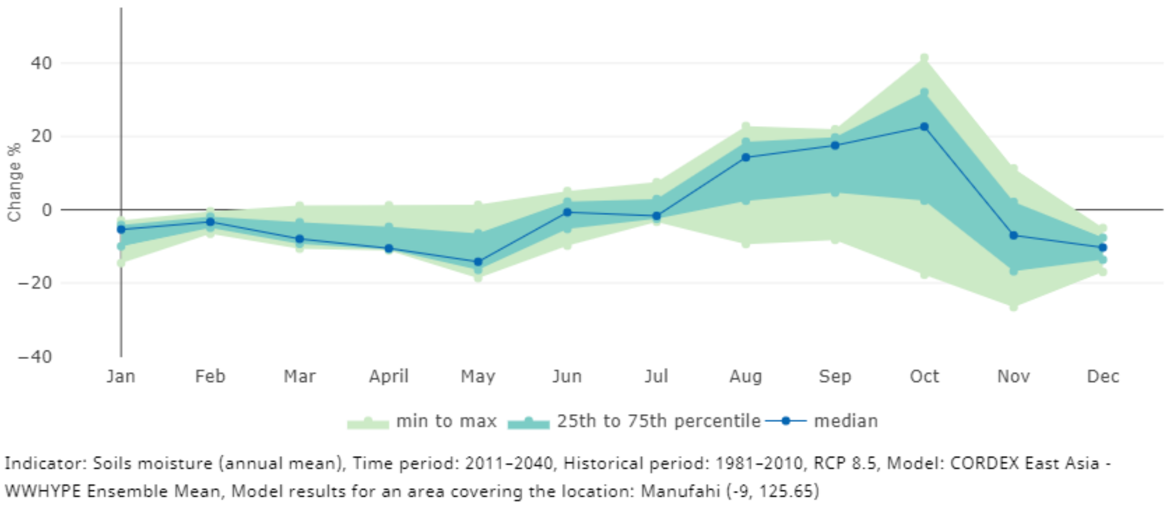


Figure 211: Projected change in monthly mean soil moisture under RCP 8.5 in the time period 2011 – 2040 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2041 – 2070 under RCP 8.5

+4°C **Temperature (annual mean)**
View Temperature details

-15% **Precipitation (annual mean)**
View Precipitation details

-1% **Aridity actual (annual mean)**
View Aridity actual details

-18% **Soils moisture (annual mean)**
View Soils moisture details

-32% **Water discharge (annual mean)**
View Water discharge details

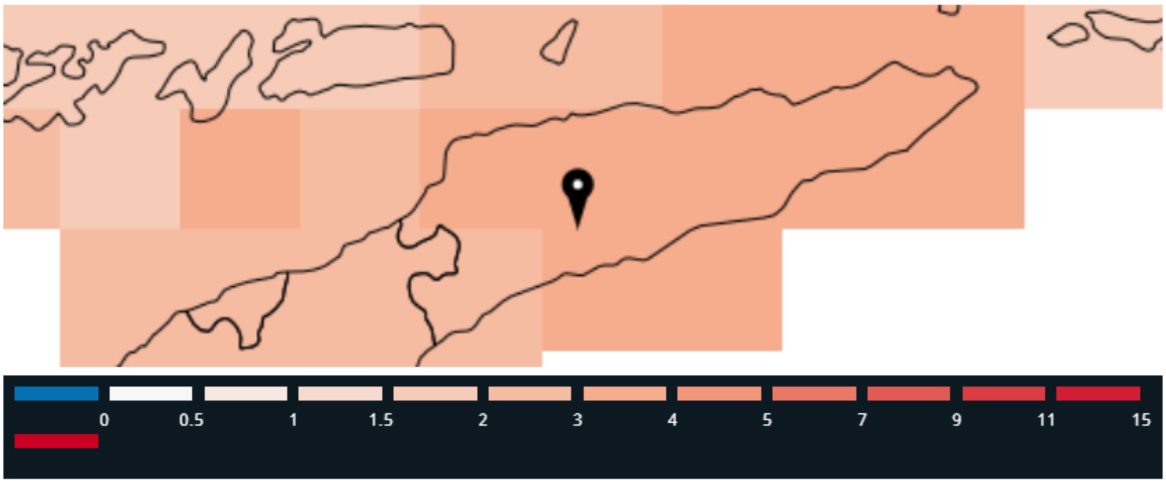
-30% **Water runoff (annual mean)**
View Water runoff details

Figure 212: Future change in key indicators in the time period 2041 – 2070 under RCP 8.5 for Manufahi, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is 3.5 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 3.4 °C and 3.5 °C



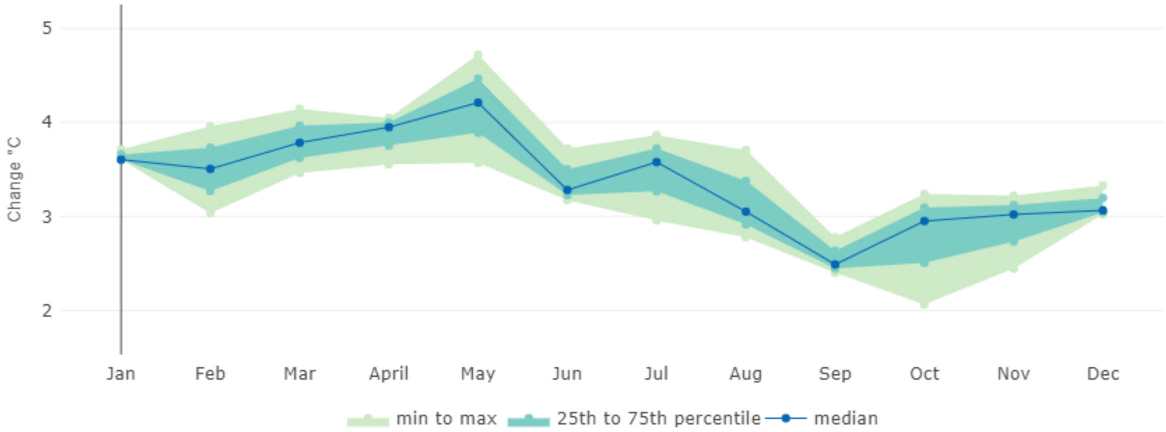
Indicator: Temperature (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 213: Projected change in annual mean temperature under RCP 8.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between 2.1 °C and 4.7 °C



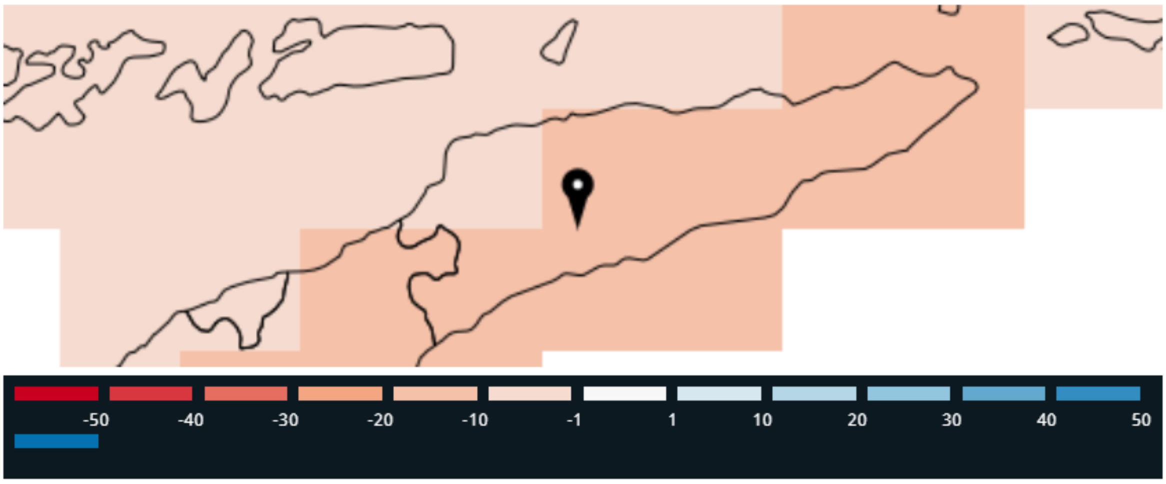
Indicator: Temperature (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 214: Projected change in monthly mean temperature under RCP 8.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is -15% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -16% and -12%



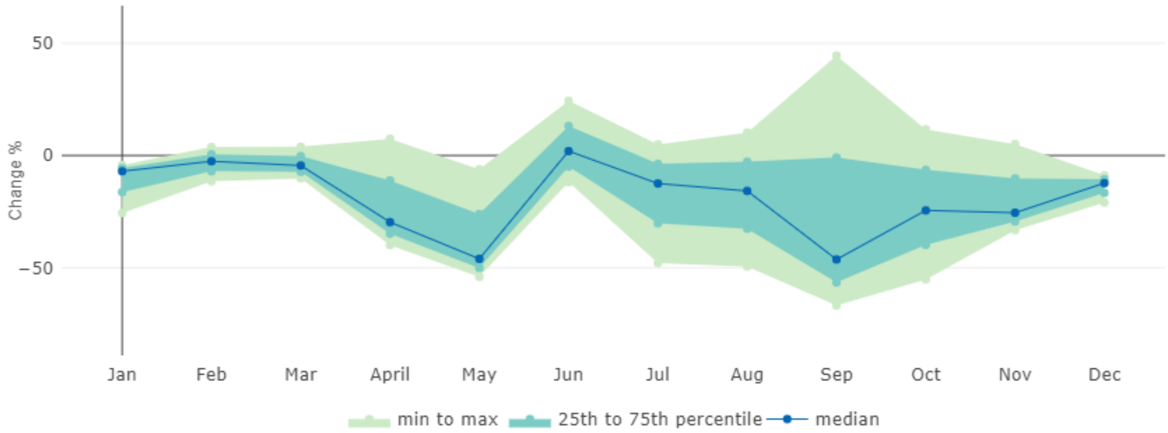
Indicator: Precipitation (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 215: Projected change in annual mean precipitation under RCP 8.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -67% and 44%



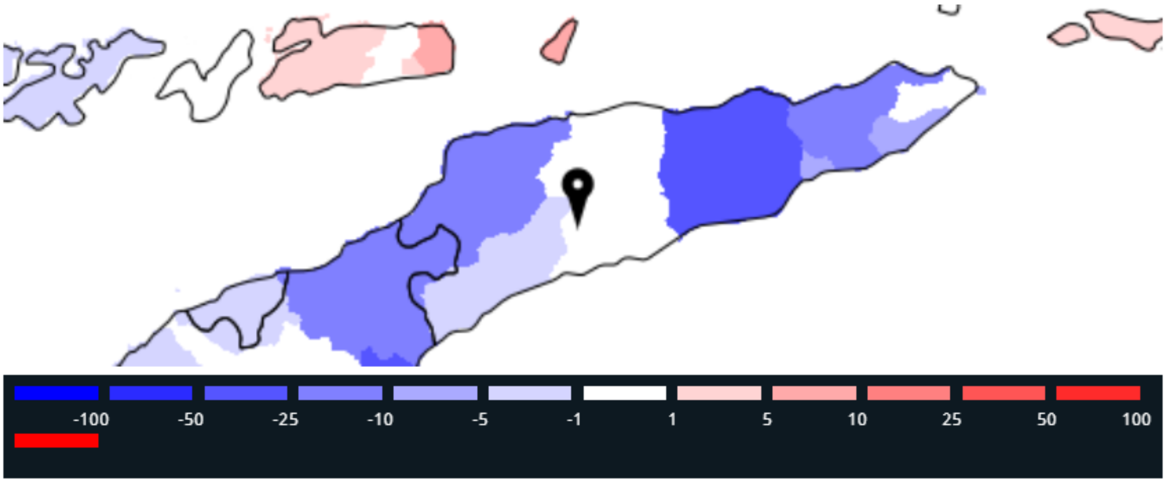
Indicator: Precipitation (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 216: Projected change in monthly mean precipitation under RCP 8.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is -0.59% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -4.7% and 8.8%



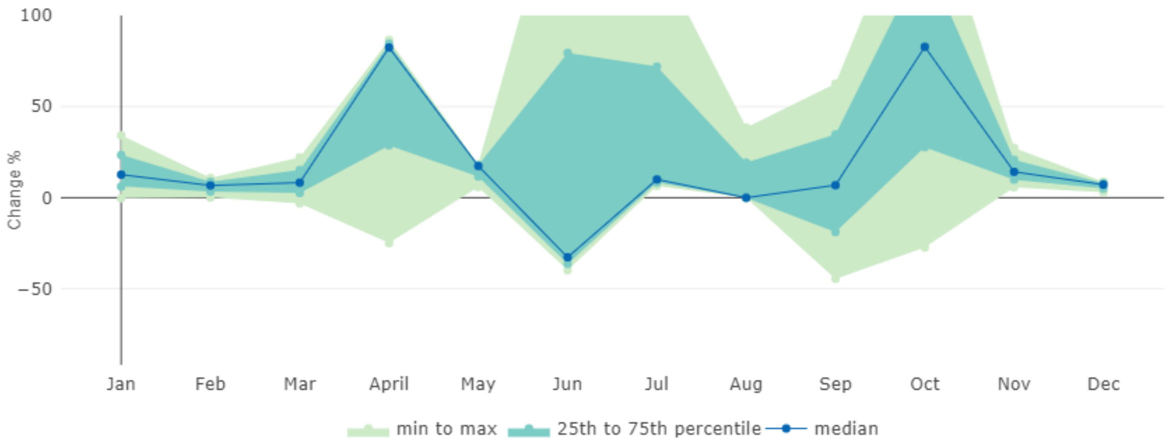
Indicator: Aridity actual (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 217: Projected change in annual mean actual aridity under RCP 8.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -45% and 190%



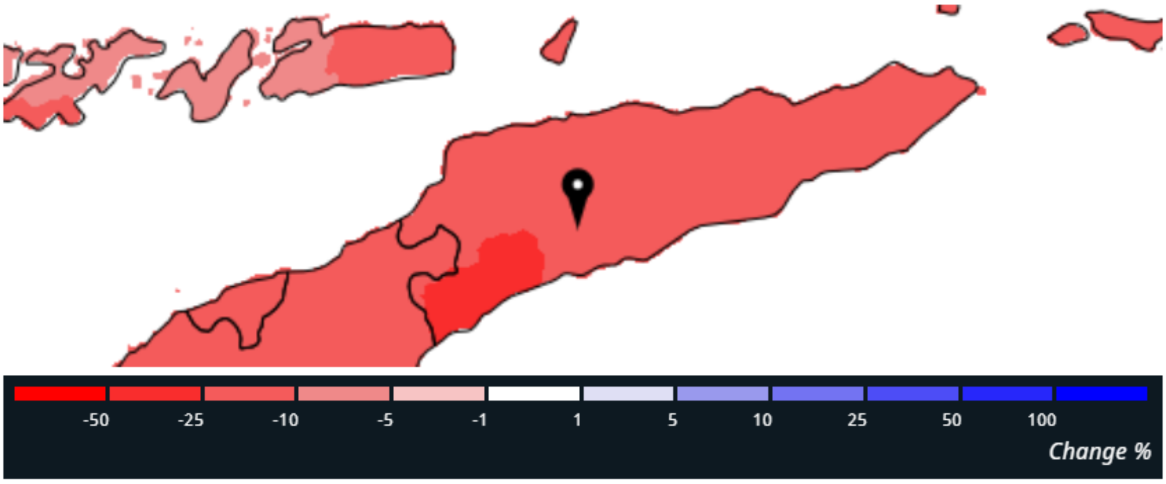
Indicator: Aridity actual (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 218: Projected change in monthly mean actual aridity under RCP 8.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Median change is -18% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -18% and -15%



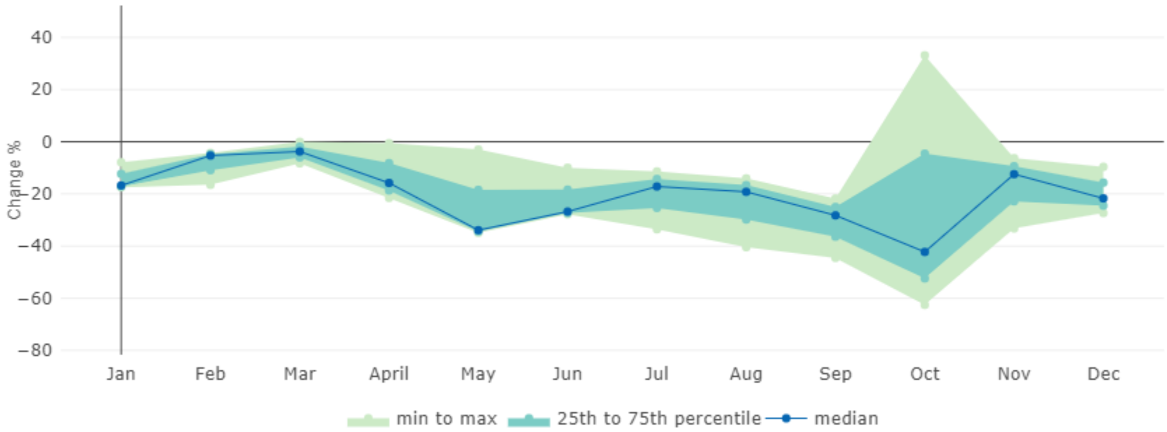
Indicator: Soils moisture (annual mean), Time period: 2041-2070, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 219: Projected change in annual mean soil moisture under RCP 8.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2041 – 2070 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -63% and 33%



Indicator: Soils moisture (annual mean), Time period: 2041-2070, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 220: Projected change in monthly mean soil moisture under RCP 8.5 in the time period 2041 – 2070 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Projected change in key indicators for 2071 – 2100 under RCP 8.5

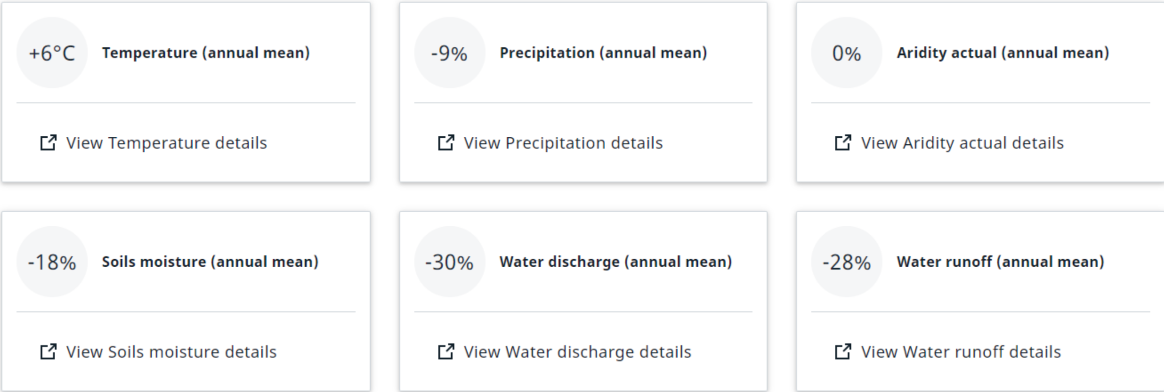
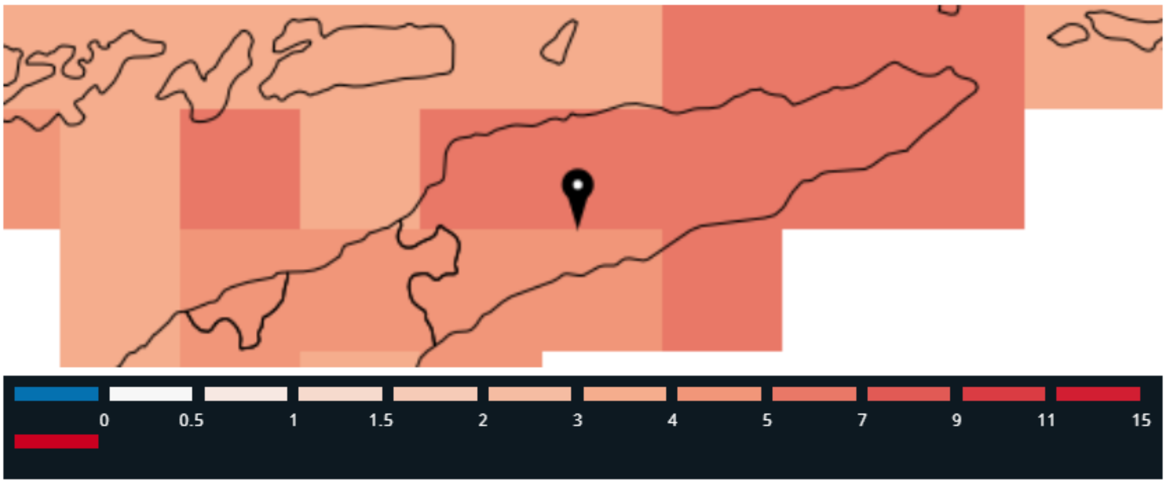


Figure 221: Future change in key indicators in the time period 2071 – 2100 under RCP 8.5 for Manufahi, Timor-Leste (Source: ClimateInformation.org, 2020)

Key message for Temperature (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is 5.8 °C (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between 5.7 °C and 5.8 °C



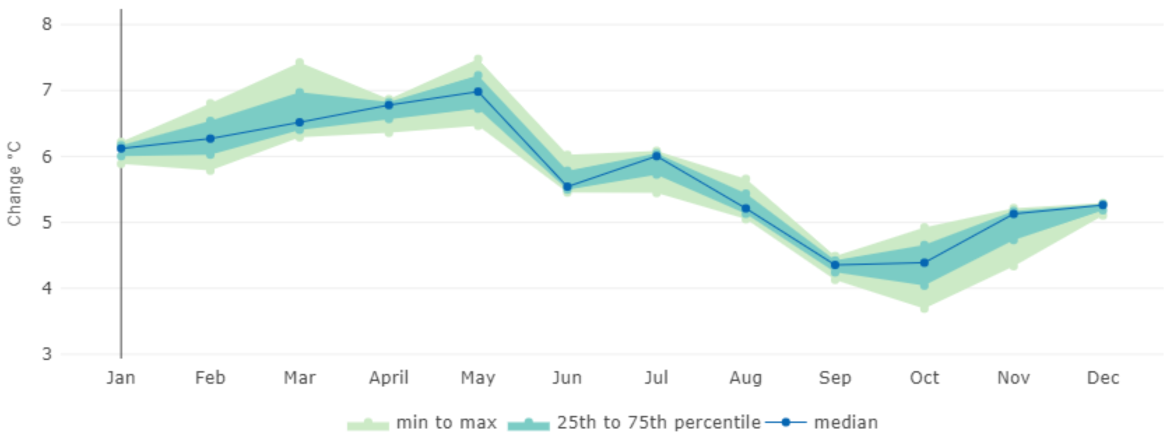
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 222: Projected change in annual mean temperature under RCP 8.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Temperature (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between 3.7 °C and 7.5 °C



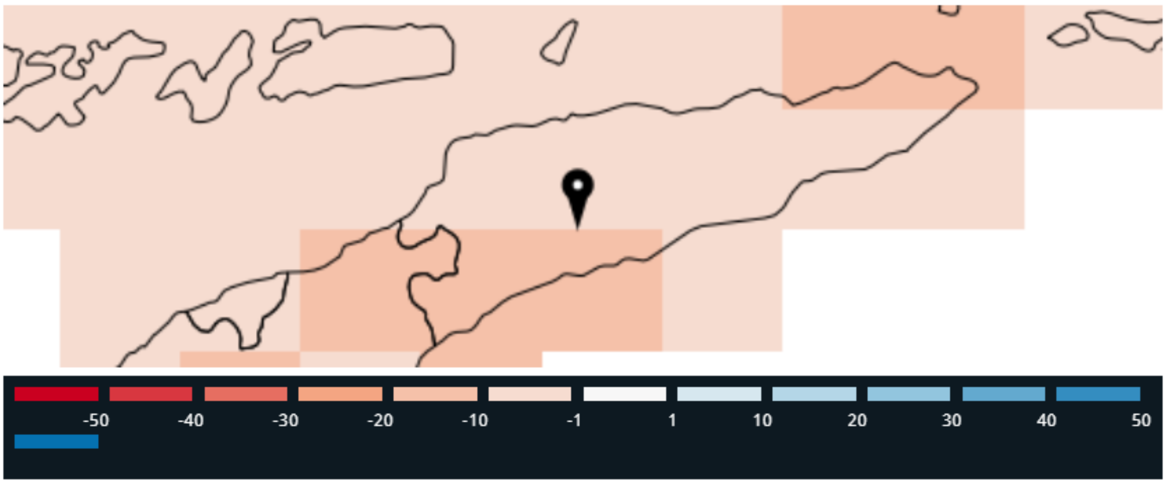
Indicator: Temperature (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 223: Projected change in monthly mean temperature under RCP 8.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is -9.5% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -15% and -9%



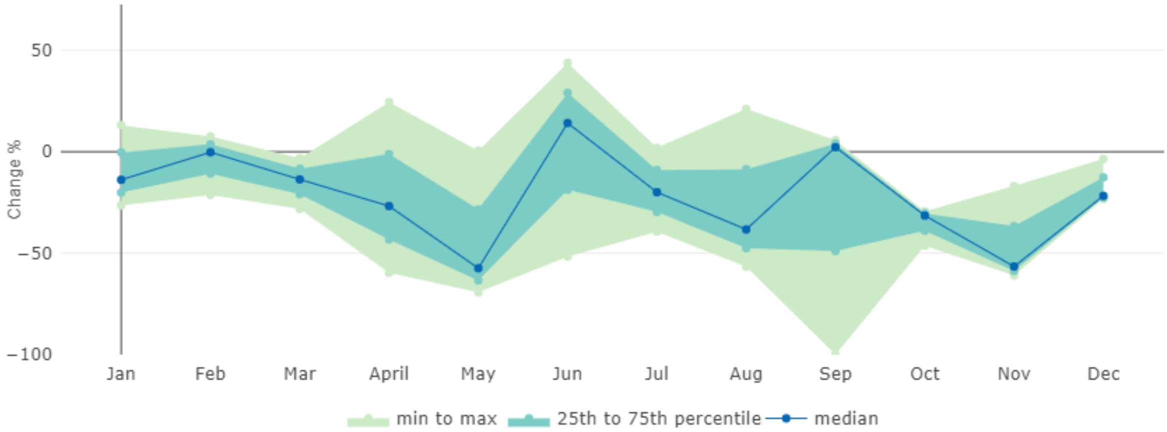
Indicator: Precipitation (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 224: Projected change in annual mean precipitation under RCP 8.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Precipitation (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -100% and 44%



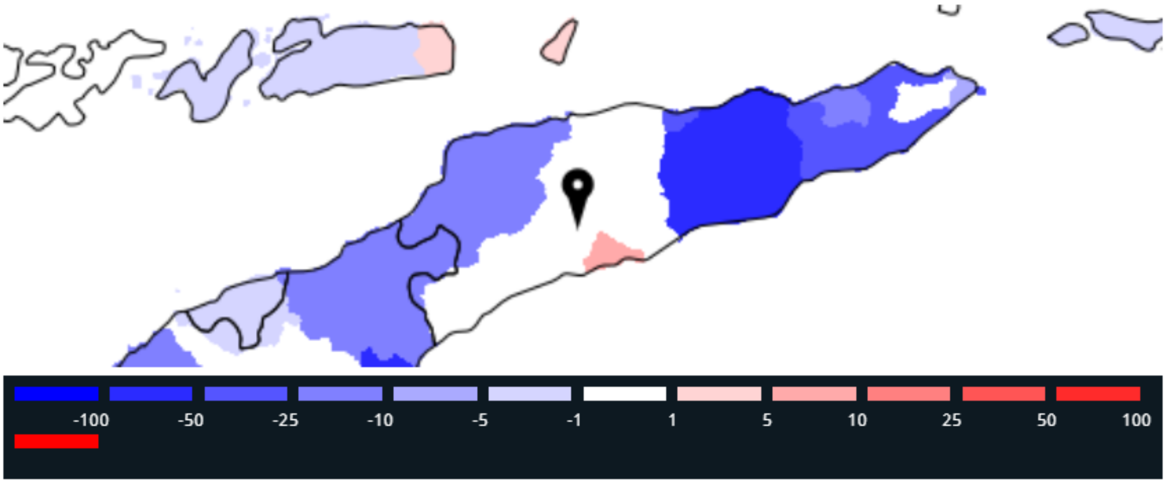
Indicator: Precipitation (annual mean), Time period: 2071-2100, Historical period: 1981-2010, RCP 8.5, Model: CORDEX East Asia Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 225: Projected change in monthly mean precipitation under RCP 8.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is 0% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -2.9% and 3%



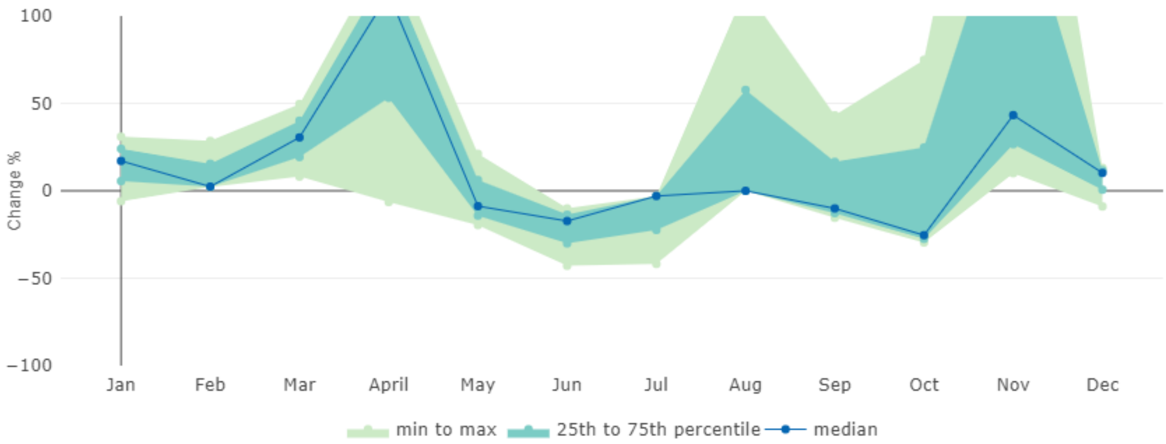
Indicator: Aridity actual (annual mean), Time period: 2071-2100, Historical period: 1981-2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 226: Projected change in annual mean actual aridity under RCP 8.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Aridity actual (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -43% and 320%



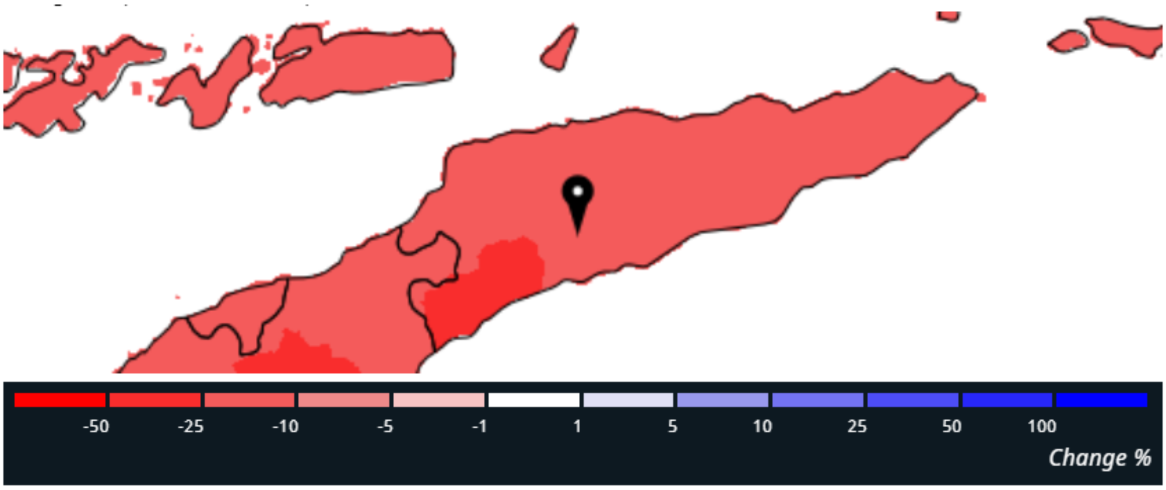
Indicator: Aridity actual (annual mean), Time period: 2071–2100, Historical period: 1981–2010, RCP 8.5, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 227: Projected change in monthly mean actual aridity under RCP 8.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (annual mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Median change is -18% (ensemble mean)
- 50% of the ensemble members (interquartile range) agree that the change lies between -23% and -17%



Indicator: Soils moisture (annual mean), Time period: 2071–2100, Historical period: 1981–2010, Model: CORDEX East Asia - WWHYPE Ensemble Mean, Model results for an area covering the location: Manufahi (-9, 125.65)

Figure 228: Projected change in annual mean soil moisture under RCP 8.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

Key message for Soil moisture (monthly mean)

For the time period 2071 – 2100 compared to 1981 – 2010 (RCP 8.5):

- Monthly mean change lies between -65% and 6.8%

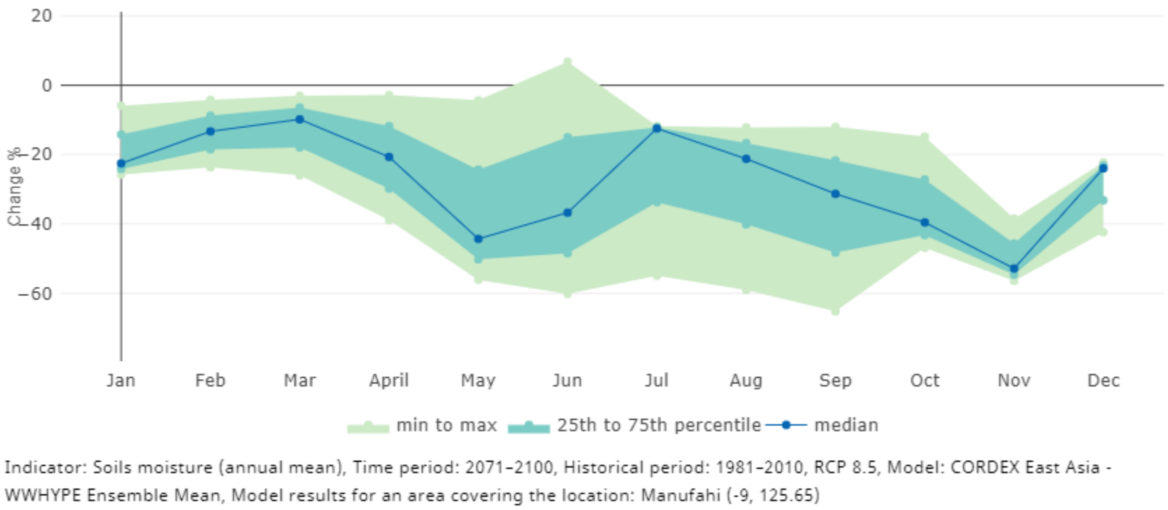


Figure 229: Projected change in monthly mean soil moisture under RCP 8.5 in the time period 2071 – 2100 for Manufahi, Timor-Leste compared to historical period 1981 – 2010 (Source: ClimateInformation.org, 2020)

3.6 – CLIMATE CHANGE IMPACTS IN TIMOR-LESTE

3.6.1 Agriculture

Approximately 85 percent of Timor-Leste's population relies on subsistence farming, which faces routine devastation due to flooding or drought events.[180] High impact meteorological events are already affecting Timor-Leste's crop production and its socio-economic stability. Notably, the agriculture sector is being impacted by heat stress, drought, heavy rainfall events and sea level rise. In coastal areas, high temperature induces evaporation from rising ground water levels, increasing salt concentration in the rooting zones of plants and reducing their growth and productivity. Increased air temperatures already affect coffee plantations in Timor-Leste and will reduce the areas suitable for coffee, Timor-Leste's most profitable cash crop. This is of concern as coffee is the principal cash crop in Timor-Leste, accounts for 90% of the non-oil exports and directly employs a quarter of the population.[181] Increases in the sea temperature, coral bleaching and drought in Timor-Leste's mainland are also expected to have a negative impact on the availability of fish for inshore fishermen.[182]

Production of maize and rice, the country's main staple crops, is already insufficient to meet current domestic demand, forcing the government to rely on imports.[183] These staple crops, in addition to peanuts, are sensitive to rising temperatures and the impacts associated with extreme rainfall, seawater inundation and salinization of coastal aquifers.

El Niño events result in less overall rainfall bringing a prolonged dry season and have significant impacts on the availability and quality of water for irrigation and domestic use.[184] Drought has devastating impacts on crop yields. During the 2015–2016 El Niño, Timor-Leste experienced a severe drought: erratic and insufficient rainfall reduced crop yields for maize (down by 40%) and rice (down by 57%) across the country.[185] Higher temperatures decrease yields by limiting germination rates;

[180] Timor-Leste, 2017. Timor-Leste's Current Forecast: Changing Climate Increases the Social and Economic Burden, COP23. Available at: https://cop23.com.fj/timor-leste/ (Accessed: 10 January 2020).
[181] UNDP, 2016. Timor-Leste: Stay Connected – Reducing Climate Risks, Building the Future
[182] USAID, 2017. Fact Sheet; Climate Risk Profile Timor-Leste.
[183] Ibid.
[184] UNDP, 2016. Timor-Leste: Stay Connected – Reducing Climate Risks, Building the Future
[185] USAID, 2017. Fact Sheet; Climate Risk Profile Timor-Leste

recent estimates suggest that yields will fall by as much as 10 percent for every 1°C increase in minimum temperature during the growing season.[186] With 80 percent of crop production dependent solely on rainfall, most farmers are restricted to only one planting season, leaving them highly vulnerable to any increase in rainfall variability.[187] Approximately one third of Timor-Leste's total population, roughly 350,000 people, were affected by the prolonged drought, which escalated the food-security crisis at the start of the dry season in July 2017. The continued trend of poor harvest yields forced communities to rely on livestock for food, and lack of diet diversity and food intake reductions escalated health problems throughout the country.[188]

The El Niño affected communities are largely those more reliant on livestock and single season farming. The loss of livestock for many communities is also the loss of their "banked" wealth and has an impact on the ability of households to send their children to school and pay other annual expenses. Livestock are also used for tilling the land and their loss makes it harder for farmers to replant.

High rainfall intensity increases erosion and leads to reduced soil fertility and reduced crop yields. It also induces flash flooding, landslides and coastal inundation. Landslides and flooding also damage or destroy important infrastructures such as roads, hospitals, schools, community houses and businesses. In 2010, La Niña unleashed an unrelenting rainy season, destroying more than 200 homes and affecting more than 14,000 families in Timor-Leste's southern region.[189] Farmers typically have two planting seasons—from late November through March and from April through June—but unpredictable flooding destroyed the July harvest and contributed to an estimated 7 percent decline in crop yields.[190] Furthermore, rising seas threaten the viability of low-lying fields (where most of the country's rice is grown) as a result of coastal flooding and soil salination.

3.6.2 Water resources

The most significant impact on the population during El Niño years is reduced ground water availability. In 2017, some people, particularly women, in rural areas such as in Liquidoe of the Municipality of Aileu found it more difficult to access clean water during the prolonged drought and had to walk more than 1 km to get clean water.[191] Analysis results of the rapid assessment in El Niño affected areas of six municipalities in Timor-Leste (Baucau, Bobonaro, Covalima, Lautem, Oecussi and Viqueque) showed that the drought caused a shortage of clean water.

Limited access to potable water is and will continue to be a major challenge in Timor-Leste. Groundwater resources are replenished by rainfall in the wet season, providing storage for use throughout the year, but increased demand for domestic, industrial and agricultural use is straining this resource. Projected changes in rainfall patterns and saltwater intrusion are likely to compound the issue, leading to reduced quality and quantity of groundwater resources. Additionally, increased temperatures and evaporation are negatively impacting the country's 12 river systems, which are generally short, fast flowing and intermittent. Changes in surface water flow have significant impacts on people and livelihoods, especially those reliant on agriculture (which accounts for more than 90

[186] Ibid.
[187] Ibid.
[188] Timor-Leste, 2017. Timor-Leste's Current Forecast: Changing Climate Increases the Social and Economic Burden, COP23. Available at: https://cop23.com.fj/timor-leste/ (Accessed: 10 January 2020).
[189] Ibid.
[190] Ibid.
[191] WMO, 2018. Timor-Leste Study - Enhancing Early Warning Systems to build greater resilience to hydrometeorological hazards in Pacific Small Island Developing States (SIDS).

percent of freshwater withdrawals). Extreme rainfall, which is projected to increase, has already led to landslides and large-scale flooding, damaging water resources and infrastructure.[192]

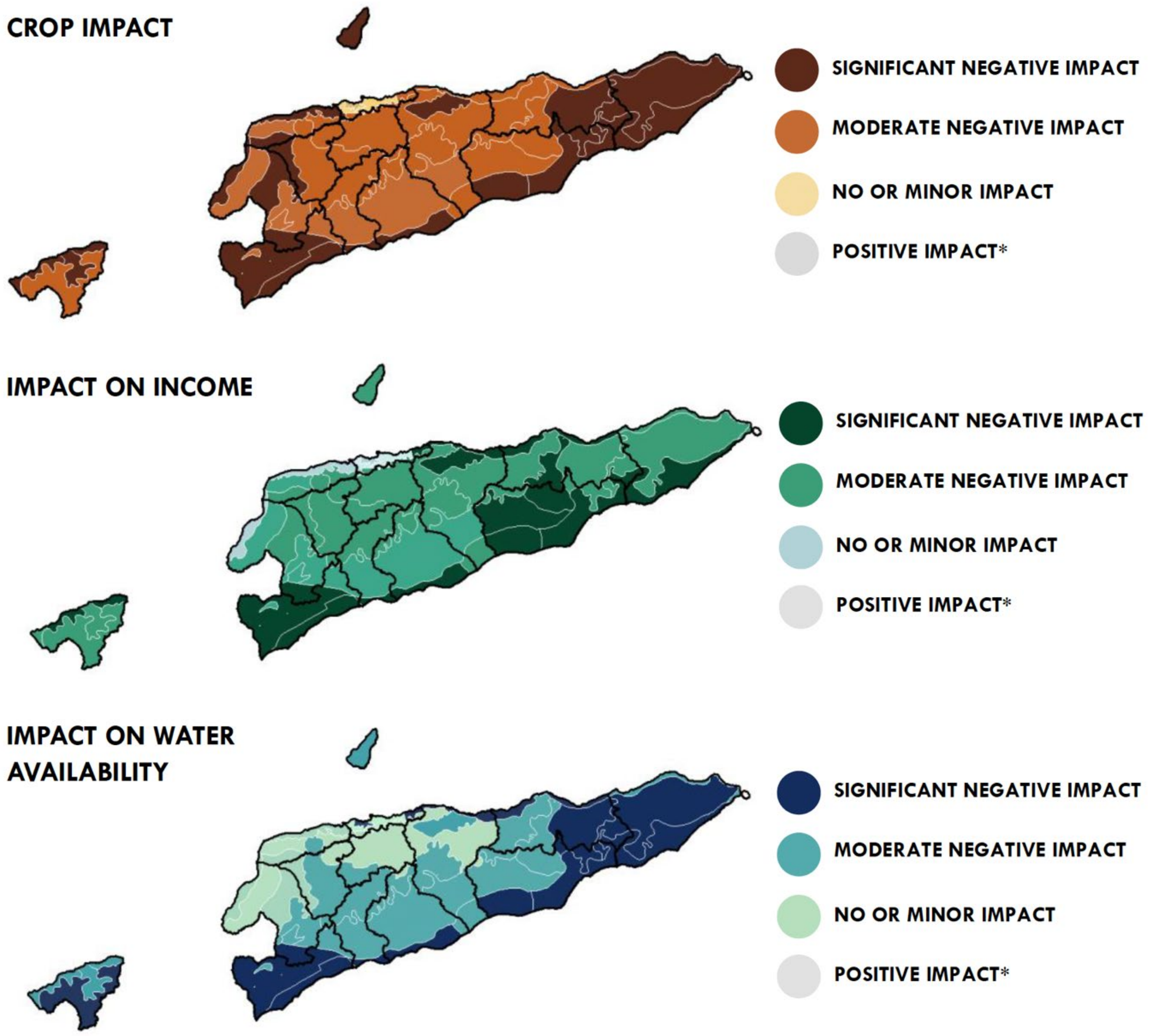


Figure 230: Reported impacts on crop, income and water availability due to the 2015/2015 El Niño, based on a rapid assessment carried out between 2 – 11 February 2016. * No positive impacts were reported. (Source: WFP, 2016)

3.6.3 Air pollution

The annual mean concentration of PM2.5 in Timor-Leste is 19 µg/m^3, which exceeds the "safe" maximum of 10 µg/m^3 recommended by the World Health Organization.[193]

Air quality is strongly dependent on weather and is therefore sensitive to climate change.[194] Climate change can affect air pollution both physically and chemically in a manner that reduces air quality. In particular, increasing temperatures and extreme heat can increase the concentration of fine particulate matter (PM2.5) and ground-level ozone (O_3).[195]

[192] USAID, 2017. Fact Sheet; Climate Risk Profile Timor-Leste.
[193] IAMAT, 2021. Timor-Leste General Health Risks: Air Pollution
[194] Jacob, D.J. and Winner, D.A., 2009. Atmospheric Environment. Effect of climate change on air quality
[195] Exhaustion.eu., 2020. The feedbacks between climate change and air pollution. Available at: https://www.exhaustion.eu/resources/the-link-and-feedbacks-between-climate-change-and-air-pollution

Meteorological conditions that influence ozone levels include air temperatures, humidity, cloud cover, precipitation, wind trajectories, and the amount of vertical mixing in the atmosphere. Higher temperatures can increase the chemical rates at which ozone is formed and increase ozone precursor emissions from both anthropogenic and biogenic (vegetative) sources. Lower relative humidity reduces cloud cover and rainfall, promoting the formation of ozone and extending ozone lifetime in the atmosphere. This effect will intensify ground level ozone events, which are expected to lead to more respiratory illness. Coupled GCM–CTM[196] studies find that climate change alone will increase summertime surface ozone in polluted regions by 1–10 ppb over the coming decades, with the largest effects in urban areas.[197]

Wildfires, which are projected to increase in frequency and severity with climate change,[198] also contribute to increased levels of PM2.5. Both of these pollutants are detrimental to human health – increasing the risk of all-cause and/or cardiovascular and respiratory mortality – which increases the burden of climate change on the health sector.[199]

Moreover, air pollution is transboundary. Mineral dust is thought to be the most abundant aerosol type by mass in the atmosphere. The global dust cycle is highly sensitive to climate change.[200] Changing climate conditions are exacerbating the risk of sand and dust storms. Increasing temperatures, in combination with drought and reduced soil moisture, are expected to contribute towards increasing frequency and intensity of sand and dust storms across Asia. The economic impact of sand and dust storms in the Asia-Pacific region is estimated at USD 5.6 billion annually.[201] Pollution in nearby regions or countries can contribute to local levels. Health effects associated with dust exposure include increased nonaccidental and cardiovascular mortality, respiratory diseases, and cardiopulmonary diseases.[202]

The impact of climate change on decreasing air quality means that stronger management systems will be needed to limit human exposure to air pollution, its impact on the national health management system and inform policy actions to minimise the risk of maladaptation. Without an adequate monitoring and warning system, lack of capacity of Timor-Leste to reduce exposure or manage the resulting impact on health and ecosystems will negatively impact on vulnerable communities and economies. This can be achieved by designing systems that utilize freely available satellite estimates with low-cost ground truthing technologies such as sensors in combination with cloud-based computing to deliver a robust indicative alerting system.

3.6.4 Infrastructure

Tropical cyclones normally occur around Timor-Leste between November and April; however, their effect tends to be weak due to proximity to the equator. The most significant hazards related to tropical cyclones are winds, high-intensity rainfall, and storm surges, which in some conditions also result in landslides, coastal flooding, and coastal erosion, all of which have impacts on infrastructure. Timor-Leste is also affected annually by tropical storms. Tropical storms (wind speed of 36-117 km/hr)

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[196] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/general-circulation-model
[197] Jacob, D.J. and Winner, D.A., 2009. Atmospheric Environment. Effect of climate change on air quality
[198] GFDRR, 2021. ThinkHazard! Timor-Leste – Wildfire. Available at: https://thinkhazard.org/en/report/242-timor-leste/WF
[199] Orellano, P. *et al.,* 2020. Environment International. Short-term exposure to particulate matter (PM10 and Pm2.5), nitrogen dioxide (NO2), and ozone (O3) and all-cause and cause-specific mortality: Systematic review and meta-analysis
[200] Kok, J.F., *et al.,* 2018. Nature Communications. Global and regional importance of the direct dust-climate feedback
[201] United Nations, 2018. Sand and Dust Storms in Asia and the Pacific: Opportunities for Regional Cooperation and Action
[202] Crooks, J.L. *et al.,* 2016. Environmental Health Perspectives. The Association between Dust Storms and Daily Non-Accidental Mortality in the United States, 1993 – 2005

can be as devastating as a cyclonic activity as they can deposit extremely high amounts of rainfall in a short time period.[203]

Strong wind events normally occur in Timor-Leste between March to April and September to October. Between 2002 and 2011 Timor-Leste experienced 19 strong wind events, which affected 2015 individuals and damaged 1863 houses.[204]

According to the National Disaster Loss Database, floods in Timor-Leste have destroyed infrastructure, damaged livelihoods and displaced residents.[205] Flooding is one of the most common disasters in Timor-Leste, resulting in destruction to infrastructure, damage to livelihoods and displacement of residents. During La Niña years above-normal rainfall leads to increased flooding and landslides in Timor-Leste.[206] Major flood events in Timor-Leste were reported in 2001, 2003, 2007, 2010, and 2011;[207] all except one of those years were during a La Niña phase. A study of 49 of the 442 sucos (villages) in Timor-Leste noted that the average annual loss due to flooding for the Riheu Suco was USD$166,430 and for the Letefoho Suco was USD$45,180.[208]

The 2010–2011 La Niña caused increased rainfall over a prolonged period in Timor-Leste resulting in flooding for the two-year period. According to the Government of Timor-Leste, the flooding destroyed 200 homes and affected 14,000 families.[209] Landslides induced by flooding are reported to be one of the most common disasters in Timor-Leste. A landslide in Bobometo village of Oecussi in 2010 destroyed at least two hectares of local farmland and forced the evacuation of 15 families living around the affected area.[210] In Timor-Leste, high occasional rainfall, steep slopes, high weathering rates and slope material with low shear resistance or high clay content are the main preconditions for landslides. A recent analysis of the landslide risk revealed that the eastern half of the country is highly prone to landslides. Apart from their potential to cause casualties and damage to communities in Timor-Leste, landslides can also cause major disruption to the fragile road network, isolating communities for long durations. Deforestation, vegetation destruction by fire or other sources and inappropriate agricultural activities in Timor-Leste have contributed to creating conditions that make areas prone to landslides.[211]

Date	Location	Disaster event	No. affected	No. deaths	Loss and damage
June 2001	Lospalos, Iliomar, Luro, Tutuala districts (Lautem province)	Flood (riverine)	2,508	1	68 houses damaged USD 20,000 provided as emergency aid grant from UNOCHA
June 2003	Covalima, Manufahi, Viqueque, Ainaro, Manatuto, Baucau provinces	Flood (riverine)	600	3	Substantial damage to infrastructure including the destruction of key roads, bridges and livestock facilities[212]

[203] BoM (Australian Bureau of Meteorology) and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report.
[204] World Bank, 2015. Report No: ACS13123 -Democratic Republic of Timor-Leste Building Disaster/Climate Resilience in Timor-Leste
[205] UNDP, 2012. Synthesis report on comprehensive national hazard profile.
[206] BoM (Australian Bureau of Meteorology) and CSIRO, 2014.
[207] World Bank, 2015. Report No: ACS13123 -Democratic Republic of Timor-Leste Building Disaster/Climate Resilience in Timor-Leste
[208] Ibid
[209] UNDP, 2012. Synthesis report on comprehensive national hazard profile.
[210] Ibid.
[211] Ibid.
[212] Government of Timor-Leste, 2016. Disaster Management Reference Handbook 2016

December 2003 – January 2004	Maliana, Cailacao districts (Bobonaro province), Hatu-Udo, Ainaro districts (Ainaro province)	Flood	450	-	16 houses severely damaged or destroyed USD 40,700 provided for relief and rebuilding[213]
January – March 2006	Suai district (Covalima province), Liquidoe district (Aileu province), Oecussi, Baucau Ainaro, Bobonaro, Viqueque provinces	Storm (Daryl)	8,730	-	At least 500 houses destroyed Corn and rice crops destroyed in at least four districts (Ainaro, Bobonaro, Baucau and Viqueque)[214]
February – March 2007	Aileu, Ainaro, Baucau, Ermera, Liquica, Manatuto, Manufahi provinces	Drought	210,000 – 220,000[215]	-	25-30% reduction in crop production (also influenced by a major locust outbreak)[216]
June – July 2007	Covalima, Manatuto, Ermera, Manufahi, Baucau, Viqueque provinces	Flood (riverine)	947	1	Covalima: 65 families lost houses, water wells, livelihoods and farms with maize and rice ready to harvest. 90% of rice and 10-20% of maize lost. Manatuto: Around 22 hectares of land washed away, affecting 42 families. Ermera: Landslide destroyed 30 houses. Manufahi: Flooding destroyed 16 houses. Baucau: 18 families lost farmland. Viqueque: One person died and the family lost house and properties.[217] USD 125,800 allocated for relief and rebuilding[218]
December 2007 – January 2008	Aileu, Ainaro, Baucau, Bobonaro, Covalima, Ermera, Lautem, Liquica provinces	Flood	-	-	-
July 2010	-	Flood	-	-	More than 200 homes destroyed, and 14,000 families affected Estimated 7% decline in crop yields

[213] Government of Timor-Leste, 2016. Disaster Management Reference Handbook 2016
[214] OCHA, 2006. Relief Web – Timor-Leste: Strong Winds and Flash Floods Information Bulletin No. 1
[215] No. people affected based on FAO estimate of rural people requiring emergency food assistance. FAO and WFP, 2007. Special Report: FAO/WFP Crop and Food Supply Assessment Mission to Timor-Leste. Available at: http://www.fao.org/3/ah866e/ah866e00.htm
[216] FAO and WFP, 2007. Special Report: FAO/WFP Crop and Food Supply Assessment Mission to Timor-Leste. Available at: http://www.fao.org/3/ah866e/ah866e00.htm
[217] IFRC, 2007. DREF Bulletin no. MDRTP002. Timor-Leste: Flooding and Land Slides. Available at: https://www.ifrc.org/docs/appeals/07/MDRTP00201.pdf
[218] Government of Timor-Leste, 2016. Disaster Management Reference Handbook 2016

2015 – 2016	Baucau, Covalima, Lautem, Oecussi, Viqueque provinces	Drought	350,000	-	Crop failure and severe livestock reduction (70,000 deaths) 60,430 households reported deaths of animals and 25,611 households (approx. 21% of all households) reported diseases in their animals[219]
March 2020	Cristo Rei, Nain Feto, Dom Alexo and Vera Cruz (Dili municipality)	Flood (riverine)	9,126	-	USD 20 million At least 190 houses destroyed

Table 1: Overview of recent climate-related extreme events affecting Timor-Leste (Source: DesInventar and EMDAT)

[219] ACAPS, 2017. Briefing Note – 3 May 2017. Timor-Leste. Anticipatory: Drought, May-July 2017. Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/20170503_acaps_start_anticipatory_briefing_note_timor_leste.pdf

4 – VULNERABILITY ASSESSMENT OF TIMOR-LESTE

Timor-Leste is highly exposed to natural disasters associated with droughts, floods, and landslides resulting from the combination of heavy monsoon rain, steep topography, widespread deforestation, and cyclones. It is also exposed to rarer but potentially more deadly hazards such as tsunamis and earthquakes. Unfortunately, there is little publicly available information on the costs of the frequent natural disasters experienced by Timor-Leste.[220] It should be noted that health is a cross-cutting sector as all climate change impacts have direct implications on human health (including heatwaves as noted above).

While Timor-Leste has a medium exposure to natural hazards, its lack of coping and adaptive capacity and strategies makes it the 15th most disaster-prone country in the world. Over 78% of Timorese are reported to have experienced “shocks” due to climate hazards.[221] The total estimated value of exposure to climate hazards in Timor-Leste is more than 570 million USD, with residential exposure contributing 42.5%, transport 38.2%, commercial 10.9%, education 3.7%, industrial 1.6%, health 0.8% and crops 0.7%.[222]

“Timor-Leste is expected to incur, on average, 5.9 million USD per year in losses due to earthquakes and tropical cyclones. In the next 50 years, Timor-Leste has a 50% chance of experiencing a loss exceeding 88 million USD and casualties larger than 300 people, and a 10% chance of experiencing a loss exceeding 530 million USD and casualties larger than 2,100 people.”[223]

“Climate change presents serious environmental challenges for Timor-Leste. Rising sea levels will increase the risk of flooding in low-lying coastal villages and the higher risk of floods, forest fires and food shortages, as a result of more extreme weather conditions caused by climate change, will directly impact on communities in Timor-Leste. Timor-Leste’s climate may become hotter and drier in the dry season and increasingly variable. Three natural resources—water, soil, and the coastal zone—are susceptible to changes in climate and sea level rises. Coral reefs are also very sensitive to changes in water temperature and chemical composition. These changes could have consequences for agricultural production, food security and their tourism industry, and increase the risk of natural disasters caused by flooding, drought or landslides.”[224]

The extent to which livelihoods are affected by a climate shock depends on their resilience capacity. Climate resilience in Timor-Leste is determined by three key factors – wealth (access to income), livelihood diversity (to better manage shocks), and climate-sensitivity of income. Timor-Leste has distinct geographical patterns of livelihood resilience:

- Urban areas and fishing communities in Atauro have the highest levels of resilience. Access to financial flows from small industrial activities and tourism results in higher incomes, diversified livelihoods and lack of dependence on rainfall patterns;
- Communities in the central highlands and southern parts of Timor-Leste have comparatively higher resilience levels due to diversified agricultural practices and income generation from cash crops;

[220] WMO, 2018. Timor-Leste Study - Enhancing Early Warning Systems to build greater resilience to hydrometeorological hazards in Pacific Small Island Developing States (SIDS).
[221] UNDP, 2016. Timor-Leste: Stay Connected – Reducing Climate Risks, Building the Future
[222] World Bank, 2015. Report No: ACS13123 -Democratic Republic of Timor-Leste Building Disaster/Climate Resilience in Timor-Leste
[223] pcrafi.spc.int/documents/163
[224] Government of Timor-Leste, 2011. Strategic Development Plan 2011-2030

- Communities in the eastern region and Oecussi have the least resilient livelihoods due to dependence on a small number of highly climate-sensitive agricultural activities and insufficient access to income.

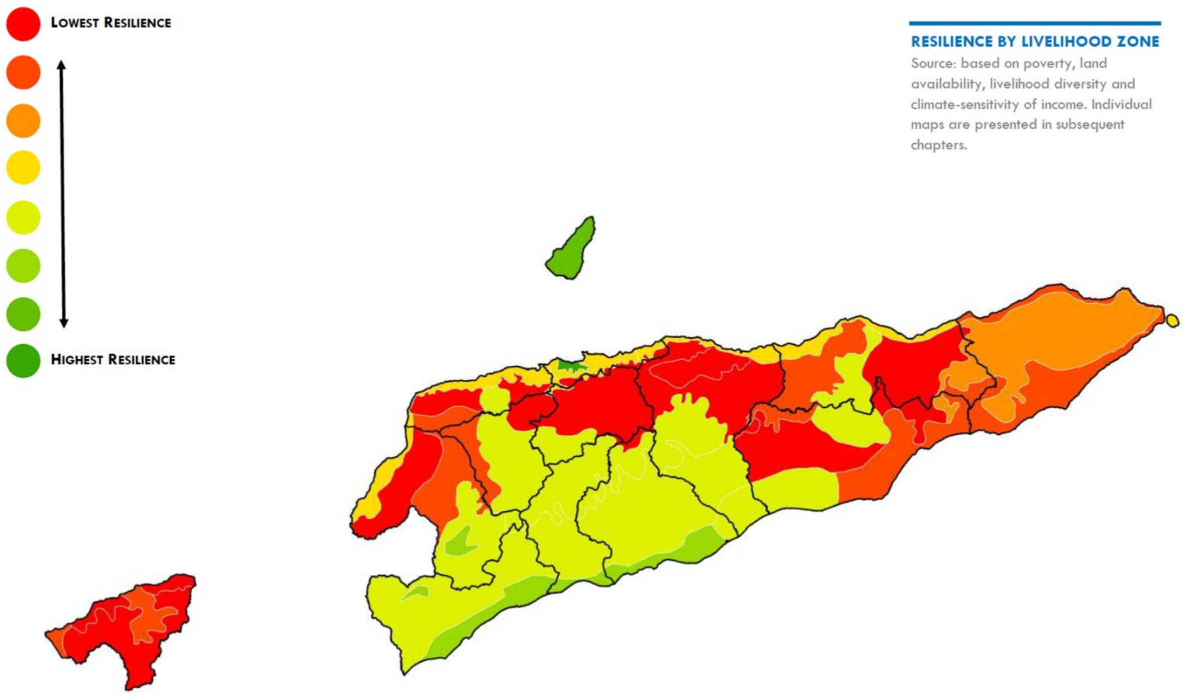

Figure 231: Resilience by livelihood zone, based on poverty, land availability, livelihood diversity and climate-sensitivity of income. (Source: WFP, 2016)

An Integrated Vulnerability Assessment by the National Directorate of Climate Change (NDCC), using data of 32 villages across all 13 municipalities in Timor-Leste, reported that at the village level, the main reported climate-related issue is water shortage. Other reported prominent vulnerabilities include floods and landslides, which causes damage to infrastructure and leave local communities with limited capacity to adapt to the negative impacts of climate change. In turn, these impacts have led to food insecurity, unsustainability within local economies, and environmental and natural resource degradation. A second Vulnerability Assessment by the NDCC has reported that there has been an increased frequency and intensity of extreme weather events in Timor-Leste, as well as longer dry seasons leading to more pervasive droughts. All 32 communities reported that the changing environmental conditions are affecting the poor to a greater degree, due to a lack of access to climate-resilient building materials, alternative incomes and livelihood diversification strategies.[225]

According to biophysical, social and economic data, 59.1 percent of *sucos* in Timor-Leste are considered vulnerable to climate change, of which most are located in the western part of the country. Therefore, improving the capacity and resilience of communities at the *suco* level is important to manage climate risk and reduce vulnerability, specifically in key sectors such as agriculture and the water sector.[226]

The Government of Timor-Leste has published material relating to climate change and has outlined several priority areas (forest, land and sea conservation; biodiversity; renewable energy; pollution

[225] Secretary of State for the Environment (2020). *Timor-Leste's National Adaptation Plan*. Dili, Timor-Leste: Government of Timor-Leste
[226] Timor-Leste, 2020. Second National Communication under the UNFCCC

control; and public awareness raising). It has also nominated targets for upcoming years, such as: 2015–Community based nurseries will be planting one million trees nationwide every year; 2020–70% of National Adaptation Programs of Actions under the United Nations Framework Convention on Climate Change will have been implemented; and 2030–Timor-Leste will have an extensive network of land and marine national parks that protect representative samples of its biodiversity.

A summary of climate impacts on climate sensitive sectors is as follows:

- Threats to coral reefs due to ocean acidification, ocean warming (bleaching) and flooding/sedimentation; water stresses, reduced water supply and water salination/pollution; flood risks and more intense extreme rainfall events.
- Risks of epidemic climate-sensitive (vector- and water-borne) diseases and malnutrition.
- Increasing burden of air pollution on the health sector.
- Increasing risks of landslides and loss of coastal zones due to sea level rise.
- Little change in drought frequency, increased vulnerability of farmers to extreme weather events, greater risks of crop loss/failures and livestock productivity, loss of biodiversity detrimental to fishing.

4.1 – AGRICULTURE AND FOOD SECURITY

Although the rural population has been decreasing steadily, about 70% of Timor-Leste's population live in badly serviced rural areas and rely on climate-sensitive rain-fed agriculture as their main source of income, with very limited access to financial services.[227] Agriculture accounts for 80% of employment, though only 8.2% of Timor-Leste's land is arable. Around 80% of households rear livestock alongside the main cropping activities. Major livestock zones are located in the easternmost regions and in Oecussi, where livestock sales are the dominant source of income for approximately six months per year.[228]

The most commonly grown crop in Timor-Leste is maize (approximately 30,000 ha), followed by paddy (18,000 ha) and cassava (10,000 ha).[229] Maize and paddy are important staple food crops. However, land suitable for paddy production is limited due to the topography of Timor-Leste; whilst maize is more widely grown in the uplands, including hillsides. The most common commercial agricultural product is coffee, which is mainly grown in the central highlands together with maize, cassava and taro. A smaller coffee zone exists near the southern coast, where communities produce cash crops during the second rainy season.[230]

There are two major seasonal patterns that influence livelihoods in Timor-Leste: in the north, single season rainfall limits crop production to key stable or cash crops; in the south, double season rainfall allows for longer-duration crops, a second crop, and production of root crops (sweet potato and taro) or more profitable cash crops (watermelon, banana, squash, kidney beans, soybeans, mung bean and peanut).[231]

[227] https://reliefweb.int/sites/reliefweb.int/files/resources/WRR_2017_E2.pdf
[228] NSD and UNFPA, 2011. Population and Housing Census of Timor-Leste 2010
[229] Ministry of Agriculture and Fisheries, 2015. 2014 Agricultural Production Statistics
[230] WFP, 2016. Timor-Leste CLEAR – Consolidated Livelihood Exercise for Analysing Resilience
[231] WFP, 2016. Timor-Leste CLEAR – Consolidated Livelihood Exercise for Analysing Resilience

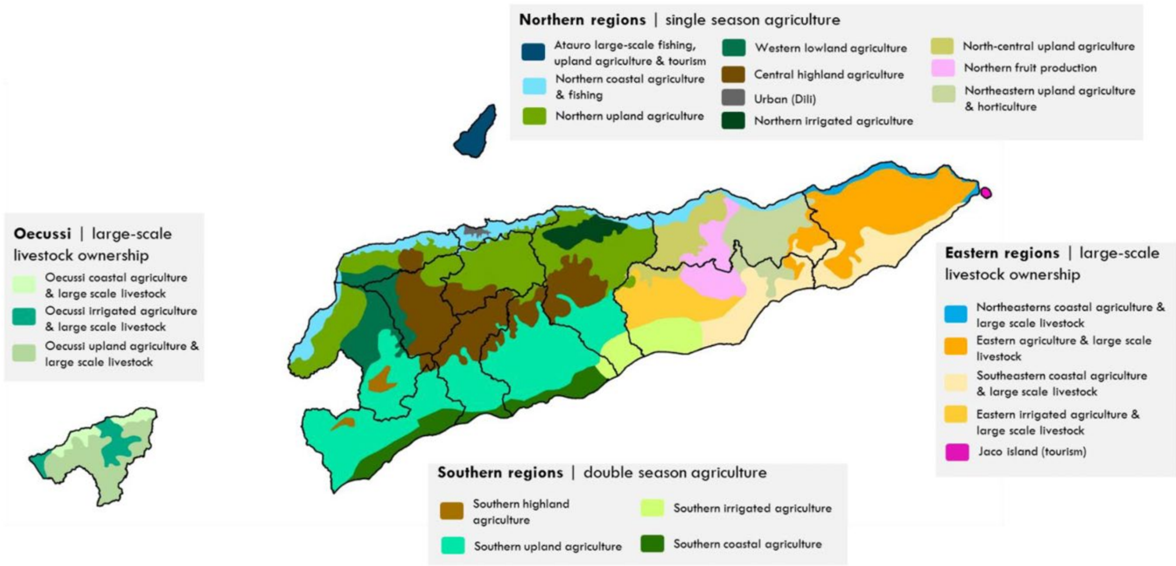

Figure 232: Livelihood zones in Timor-Leste (Source: WFP, 2016)

The widely practised "swidden" subsistence agriculture,[232] combined with slashing and burning vegetation during the dry season to clear land, has resulted in uncontrolled fires, land degradation, deforestation, loss of biodiversity, soil erosion, slope instability, and water regime degradation. Low agricultural production combined with a lack of access to markets, inputs and basic services contributes to high food insecurity, particularly in rural areas. About 74% of the rural population suffers moderate and severe food insecurity,[233] which is exacerbated by extreme climate events of increasing severity, duration and incidence.

Rugged terrain, poor clay soils and varying rainfall across Timor-Leste pose chronic challenges to agriculture and food security in Timor-Leste. The poor soil and climatic conditions result in a constant undersupply of food, leaving the country reliant on food imports. The country's main long-term challenge to provide a stable source of staple crops is further adversely influenced by the rapid urbanization and poor transportation infrastructure. Given the high rate of dependency on agriculture as a source of income, the population is highly vulnerable to food loss and climatic changes. Almost all climate hazards that are experienced in Timor-Leste influence agriculture and therefore food security.[234]

Moreover, extreme climate events, such as drought, negatively impact households as they experience delayed planting, crops not growing, and sick and dying animals due to issues accessing water and fodder. Households also have to rely on less preferred foods from their own production (e.g. tubers and root crops), skip meals and reduce meal portion sizes to cope with the food shortages. As droughts affect farming and livestock, access to animal protein declines, thereby worsening household insecurity and undernutrition.[235]

[232] Swidden agriculture is not inherently destructive of soil fertility and has been practised sustainably in Papua New Guinea on steep slopes for at least 10,000 years: Bourke, RM, *History of Agriculture in PNG*, press-files.anu.edu.au/downloads/press/p53311/pdf/history.pdf

[233] Food and Nutrition Security Task Force. Ministry of Agriculture and Forests Algis Map. Dili, January 2012.

[234] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

[235] Secretary of State for the Environment (2020). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF

Long-term systematic changes in climate variability will have a large influence on agricultural production. In coastal areas, high temperature induces evaporation from rising ground water levels, increasing salt concentration in the rooting zones of plants and reducing their growth and productivity. Increased air temperatures already affect coffee plantations in Timor-Leste and will reduce the area suitable for growing coffee. Any increase in the frequency and intensity of extreme events such as floods and droughts will affect grain, horticultural, forestry and livestock production.

4.2 – HEALTH

Timor-Leste has made significant improvements in the health sector since becoming independent in 2002, with substantial improvements in health outcomes – such as increased life expectancy from 48.5 years in 1990 to 67 years in 2014, and significant reductions in infant and maternal mortality rates.[236] However, climate change impacts and variability present considerable risks to human health and threaten to undermine recent developments. The direct impacts of climate change in Timor-Leste include increased heat stress, floods, drought, increased frequency and intensity of tropical storms; with indirect impacts caused by adverse changes in air pollution, increased spread of disease vectors, water shortages, food insecurity and malnutrition, displacement, and mental ill health.[237]

Recent national emergencies, including the COVID-19 pandemic since 2020 and severe flooding in April 2021, have revealed underlying weaknesses in the health system of Timor-Leste. Despite improvements in health outcomes since independence, there are still shortages in medical equipment, supplies (e.g. personal protective equipment) and medicines. These shortages have proved to be a significant challenge that has been exacerbated during the COVID-19 and the recent floods. The floods have also raised concerns of increased transmission of climate-sensitive communicable diseases (e.g., dengue and water-borne diseases).[238]

More than 450,000 households in Timor-Leste suffer annually from displacement, poor water quality, injury and mortality due to floods and landslides. Vector-borne diseases such as dengue and malaria are major public health concerns, with 75 percent of the population at risk and malaria being the leading cause of death in children under five. Increasing temperatures are likely to cause such diseases to become more widespread. The districts of Viqueque and Lautem have the highest malaria rates and greatest risk of future increases, while Manatuto is the most exposed to dengue. Increasing frequency and intensity of flooding compromises potable water sources and leads to outbreaks of water-borne diseases such as diarrhoea and typhoid. In addition to heat stress, extreme humidity and temperature levels are linked to severe respiratory infections, such as pneumonia, asthma, and other lung and nasal diseases.[239] Timor-Leste is undergoing an epidemiological transition as the burden of noncommunicable diseases increases, whilst infectious disease prevalence remains high,[240] which will likely further compound the health impacts of climate change.

Air pollution poses further health risks. The annual mean concentration of PM2.5 in Timor-Leste is 19 $\mu g/m^3$, which exceeds the "safe" maximum of 10 $\mu g/m^3$ recommended by the World Health Organization.[241] PM2.5 is a significant contributor to ill health (including cardio- and cerebrovascular

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[236] World Bank, 2017. Turning Challenges into Opportunities: the Medium Term Health Expenditure Pressure Study in Timor-Leste
[237] Watts, W. *et al.* 2015. The Lancet. Health and climate change: policy responses to protect public health
[238] World Bank (2021). *Timor-Leste Economic Report: Charting a New Path*. Washington, DC: International Bank of Reconstruction and Development / The World Bank
[239] USAID, 2017. Fast Sheet. Climate Risk Profile Timor-Leste
[240] World Bank, 2017. Turning Challenges into Opportunities: the Medium Term Health Expenditure Pressure Study in Timor-Leste
[241] IAMAT, 2021. Timor-Leste General Health Risks: Air Pollution. Available at: https://www.iamat.org/country/timor-leste-/risk/air-pollution

disease, adult chronic and child acute respiratory illnesses, and lung cancer[242]) and is identified as the highest priority pollutant for air quality monitoring.[243] Household air pollution is a particular concern. In Timor-Leste, almost 50% of total deaths from ischaemic heart disease, stroke, lung cancer, chronic obstructive pulmonary disease in adults and acute lower respiratory infections in children under 5 years are attributable to household air pollution.[244] Moreover, air pollution disproportionately affects the most vulnerable, particularly children in uniquely damaging ways owing to a combination of behavioural, environmental and physiological factors. Other vulnerable populations include the elderly, women, people with existing lung or cardiovascular diseases, and the poor with limited access to healthcare services.

In 2019, Timor-Leste was ranked 110th out of 117 countries on the Global Hunger Index (GHI), with the GHI score indicating a "serious level of hunger".[245] El Niño years bring droughts and diarrhoeal diseases due to scarcity of potable water are the major concern, as well as infectious and respiratory illnesses. La Niña events are associated with elevated disease incidence and with higher rates of physical injury and loss of essential assets.

Disasters cause an increased risk of vector- and rodent-borne diseases (including dengue, malaria, chikungunya, zika, leptospirosis), food- and water-borne diseases (including cholera, cryptosporidium, rotavirus, *E. coli* infection, giardia, shigella, typhoid, hepatitis A), and biotoxin-mediated illness (ciguatera and shellfish poisoning).

"On a timescale of weeks to seasons, predictions provide outlooks for climate-sensitive diseases that are linked to changing environmental conditions, such as vector-borne diseases like malaria and dengue fever, or diseases that increase in severity with the onset of dust in the dry season, such as meningococcal meningitis, and end with the start of the rainy season. Understanding these relationships provides opportunities to plan interventions, such as mobilising community health workers to raise awareness of health risks in vulnerable communities and to increase the readiness of the health care system to respond to epidemic outbreaks.[246]

"The link between climate variability in tropical regions and the prevalence of malaria, for example, in a given season or year is well established. However, climate is not the only factor involved and it is important that any disease forecast model employed incorporates appropriate health data and is tuned to the specifics of the area in which it is to be used." [247]

Direct impacts of increased frequency and/or intensity of extreme weather events following climate change on health include exposure to thermal extremes, damage to public health infrastructure and increased frequency of physiological disorder and injuries. Indirect impacts of climate change on health include disturbances to ecological systems, resulting in greater incidence of vector-borne diseases, infectious diseases, malnutrition and hunger which subsequently disturb child growth and development.[248]

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[242] IPCC, 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability. Chapter 11 – Human health: impacts, adaptation, and co-benefits

[243] WMO, 2014. Air Quality and Human Health, a Priority for Joint Action. Available at: https://public.wmo.int/en/resources/bulletin/air-quality-and-human-health-priority-joint-action

[244] WHO, 2015. Climate and Health Country Profile – Timor-Leste

[245] Concern Worldwide and Welthungerhilfe, 2019. Global Hunger Index 2019 – Timor-Leste

[246] D.P. Rogers, M.A. Shapiro, G. Brunet, J-C. Cohen, S.J. Connor, A.A. Diallo, W. Elliott, K. Haidong, S. Hales, D. Hemming, I. Jeanne, M. Lafaye, Z. Mumba, N. Raholijao, F. Rakotomanana, H. Teka, J. Trtanj, and P.-Y. Whung. 2010, Health and climate – opportunities. World Climate Conference 3 paper. Available online at www.sciencedirect.com

[247] SPREP, Pacific Roadmap for Strengthened Climate Services 2017-2026

[248] Secretary of State for the Environment (2020). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF

The Ministry of Health and the World Health Organization have jointly conducted a health vulnerability and adaptation assessment for Timor-Leste, as a part of the Health National Adaptation Plan (HNAP). The assessment showed that under high-emissions scenarios, heat-related mortalities among the elderly are projected to increase significantly relative to the baseline (between 1961 – 1990) due to higher temperatures and longer heatwaves. Therefore, there is a need to improve capacities within the Ministry of Health and other stakeholders to address the health risks of climate change, such as through mainstreaming climate change into new policies and programmes for climate-sensitive diseases and risks; to improve early warning systems for disease vectors; improve research capabilities to better understand the link between climate/weather events and health impacts.[249]

4.3 – WATER

4.3.1 Overview of hydrology and water resource management

Timor-Leste has been broadly divided into twelve 'Hydrologic Units', which are groupings of climatologically and physiographically similar and adjacent river basins. Each of these hydrologic units comprise a number of rivers, 29 main river systems in total, of which 12 in the north and 17 in the south. All rivers are generally short and fast-flowing.[250] The table below presents the units with the corresponding area in the country. The total length of the rivers is about 4,286 km with a total river surface area of around 18 342 ha (La'o Hamutuk, 2010).

Name of unit	Area (km^2)	As % of country
Loes	2,184	14.7
Laclo	2,024	13.6
Clere and Belulic	1,917	12.9
Irabere	1,614	10.9
Mola and Tafara	1,533	10.3
Seical	1,510	10.2
Tukan and Sahen	1,375	9.2
Laleia	1,006	6.8
Lifau and Tono Besi	812	5.5
Vero	744	5.0
Atauro Island	140	0.9
Jaco Island	11	0.1
Total	**14,870**	**100**

Table 2: Hydrologic units in Timor-Leste (Source: La'o Hamutuk, 2010)

Given the temporal variations in rainfall and the low capacity of upland areas to hold water, very few rivers flow all year round, most being ephemeral but generally with significant underbed flows in the lower reaches.[251] Internal renewable surface water resources are about 8.129 km^3/year and groundwater resources at 0.886 km^3/year. An estimated 0.8 km^3/year or 90 percent returns to the

[249] Secretary of State for the Environment (2020). *Timor-Leste's National Adaptation Plan*. Dili, Timor-Leste: Government of Timor-Leste
[250] Australian Water Research Facility (AWRF), 2006. Situation Analysis Report – Timor-Leste
[251] Australian Water Research Facility (AWRF), 2006. Situation Analysis Report – Timor-Leste

rivers as base flow and may be considered to be the overlap between surface water and groundwater. Therefore, total internal renewable water resources (IRWR) are estimated as 8.215 km^3/year.

Renewable freshwater resources			
Precipitation (long-term average)	-	1,500	mm/year
	-	22,300	million m^3/year
Internal renewable water resources (long-term average)	-	8,215	million m^3/year
Total actual renewable water resources	-	8,215	million m^3/year
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2009	7,468	m^3/year
Total dam capacity	-	-	million m^3

Table 3: Renewable freshwater resources in Timor-Leste (Source: FAO Aquasat database)

The sustainable yield of the aquifers, which can be considered to be the exploitable groundwater, is around 0.266 km^3/year.[252] Some river basins are shared with Indonesia in the border area and Oecussi district. About 9 percent of the Loes river basin, 20 percent of the Tono river basin and 60 percent of the Noel Besi river basin lie in Indonesia, the latter two being in Oecussi district. However, no information on the amount of water crossing the borders is available.

Timor-Leste has only one large freshwater lake – Lake Ira Lalaru – a large, shallow, seasonally fluctuating lake, which has formed in the lowest part of the Fuiloro plateau, covering between 10 and 55 km^2 depending on the season. Lake Ira Lalaro has a catchment area of 406 km^2, but apart from very heavy rainfall events the catchment characteristically produces little runoff as the lake is situated in a limestone karstic area. While several small watercourses drain into the lake none of these are perennial.[253]

Irrigation is the highest water user in the country abstracting 90 percent of the total freshwater withdrawals mainly from free or unregulated river intakes.[254] This makes abstraction during the dry season difficult and limits the area that can be irrigated during the dry season.

	2013	2014	2015	2016	2017	2018	2019	2020	Total
Area currently irrigated	46,300	46,300	46,300	46,300	46,300	46,300	46,300	46,300	46,300
9 schemes in pipeline		2,488	5,946	11,909	12,409	12,409	12,409	12,409	12,409
20 new schemes					2,500	5,000	7,500	10,000	10,000
6 schemes + new dams					1,500	3,000	4,500	6,000	6,000
PDD I and II schemes	2,500	5,000	7,500	10,000	10,000	10,000	10,000	10,000	10,000
Total hectares irrigated		48,800	53,788	59,746	68,209	72,709	76,709	80,709	84,709
Incremental hectares irrigated	2,500	4,988	5,958	8,463	4,500	4,000	4,000	4,000	**38,409**

Source: World Bank 2015.
Note: The current irrigated area reported by the MAF is approximately 46,300 ha. However, investigations (Freach 2013) indicate that the currently irrigated area may cover only 33,300 ha.

Figure 233: MAF Irrigation development plan 2013 – 2020 (Source: World Bank, 2015)

[252] Australian Water Research Facility (AWRF), 2006. Situation Analysis Report – Timor-Leste
[253] Australian Water Research Facility (AWRF), 2006. Situation Analysis Report – Timor-Leste
[254] Asian Development Bank, 2004. Timor-Leste Integrated Water Resource Management "Water for All – Water for Growth"

4.3.2 *Vulnerability of the water sector*

Water resources in Timor-Leste are already under pressure from increasing population numbers and the expansion of agriculture onto marginal land. Around one-quarter of households in Timor-Leste do not have access to safe drinking water,[255] and almost 40% of the population is at least 30 minutes from the nearest water source.[256] The two dominant causes of infant and child mortality in Timor-Leste – lower respiratory infection and diarrhoeal disease – are directly linked to a lack of clean water supply, poor sanitation and hygiene.[257]

Livelihoods in Timor-Leste are highly dependent on natural resources – in particular, water resources for irrigation. Water insecurity is a major constraint for crop production and rural populations. “Surface water flows are highly variable from wet season peaks, which bring flash floods carrying large volumes of sediment, to low flows in the dry season”.[258]

Climate and water data collected on weekly, seasonal and annual timescales and at regional, national and local levels are essential to the development of effective water management strategies, including flood and drought preparedness and response. As for agriculture, climate data and information underpin water resource planning, the management of current supplies, and assessments of future needs for both community and commercial uses. Calculations of the frequency and duration of heavy rainfall, probable maximum precipitation, low-flow and flood forecasting all require cooperation between DNMG, DNGRA, agricultural extension officers, local NGOs, water managers and disaster management organisations.

4.4 – ENERGY

Timor-Leste is one of the most natural resource-dependent countries in the world. In 2017, the oil sector accounted for 36% of total GDP, 98% of exports and 41% of total imports.[259] Such heavy reliance on few and finite resources represents a risk for sustainable development in Timor-Leste, especially as energy demand increases with economic development and population growth. The energy sector is linked to climate variability and change in numerous ways. Energy production strongly contributes to climate change through the emission of greenhouse gases, whilst also being impacted by climate variability and change through changes in energy supply (e.g. disruption to operations and distribution) and demand (i.e. population growth and changing power needs).

Climate projections most relevant to the energy sector and their implications are detailed below:[260]

- **Increasing temperatures:** The relationship between daily heat and demand for electricity can be estimated using the Cooling Degree Days index, which captures the amount of heat that society would like to get rid of through some form of active cooling – for example, air conditioning. For all RCPs, longer periods are projected for when temperature is above the cooling base level, resulting in more cooling degree days and greater energy requirements by the cooling system.

[255] World Bank, 2020. Country Partnership Framework for The Democratic Republic of Timor-Leste (FY2020-FY2024)
[256] ADB, 2014. Timor-Leste Country Gender Assessment
[257] Government of Timor-Leste, 2011. Strategic Development Plan 2011-2030
[258] World Bank, 2020. Country Partnership Framework for The Democratic Republic of Timor-Leste (FY2020-FY2024)
[259] Extractive Industries Transparency Initiative, 2020. Timor-Leste. Available at: https://eiti.org/timorleste
[260] World Bank, 2020. Climate Change Knowledge Portal. Timor-Leste. Climate by Sector – Energy. Available at: https://climateknowledgeportal.worldbank.org/country/timor-leste/climate-sector-energy

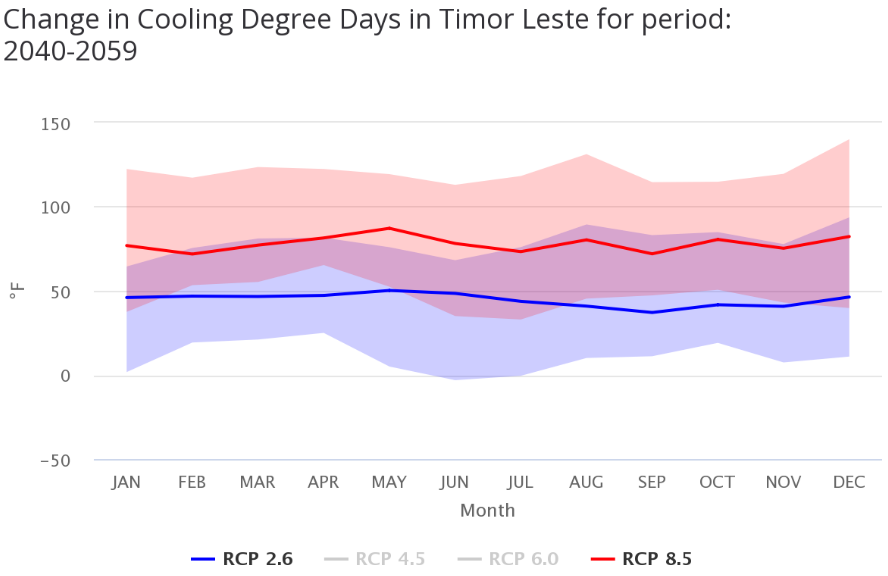

Figure 234: Change in Cooling Degree Days in Timor-Leste for the period: 2040 – 2059 (Source: World Bank Climate Change Knowledge Portal)

- **Increase in frequency or severity of extreme rainfall:** Projected increases in rainfall can lead to flooding, which can have significant impacts on power production. For example, local flooding can disrupt transportation lines for fuel, or excessive rainfall and flooding can disrupt power distribution networks.
- **Change in frequency or severity of drought events:** The Standardised Precipitation Evapotranspiration Index (SPEI) is a widely used drought indicator. The direction of SPEI change provides insight into increasing or decreasing pressure on water resources for direct power production or indirectly through cooling. The combination of dry conditions and high temperatures results in heightened cooling needs and increased demand for water pumping. Lack of water can restrict cooling and thus power production may need to be slowed.

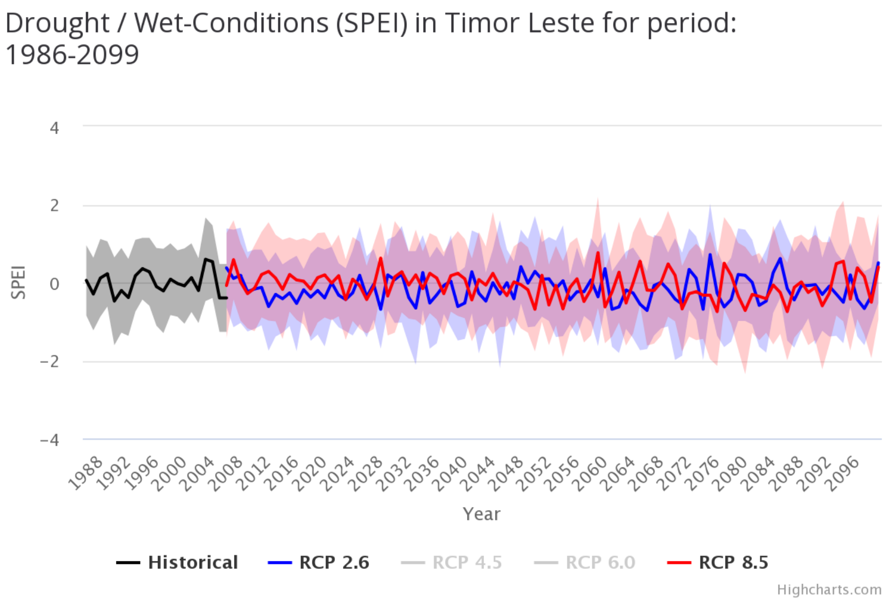

Figure 235: Standardised Precipitation Evapotranspiration Index (SPEI) in Timor-Leste for the period: 1986 – 2099 (Source: World Bank Climate Change Knowledge Portal)

4.5 – COASTAL AND MARINE RESOURCES

Timor-Leste has a long coastal area, extending over 700km and including unique resources both on land and sea.[261] As only two out of 13 municipalities in Timor-Leste are landlocked, municipalities are highly vulnerable to the shorelines and specifically on the southern coast. One key vulnerability of these municipalities is that in many areas, the roads are constructed close to the coastline and are therefore affected by severe coastal erosion. The overall resilience of coastal areas is further reduced by out-migration to urban centres by the economically productive individuals, leaving behind the most vulnerable people including the elderly, children and poor women.[262]

Fishing is an essential resource for northern coastal communities and on Atauro Island; and is a major protein source for many Timorese people. Fishing is less common on the southern coast due to the existence of stronger waves that limit fishing potential.[263]

The vulnerability of Timor-Leste's coastal and marine resources is influenced by various climate change-related phenomena and events:

- Fish stocks and their rate of replenishment are quite sensitive to climatic variability and longer-term climate change with different fish populations responding in different ways. Reef health in Timor-Leste is highly susceptible to ocean warming, acidification and deoxygenation.
- Increased air temperature has the potential to cause migration/displacement of fish; cause loss or destruction of coastal vegetation, species and habitats; and cause loss of health, diversity and productivity of inshore marine systems and fisheries.
- Changes in precipitation patterns and intensity have the potential to increase sedimentation, which reduces aquatic reproduction, productivity and cause local extinctions due to increased flood frequency and intensity; destroy freshwater and shallow marine habitats and species due to increased river flows, run-offs, flooding and sedimentation; and damage coastal saline habitats including wetlands and mangroves due to flooding.
- More intense storm activity has the potential to reduce health, diversity and productivity of coastal and in-shore marine ecosystems and species; destroy coastal vegetation, species and habitats; physically damage coral reefs and mangroves due to strong wave action; increase erosion of beaches, shorelines and coastal lands; damage breeding and nesting habitats; and damage vital infrastructures such as offshore oil and gas infrastructure.
- A rise in shallow seawater temperatures, sea-level rise and increased seawater acidification has the potential to destroy coastal vegetation, species and habitats; reduce health, diversity and productivity of offshore marine ecosystems, fisheries and marine megafauna; reduce the survival of many species due to loss of plankton productivity; salinisation of soil, freshwater, coastal lands, infrastructure and agriculture due to seawater intrusion; and reduce health and survival of many marine species due to increased seawater acidification.[264]

[261] Secretary of State for the Environment (2020). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF
[262] Secretary of State for the Environment (2020). *Timor-Leste's National Adaptation Plan*. Dili, Timor-Leste: Government of Timor-Leste
[263] WFP, 2016. Timor-Leste CLEAR – Consolidated Livelihood Exercise for Analysing Resilience
[264] Secretary of State for the Environment (2020). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF

5 – INTRODUCTION TO EARLY WARNING SYSTEMS

Early Warning Systems (EWSs) have been shown to be effective tools for reducing loss of life and damage through improved emergency preparedness and response. The United Nations Office for Disaster Reduction (UNDRR)[265] defines EWSs as "the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss". It has been demonstrated that "the devastating impacts of extreme hydrometeorological events can be greatly reduced through improved impact-based warning information linking threat levels to emergency preparedness and response actions that are easily understood by authorities and the population, who can then take the appropriate mitigation actions."[266]

Disaster preparedness activities combined with risk reduction measures can prevent disaster situations from developing. They can save lives and livelihoods in a disaster, enabling affected populations to get back to normality quickly. Disaster preparedness is a continuous and integrated process arising from a wide range of risk reduction activities and resources rather than being a distinct sectoral activity by itself. It requires the contributions of many different areas—ranging from awareness, training and logistics, to health care, livelihood recovery and institutional development.

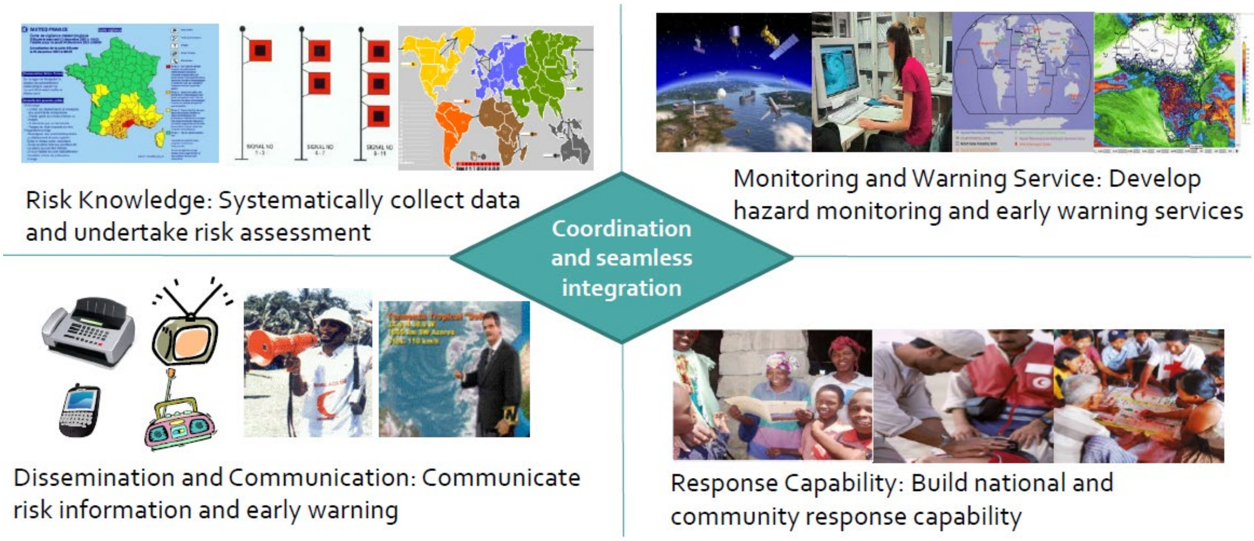

Figure 236: Four interacting elements of an effective and complete early warning system (Source: Green Climate Fund)[267]

UNDRR posits that to be effective and complete, an early warning system needs to comprise four interacting elements:[268]

- Risk Knowledge – Systematically collect data and undertake risk assessment
    - Are the hazards and vulnerabilities well known?
    - What are the patterns and trends in these factors?
    - Are risk maps and data widely available?

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[265] UNDRR, 2009

[266] GCF Concept Note: Enhancing Early Warning Systems to build greater resilience to hydro and meteorological hazards in Pacific Small Island Developing States (SIDS), 2017

[267] GCF Presentation, Josef D. Intsiful, 24 October 2017

[268] ISDR-PPEW 2005c Project overview plan, Early Warning Strengthening Project

- Monitoring and Warning Service – Develop hazard monitoring and early warning services
    - Are the right parameters being monitored?
    - Is there a sound scientific basis for making forecasts?
    - Can accurate and timely warnings be generated?
- Dissemination and Communication – Communicate risk information and early warnings
    - Do warnings reach all of those at risk?
    - Are the risks and warnings understood?
    - Is the warning information clear and useable?
- Response Capability – Build national and community response capabilities.
    - Are response plans up-to-date and tested?
    - Are local capacities and knowledge made use of?
    - Are people prepared and ready to react to warnings?

5.1 – Impact-based Forecasting

"Impact Based Forecasting (IbF) is a process in which data is collected and integrated to predict the impact of impending disasters on vulnerable people living in areas that are prone to these disasters."[269] IBF is a subset under the Decision Support System (DSS) framework (see Section 5.2) that estimates the potential impacts of hazards with different intensities. It uses data and information on extreme weather or climate events (such as floods, droughts and heatwaves) and estimates the socio-economic impact. Whereas the IBF sub-component generates potential impacts in the extreme of extreme weather/climate events, the DSS generates information throughout the year for both resource management (e.g., for the agriculture sector – application of fertilizers, changing irrigation schedules or harvesting crops) and for risk management as and when an extreme event occurs, utilizing IBF for disaster management purposes.

IBF has been demonstrated that "the devastating impacts of extreme hydrometeorological events can be greatly reduced through improved impact-based warning information linking threat levels to emergency preparedness and response actions that are easily understood by authorities and the population, who can then take the appropriate mitigation actions."[270]

In practice, this means that agencies engaged in identifying approaching hazards and communicating warnings must use terms and language appropriate to their audiences. Information is generated by climatologists and meteorologists, but many people in their audiences, including the staff of the Disaster Management Directorate and the national broadcaster, do not have the adequate level of education or training to understand and interpret the information in order to respond with appropriate actions.

Scientists prefer to make statements that they know to be correct, such as that a low pressure system is approaching their country, and to avoid making statements they regard as speculative, such as that the system will bring storms of specific severity in a specific time period. However, this "speculative" information is what their listeners need to know. There is always a level of uncertainty in a forecast, and it is difficult to explain degrees of confidence. This uncertainty adds to the reluctance of staff to make definitive statements predicting rainfall, wave heights, flood risk or wind speeds and their likely impacts, but the National Disaster Management Directorate (NDMD) and Timor-Leste's disaster relief NGOs need to know what kinds of preparation they should make.

[269] https://www.510.global/impact-based-forecast/
[270] GCF Concept Note: Enhancing Early Warning Systems to build greater resilience to hydro and meteorological hazards in Pacific Small Island Developing States (SIDS), 2017

Communities also need to get timely reliable forecasts, particularly for extreme events, that include clear statements on the probable impacts and specific advice on how to prepare, in their own language. This can be as detailed as advice to avoid fishing or travel, to secure items that could be lifted by cyclonic winds, to check guttering and water tanks before a drought, or to bring boats high above the high tide line if a storm surge is expected.

Impact-based forecasting consists of three steps as illustrated in the figure below.[271] The first step is to understand the risk. This can be done through risk modelling, vulnerability assessment and community risk assessments. Geographic and population data (where people live and how many people live there) enables development of risk models to predict what areas are (most) vulnerable and to assess a community's risk. Risk knowledge leads to better understanding and identification of potential future impacts.

"Many NMHSs around the world are moving towards a Multi-hazard Impact-based Forecast and Warning Services approach that translates meteorological and hydrological hazards into sector and location-specific impacts and the development of responses to mitigate those impacts…In order to significantly reduce losses, communities and individuals need to become more resilient through actions that integrate weather and climate information in decision-making processes.[272] Therefore, DNMG needs to go beyond providing accurate forecasts and timely warnings to be able to understand and anticipate the likely impacts. It is critical that DNMG works closely with the critical decision makers in key sectors to understand i) what weather and climate events have high impacts; ii) how and what events affects their key decisions; and iii) how should they communicate weather and climate information including uncertainty.

Through the development of Standard Operating Procedures (SOPs), effective and timely actions can be taken once there is the likelihood of potential or impending severe weather or climate event.

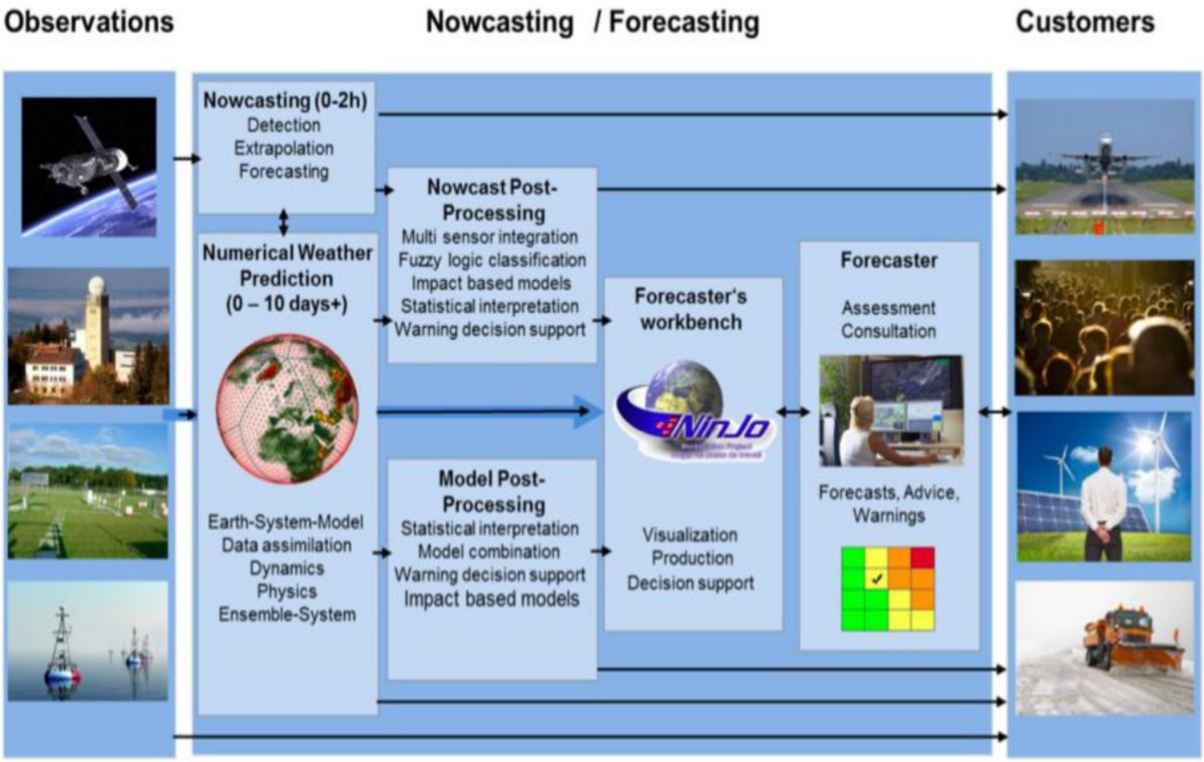

Figure 237: Pathway towards multi-hazard impact-based forecasting and warning services (Source: WMO)

[271] https://www.510.global/impact-based-forecast/
[272] https://public.wmo.int/en/resources/bulletin/impact-based-forecasting-and-warning-weather-ready-nations

The Project will use the translation of technical information into national and local languages, the delivery of local-scale impact-based advice, and community activities to improve the acceptance of science-based information products. Agreement on understandable, non-technical climate and weather terms, and the routine use of those terms in broadcasted weather reports, will make it easier for the DNMG, the NDMD and communities to understand each other. Better communication will significantly enhance social resilience to climate change and build national response capability to multiple climate-related hazards—both the increasing severity of droughts, floods and cyclones and the long-term changes of rising temperatures and sea levels.

The Project will work with partner agencies and communities to co-design and co-produce information products, drawing on their specialised knowledge of their environment to create warnings that are actionable and effective. The particular climate information needs of the elderly, people living with disabilities and most geographically and/or socially vulnerable communities (e.g. on remote outer islands) will be taken into account, as well as gender responsiveness.

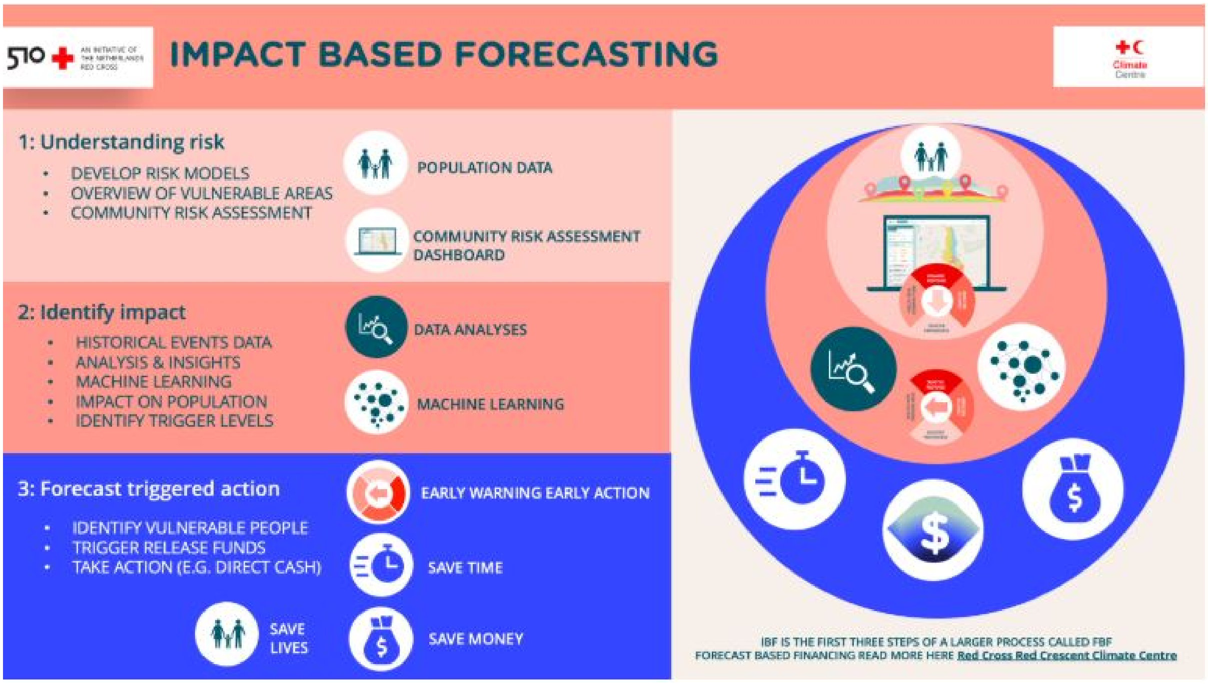

Figure 238: Three steps of impact-based forecasting[273]

5.2 – Decision Support System

A Decision Support System (DSS) is an overarching framework that encompasses different data layers and logical information to support an effective decision-making process. DSS uses all possible datasets and models to process and generate information to support timely decision-making. The DSS integrates the local user knowledge with the modelling world using machine learning techniques. It functions utilizing existing and operational mechanisms within the department and brings an automated and efficient way of information processing and dissemination.

[273] https://www.510.global/impact-based-forecast/

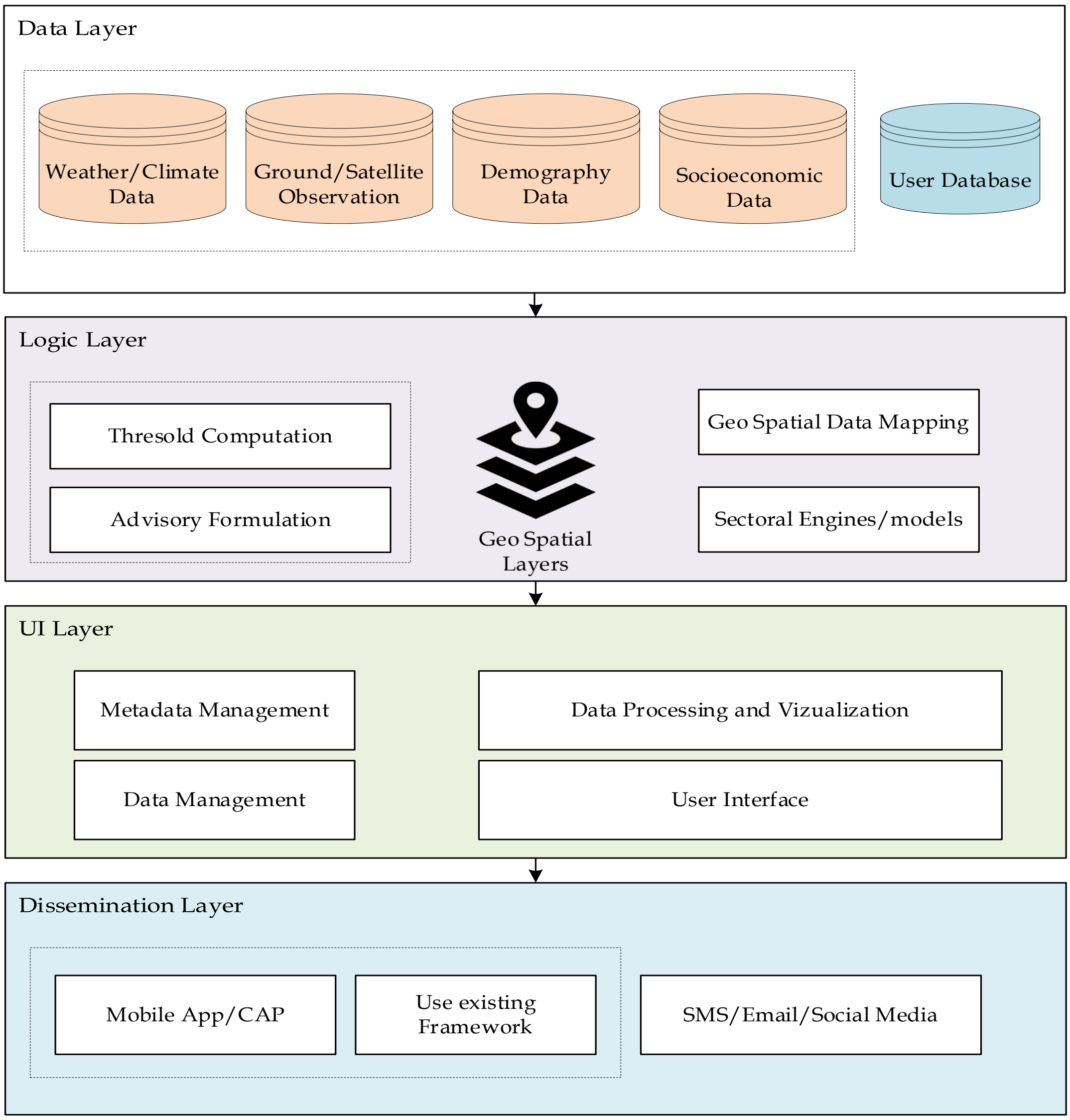

Figure 239: Generic decision support framework (Source: RIMES)

5.3 – Forecast-based Financing

Forecast-based Financing (FbF) is a system developed by the International Federation of Red Cross and Red Crescent Societies that enables access to humanitarian funding for early action based on in-depth forecast information and risk analysis. The goal of FbF is to anticipate disasters, prevent their impact, if possible, and reduce human suffering and losses.[274]

"A key element of FbF is that the allocation of financial resources is agreed in advance, together with the specific forecast threshold that triggers the release of those resources for the implementation of early actions. The roles and responsibilities of everyone involved in implementing these actions are defined in an Early Action Protocol (EAP). This ensures the full commitment of implementation among the involved stakeholders."[275]

[274] https://www.forecast-based-financing.org/about/
[275] Ibid.

Using meteorological models and historical data, experts can forecast the probability of extreme weather events with increasing accuracy. Combining weather forecasts with risk analysis allows IFRC funding to be released so people can prepare for extreme weather.[276]

IFRC has successfully used the model in Mongolia, where it estimates the ratio of cost to benefit as at least 1:6, and states that "Forecast-based financing helps communities move from reacting to disasters to anticipating them. Climate change, which brings disasters that are increasing in frequency, length and intensity makes this kind of finance model even more crucial. Simply waiting for disasters to strike is no longer an option."[277]

FbF is initiated in the third step in Figure 35. This is based on a humanitarian agency and key stakeholders, including NMHSs and targeted communities, agreeing on selected actions that are to be taken when a trigger point is reached (for example, climate forecast reaches a certain threshold). Each action is allocated funding that will be released when that threshold is met. It should be noted that FbF will not replace but will complement the disaster programmes already in place in Timor-Leste.

[276] https://www.forecast-based-financing.org/2020/01/14/forecast-based-early-action-triggered-in-mongolia/
[277] Ibid

6 – NEEDS ASSESSMENT FOR CLIMATE INFORMATION AND EARLY WARNING SERVICES IN TIMOR-LESTE

6.1 – BASELINE CLIMATE INFORMATION AND EARLY WARNING SERVICES

This section provides an analysis of the current capacity of Timor-Leste to deliver climate information and early warning services (CIEWS), its national priorities and strategies related to climate change, and key stakeholders. This analysis draws on i) primary data collection including in-country consultation workshops, interviews and questionnaire responses with key stakeholders engaged in the generation, distribution and use of information and warnings about hydrometeorological hazards in Timor-Leste (see Annex 7); and ii) comprehensive desk review of existing literature, reports and assessments conducted by Timor-Leste, regional organisations, academia and partners – including the World Meteorological Organization (WMO), Australian Bureau of Meteorology (BoM), UN Resident Coordinator's Office (RCO) for Timor-Leste and the World Bank.

The baseline CIEWS in Timor-Leste are further outlined below, based on the four key elements of early warning systems identified in the WMO Multi-Hazard Early Warning Systems (MHEWS) Checklist.[278]

6.1.1 National stakeholders

Timor-Leste has a demonstrated commitment to addressing environmental and climate change issues and has fully engaged with international frameworks governing these issues. Government, sectors, communities and NGOs are already implementing actions to increase their resilience and adapt to a changing climate, but are constrained by limited institutional, financial, technical and human resource capacities – as well as a significant lack of data – rather than the willingness and impetus to act. Hence, the 'appetite' is there to engage with climate information and early warning services (CIEWS), but a comprehensive approach to capacity building and data amelioration is required to deliver transformative impact. The key national actors with regard to CIEWS are listed below.

Coordinating Minister of Economic Affairs

The Nationally Designated Authority (NDA) for interaction with the Green Climate Fund is the Acting Executive Secretary of the Office of the Secretariat of State for the Environment and the Principal Adviser for Climate Finance and Resource Mobilisation. Timor-Leste's Secretary of State for the Environment sits under the Office of the Coordinating Minister of Economic Affairs.

The Coordinating Minister for Economic Affairs assists the Prime Minister in coordinating and supervising the members of Government responsible for implementing policies for economic governance areas, including: the Minister for Tourism, Trade and Industry; the Minister for Agriculture and Fisheries; the Secretary of State for Employment and Vocational Training; the Secretary of State for Cooperatives; and the Secretary of State for the Environment.

National Directorate for Meteorology and Geophysics (DNMG)

The Timor-Leste Meteorological Service falls under the National Directorate for Meteorology and Geophysics (DNMG), Ministry of Transport and Communication. Its mandate is to provide information on actual weather to the public, and to provide warnings to communities in any predicted extreme weather such as heavy rainfall, thunderstorm, strong wind, tropical cyclone (storm surge), and sea level rise, as well as El Niño / La Niña advice. Basic weather and climate services are provided by DNMG

[278] WMO, 2018. Multi-hazard Early Warning Systems: A Checklist

as a public good, funded from very limited public sector resources and with the assistance of the neighbouring countries of Indonesia and Australia.

The DNMG is responsible for performing the following tasks:[279]

- Preparation and implementation of national information systems and meteorological monitoring, climatology and seismology, and the national civil protection plan, in collaboration with relevant institutions;
- Ensure the provision of meteorological, climatological and seismological information to relevant public and private entities; and
- Promotion of scientific research and participation of Timor-Leste in national and international organizations in the field of meteorology, climatology and geophysics.

The DNMG is heavily dependent on support from external agencies, including: i) the Australian Bureau of Meteorology (BoM), through its main office in Melbourne and also through the regional office in Darwin, with the latter's support including forecasting advice for aviation support services and cyclone movements; ii) the Indonesian Meteorology, Climatology and Geophysical Agency (Badan Meteorologi, Klimatologi dan Geofisika – BMKG); (iii) the Thai Meteorological Department, which supports development of the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES); iv) the Centre for International Agricultural Research (CIAR), which established 22 monitoring stations in Timor-Leste for weather monitoring for agriculture and is currently supported by the European Union; and v) Conoco Phillip, which is supporting DNMG through the provision of Automatic Weather Stations (AWSs) that provide forecasting information for commercial aviation.

National Disaster Management Directorate (NDMD)

The National Disaster Management Directorate (NDMD) under the Ministry of Social Solidarity is responsible for providing disaster risk management, coordination and technical support to the Government and community in Timor-Leste. NDMD is composed of the Disaster Operation Centre (DOC), the Departments of Preparedness and Formation, Prevention and Mitigation, Response and Recovery, and disaster management committees at district, sub-district and village (*suco*) levels. It works in support of the National Disaster Coordinator (NDC) during disaster response operations.[280]

Duties and responsibilities of NDMD are:

- Act as Timor-Leste's centre for disaster risk reduction activities – collecting information, monitoring overseas developments and proposing developments for incorporation into the national disaster risk reduction system;
- Developing strategies in disaster risk reduction including preparedness and response plans and procedures and assisting in district planning;
- Administering and providing secretariat support to the inter-agency council;
- Establishing and sustaining links to risk assessment and monitoring in the region, and interpreting and providing warning and strategic planning;
- Acting as the contact point for initial reports of emergencies and disasters in conjunction with the DOC;

[279] Ministry of Transport and Communications. National Directorate of Meteorology and Geophysics. Available at: http://www.mtc.gov.tl/mtc/index.php/en/services-dir/dgmtc/national-directorate-of-meteorology-and-geophysics
[280] Government of Timor-Leste, 2019. Disaster Management Reference Handbook 2019

- Coordinating disaster risk management including scheduling of regular meetings of stakeholders;
- Organising and leading multi-sector damage and needs assessment teams during response when necessary;
- Developing and conducting public information and awareness programs in cooperation with other relevant agencies;
- Developing disaster risk reduction and emergency response training programs in conjunction with relevant partners;
- Maintaining and developing a National Disaster Risk Management Information System;
- Developing or identifying the sources of baseline data for use in disaster preparedness and response activities;
- Maintaining, reviewing and developing the National Disaster Risk Management Policy (NDRMP) and advising on other sector and development policies, strategies and legislation related to disaster risk management; and
- Administering a national regional strategic stockpile of disaster response assets.[281]

Ministry of Agriculture and Fisheries (MAF)

The Ministry of Agriculture and Fisheries (MAF) is the Government department responsible for the development of the rural sector in Timor-Leste, through the design, implementation, coordination and evaluation of policy in the areas of agriculture, forests, fisheries and livestock.

The Agriculture and Land Use Geographic Information System (ALGIS) established under MAF is responsible for collecting, monitoring, and analysing climate data relevant to agriculture activities. The data is intended to be shared with relevant government institutions such as DNMG, local and international NGOs, students, and farm field schools who work with the community.

MAF is also responsible for the management of irrigation water associated with conducting feasibility studies for irrigation schemes and water storage, and their construction; and, in coordination with the Coordinating Minister for Economic Affairs, the Ministry of Tourism, Trade and Industry, and the Ministry of Public Works, manage forest resources and catchments.

National Directorate for Climate Change (NDCC)

The National Directorate for Climate Change (NDCC), under the Secretary of State for the Environment, Ministry of Economic Affairs, provides support, facilitates funds and implements projects to provide clean water to communities vulnerable to drought, as part of the government response to drought.

In 2012, the NDCC established a working group for climate change adaptation, which brings together stakeholders from government and non-government agencies (e.g., UNDP, GIZ, Camoes, USP, World Vision, Mercy Corps, CRS, Hivos, WaterAid, Oxfam, Care International) working in the area of climate change to facilitate and exchange data and best practices, and to support the NDCC in fulfilling its mandate.[282] The Working Group on Climate Change (WG-CC) was officially validated by Ministerial Diploma No.2 (2017) with the mandate to “coordinate, engage, facilitate, support and influence

[281] Asian Disaster Preparedness Center, 2013. A Comprehensive National Risk Assessment and Mapping: Timor-Leste; A Country Situation Report on Disaster Risk Assessment-related Initiatives
[282] Timor-Leste, 2016. Timor-Leste Intended Nationally Determined Contributions (INDC)

stakeholders to achieve better outcomes for Timor-Leste and its citizens in preparation for the impacts of climate change".

Ministry of Public Works

The Timor-Leste Ministry of Public Works (MPW) is responsible for the development, construction, and maintenance of the vital infrastructure of the country. The Hydrology and Water Resource Management Divisions are departments of the Ministry of Public Works. The MPW is in the process of establishing a public institute that will propose, monitor, and ensure the implementation of a national water resources policy in order to ensure its sustainable and integrated management, as well as to ensure the supervision of the public water supply services, urban wastewater sanitation and municipal solid waste.

National Directorate for Water Resources Management

The National Directorate for Water Resources Management (DNGRA) is responsible for monitoring and research on the quality and volume of water resources to support current water supply needs and future development of the water resource. Alignment of their work program to the water supply needs of the rest of the government and the private sector is limited, under-resourced and challenged by institutional capacity. The DNGRA is primarily focused at the national level on developing law and policy and implementing monitoring programs, for hydrometeorology and seawater intrusion. The Directorate has approximately 60 staff, 45 of whom are throughout the municipalities supporting the National Hydrometeorological Monitoring Program. Water Resources staff of the Municipal Water, Sanitation Service and Environment Services (SMASA) coordinates that program for their respective municipalities.

Timor-Leste Red Cross Society (Cruz Vermelha de Timor-Leste – CVTL)

Timor-Leste Red Cross Society (Cruz Vermelha de Timor-Leste – CVTL) was legally recognized as an auxiliary to the Government in 2005. CVTL plays a key role in disaster risk management, including participating in national emergency planning and national and district-level disaster simulation exercises. Involvement of CVTL is key for the preparedness and response capacities of NDMD and District Disaster Management Committees. The International Federation of Red Cross and Red Crescent Societies (IFRC) supports CVTL through technical advice, coordination and knowledge sharing, as needed, working before, during and after disasters and health emergencies to meet the needs and improve the lives of vulnerable people

Communities

Timor-Leste's Second National Communication[283] highlights that communities are undertaking "short-term coping or adaptive strategies toward the climate change impact such as collecting water from elsewhere, consuming different food, and making sandbags to stop erosion". Longer-term approaches include "planting trees, conserving soil and water, and plans to build retaining walls by sending a proposal to the government". These strategies demonstrate the awareness of people about climate change adaptation, which requires the continuous support from government.

Local knowledge on climate change and disaster risk reduction is particularly valuable where government capabilities are limited and where long-standing customary practices of natural resource management still exist and may be harnessed to enhance effectiveness of governance processes.

[283] Timor-Leste, 2020. Second National Communication under the UNFCCC

Focus group discussions in the Laclo and Caraluan River catchments – the largest rivers in Timor-Leste in terms of catchment size, high flood-risk areas, and important areas for productive agriculture and rural livelihoods – indicate that local people have made many of the connections on the impacts and consequences of climate hazards that have been determined by scientific investigations (although they simultaneously hold 'naturalist' explanations). Communities understand that actions in upstream catchment areas affect downstream areas but lack knowledge on what they can do to ameliorate the impacts whilst maintaining their livelihoods. Downstream, people are aware that actions in the headwaters affect them and that they hope for mitigation.[284] This suggests a local demand for CIEWS, if they are aware of its value in reducing risk and providing livelihood protection.

Tara Bandu is a Timorese custom that "enforces peace and reconciliation through the power of public agreement"[285] and generally involves some aspect of reducing or preventing community conflict, protecting the environment, managing natural resources, and improving community welfare. The use of *Tara Bandu* can be traced back to pre-colonial times when local chiefs held authority in Timor. However, following invasion of Timor-Leste in 1975, the Indonesian occupiers outlawed *Tara Bandu* systems and asserted control over forest and marine resources.[286]

Since independence in 2002, *Tara Bandu* has experienced resurgence, as it is protected in Timor-Leste's Constitution and is widely considered by Timorese people as an important and legitimate means to enhance traditional culture and mutual respect within society.[287] Communities across Timor-Leste have established new *Tara Bandu* resource management regimes and traditional customs have been incorporated into legal frameworks pertaining to natural resource management and in the management of marine protected areas.[288]

Tara Bandu represents an important entry point for strengthening engagement with and involvement of local communities in resilience building efforts, such as enhancing preparedness and response capabilities.

6.1.2 – Risk knowledge

Understanding its disaster risk—the combination of hazard, exposure, and vulnerability—requires Timor-Leste to understand the social, economic, geographic and environmental patterns that drive disaster risk and exacerbate risk, such as housing, land tenure and management, poverty, gender, urbanisation patterns and demographic changes.

The Government of Timor-Leste is pursuing better risk knowledge through census and household surveys, compilation and analysis of demographic statistics, and analysis of the impacts of significant disasters.

Current status

- Are the hazards and vulnerabilities well known?
    - Some vulnerability and risk assessments have been conducted by development partners. In particular, the GCF-funded UNDP project on "Safeguarding rural communities and their physical assets from climate induced disasters in Timor-Leste" (FP109) is currently undertaking a systematic process of flood risk mapping and vulnerability assessment.

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[284] McWilliam, A. *et al.,* 2020. International Journal of Disaster Risk Reduction. Disaster Risk Reduction, modern science and local knowledge: Perspectives from Timor-Leste

[285] The Asia Foundation, 2013. *Tara Bandu*: Its Role and Use in Community Conflict Prevention in Timor-Leste

[286] Timor-Leste, 2021. Timor-Leste's National Adaptation Plan

[287] The Asia Foundation, 2013. *Tara Bandu*: Its Role and Use in Community Conflict Prevention in Timor-Leste

[288] Timor-Leste, 2021. Timor-Leste's National Adaptation Plan

- Communities hold traditional knowledge, but poverty and population pressure constrain its use and application.
  - Post-disaster analyses have been undertaken after recent droughts.
- What are the patterns and trends in these factors?
  - Trends have not been systematically recorded or analysed—there are too few functioning observation stations and data records are incomplete.
  - Regional data cannot be verified without on-ground observations.
- Are risk maps and data widely available?
  - Some suco (village) scale risk maps are publicly available.
  - Some other risk maps exist but they are not consistent or readily available.
  - Regional maps are available, but their data is not downscaled to a level that would support decision making.

There is little publicly available information on the costs of the frequent natural disasters experienced by Timor-Leste, but the known severe impact of disasters on socio-economic and environmental wellbeing could be reduced if reliable warnings were available to the affected communities and if communities knew how to respond appropriately.

The National Risk Management Policy is now in the progress of revision. The Government considers the development of policies that contain measures to prevent extreme events becoming natural disasters in order to save human lives and assets a high priority. Priorities include:

- Promote studies of the identification of risks zones;
- Create early warning systems, particularly relating to rainfall and droughts;
- Conduct training and capacity building of human resources in disaster risk management;
- Be able to provide immediate response when disaster occurs; and
- Establish inter-sectoral coordination mechanisms to respond to natural disasters.

6.1.3 – Observations and Monitoring

The World Meteorological Organization categorises the climate services provided by national meteorological services on a scale from Essential to Advanced, as shown in the figure below.

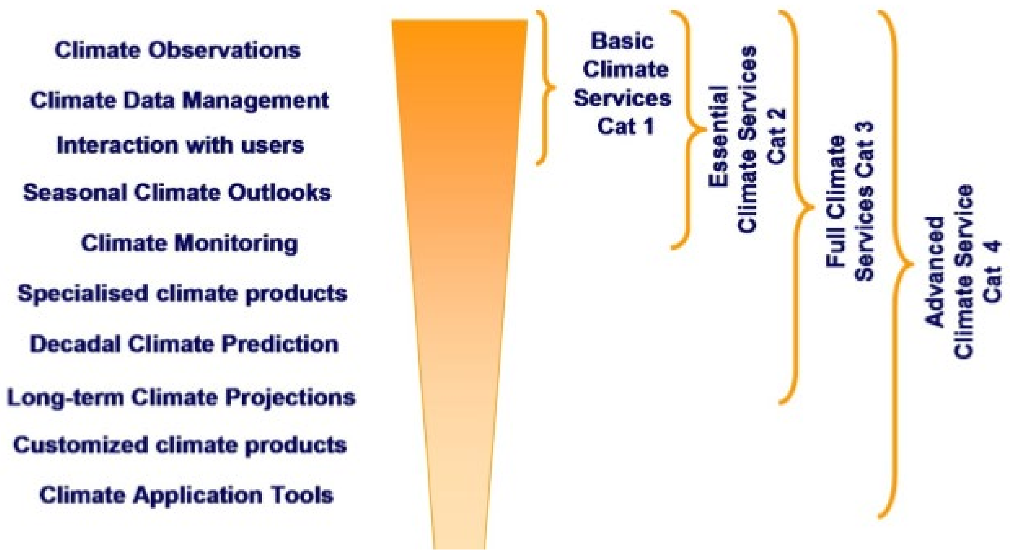

Figure 240: Types of climate products and services by category of national climate service provider (Source: WMO)

The National Directorate for Meteorology and Geophysics (DNMG) is a Category 1[289]—basic level meteorological service. It is poorly resourced – it has 23 staff, a small budget (USD 299,000 in 2019)[290] and limited equipment – and provides only basic weather services, which many communities are currently unable to access. Timor-Leste's observation network and resulting data availability is therefore rudimentary.[291]

Maintaining adequate observation networks is very challenging, both financially and physically. Whilst DNMG is responsible for collecting all the information from the country's weather stations in a database,[292] it has no ownership over the stations operated by other entities. Although satellite data can provide broad scale weather information, if verification at ground level is impossible then timely and reliable local forecasts cannot be developed.

Current status of DNMG's hydrometeorological observation network

The National Directorate for Meteorology and Geophysics (DNMG) operates the following stations:

- 1 AWOS[293] in Oecusse, installed by Vaisala in 2017;
- 2 Manual observation stations in Dili and Baucau, installed in 2011;
- 2 AWS[294] in Dili and Oecusse; and
- 6 AWS provided by UNDP in 2018 – 2019 (5 of which have been installed). These AWS do not meet the WMO observation standard as they are unable to have their data ingested into the Climate Data Management System (CDMS) at DNMG.

The manual stations were installed by DNMG in 2011. The table below shows the observational instrumentation found at each manual station.

No.	Name	Type	Quantity	Location
1	Barograph	Franz Ketterer	2	Dili, Baucau
2	Mercury barometer	Dr. Muller/R. Fuess 11a-9	1	Dili
3	Digital barometer		1	Baucau
4	Thermo-hydrograph	Franz Ketterer	2	Dili, Baucau
5	Automatic rain gauge	Hellman	2	Dili, Baucau
6	Anemometer	Model 26800/Young	2	Dili, Baucau
7	Evaporation pan		2	Dili, Baucau
8	Campbell Stokes		2	Dili, Baucau

Table 4: Manual observation instrumentation in Timor-Leste (Source: DNMG, 2011)

[289] WMO, 2015. WMO Capacity Development Strategy and Implementation Plan. Annex 5 – Categorization of National Meteorological and Hydrological Services. Available at: https://library.wmo.int/doc_num.php?explnum_id=7871
[290] Timor-Leste, 2019. State Budget 2019
[291] Reported during in-country consultations, 22-24 November 2017.
[292] UNDP, 2019. FP109: Safeguarding rural communities and their physical assets from climate induced disasters in Timor-Leste. Annex 2 – Feasibility Study
[293] An automated weather observation system (AWOS) provides continuous, real-time weather reports for pilots, airport operators and managers. It consists of sensors and systems, specially designed for aviation purposes, for collecting data from representative sites along the runway. An AWOS will contain an anemometer, a wind vane, a barometer, a thermometer, a sunshine recorder, a rain gauge, a hygrometer, a ceilometer, and a visibility meter.
[294] An automatic weather station automatically transmits or records observations obtained from its measuring instruments. Usually, a standard AWS will contain an anemometer, a wind vane, a barometer, a thermometer, a sunshine recorder, a rain gauge and a hygrometer.

The Dili Airport weather station is operated with the assistance of the Australian Bureau of Meteorology (BoM), which collects, processes and analyses the data for forecasting and for airport operational purposes. ConocoPhillips, an American multinational energy corporation, is also supporting the DNMG through the provision of AWSs, which provide forecasting information for commercial aviation.

The following table and figure provide an overview of the current hydrometeorological observation network operated by DNMG.

No.	Municipality	Lat.	Long.	Type	Status	Additional details
1	Dili (Airport)	-8.556	125.56	AWS	**Active** but requires calibration and maintenance. Not GBON compliant.	WIGOS ID: 0-200000-0-97390
2	Dili/Comoro	-8.55	125.57	Manual Station	**Active** but requires calibration and maintenance. Not GBON compliant.	WIGOS ID: 0-200000-0-97388
3	Baucau	-8.5	126.4	Manual Station	**Active** but requires calibration and maintenance. Not GBON compliant.	WIGOS ID: 0-200000-0-97395
4	Oecusse	-9.2	124.36	AWS	**Active** but requires calibration and maintenance. Not GBON compliant.	WIGOS ID: 0-200000-0-97385
5	Oecusse	-9.3	124.29	AWOS	**Active** but requires calibration and maintenance. Not GBON compliant.	Installed by Vaisala in 2017
6	Dare	-8.592	125.58	AWS	**Active** but requires calibration and maintenance. Not GBON compliant nor ingesting into the CDMS.	Installed by UNDP in 2018/2019
7	Madabeno	-8.64	125.572	AWS	**Active** but requires calibration and maintenance. Not GBON compliant nor ingesting into the CDMS.	Installed by UNDP in 2018/2019
8	Aituto	-8.901	125.592	AWS	**Active** but requires calibration and maintenance. Not GBON compliant nor ingesting into the CDMS.	Installed by UNDP in 2018/2019
9	Vila	-8.996	125.505	AWS	**Active** but requires calibration and maintenance. Not GBON compliant nor ingesting into the CDMS.	Installed by UNDP in 2018/2019
10	Cassa	-9.134	125.544	AWS	**Active** but requires calibration and maintenance. Not GBON compliant nor ingesting into the CDMS.	Installed by UNDP in 2018/2019
11	Liurai	-	-	AWS	**Inactive**	Provided by UNDP in 2018/2019 but not installed

Table 5: DNMG observational network documented in 2021 (Source: DNMG)

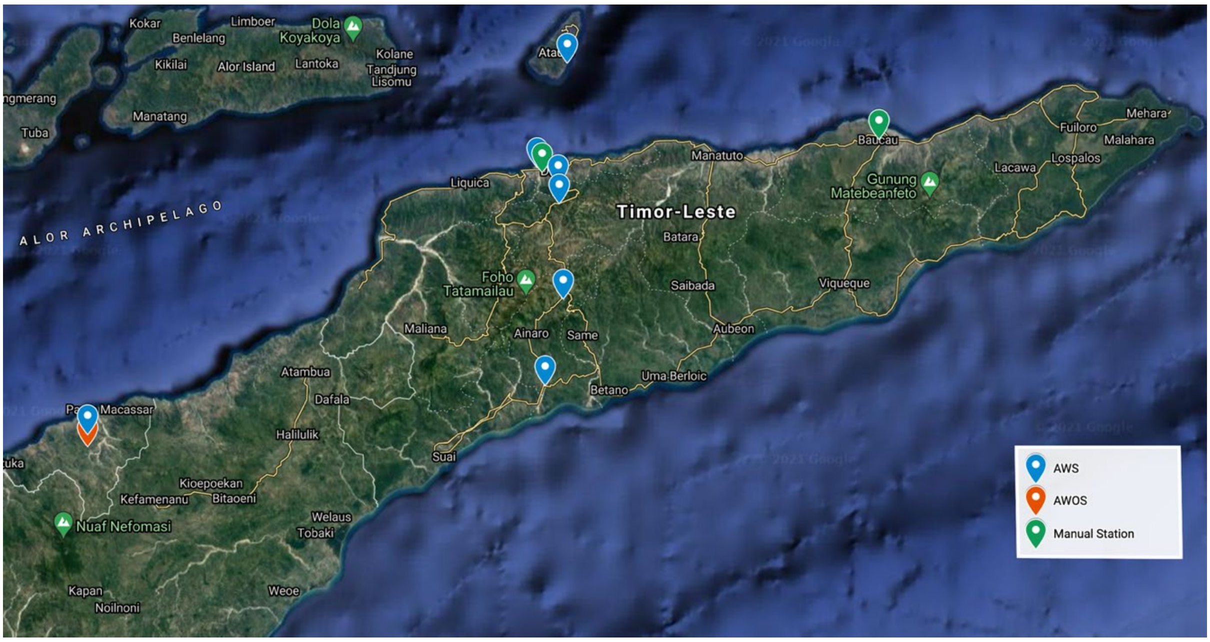

Figure 241: Current DNMG observational network in Timor-Leste

All of the installed stations are active but require calibration and maintenance. None are compliant with the WMO Global Basic Observing Network (GBON) draft technical requirements:[295]

- For surface land-based observations, weather stations are used. These are typically Automatic Weather Stations that measure basic surface variables such as atmospheric pressure, temperature and humidity, and where applicable snow cover.
- Members must operate surface land observing stations measuring atmospheric pressure, air temperature, humidity, horizontal wind, precipitation and snow depth, at a horizontal resolution of 200 km or better, and data must be reported hourly.
- Members with networks operating at higher horizontal resolution must report their observations either at the full resolution of the network or at a minimum resolution of 100 km, whichever is larger.

The GBON draft technical requirements will be submitted to the World Meteorological Congress in 2021 for its approval.

In addition to the stations documented above, and as indicated in the Seeds of Life map (See section below on "Observational network documented in 2014"), the hydrometeorological network consists predominantly of agrometeorological stations (58 manual weather stations providing information related to rainfall[296]) operated by the Agriculture and Land-use Geographic Information System (ALGIS) within the Ministry of Agriculture and Fisheries (MAF) and various development partners, and rain gauges operated by the National Directorate for Water Resources Management (DNGRA). The features of these stations and their condition vary widely. The recent severe flooding in April 2021 has

[295] WMO, 2020. The gaps in the Global Basic Observing Network (GBON)
[296] Timor-Leste, 2020. Second National Communication under the UNFCCC

caused significant damage to infrastructure in Timor-Leste,[297] which is likely to have also impacted on the hydrometeorological observation network.

Human resources and technical capacity at DNMG

The National Directorate for Meteorology and Geophysics (DNMG) is responsible for meteorological observations and monitoring. The DNMG has a total of 23 staff. The staffing roles are summarised below:

- 2 Meteorologists: 1 person with MSc (Atmospheric Science), and 1 person with a degree in meteorology, who is due to retire soon;
- 3 Weather Forecasters: degrees in Physics, Science, Accounting and Information;
- 3 climate staff: Telecommunications and Information degrees;
- 1 in IT Section with a Bachelor's degree in Information Technology;
- 8 meteorological observers; and
- Remaining staff are in administration and finance.

The eight staff who support the observational network are all high school graduates, with six located in Dili, one in Baucau and one in Oecusse. There is only one staff member in IT, who is responsible (under guidance from the Director) for working with external contractors to maintain DNMG's systems and equipment. The Climate Section of DNMG consists of a small team providing basic services that largely consists of archiving historical data.

The current network of 2 manual stations, 1 AWOS and 7 AWS is not maintained by DNMG staff as they do not have the required training to undertake this work. The Government of Timor-Leste has been undertaking procurement processes to maintain the current network. However, this process is often quite lengthy and very expensive.

Due to the procurement rules for both the Government and appropriate suppliers such as the Australian Bureau of Meteorology or the Indonesia Weather Bureau (BMKG), it is not possible for the Government to directly hire expert technicians straight from international weather agencies. Instead, the Government must go through a local supplier (i.e., El Nusa, Simile, Catalpa etc.) who then in turn hires the international technicians to provide support for the DNMG network.

Current status of hydrological monitoring

The National Directorate for Water Resource Management (DNGRA) operates 14 water level monitoring stations across Timor-Leste. The data is collected but not analysed.[298] In addition, the National Hydropower Master Plan project supported by the Government of Norway established the National Hydrometeorological Monitoring Program consisting of 35 rainfall stations and six river height monitoring stations, which have been collecting data daily from 2009 to the present. In 2012, with support from the Community Water Supply, Sanitation and Hygiene Program (Be'e Saneamentu no Ijiene iha Komunidade – BESIK) four seawater intrusion monitoring boreholes were established in the Dili Aquifer to record groundwater depth and water quality on an hourly basis. However, there is no public reporting of the data or internal analysis to inform management actions or decision-making

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[297] UN RCO Timor-Leste, 2021. Timor-Leste: Floods. Situation Report No. 6 (As of 21 April 2021) https://reliefweb.int/sites/reliefweb.int/files/resources/TL%20April%20Flood%20Response%20Situation%20Report%206%20%2821%20Apr%2021%29%20%28final%29.pdf

[298] DNMG, 2017. First Steering Committee Meeting SAOFFG System. Timor-Leste Country Report. Available at: https://www.wmo.int/pages/prog/hwrp/flood/ffgs/saoffg/presentations/scm1/Countries/TimorLeste.pdf

in either of these programs.[299] The recent severe flooding in April 2021 has caused significant damage to infrastructure in Timor-Leste, with a third of the capital Dili's water systems out.[300] The flooding is also likely to have compromised hydrological observations infrastructure.

Current status of groundwater monitoring

With support from the Government of Australia, the National Hydrogeology Framework was developed. It outlines a method to collect data and categorise, map and monitor groundwater resources and is a useful tool for groundwater managers.

The 'Hydrogeological Map of Timor-Leste' (see below) has also been developed. It is the first map which allows aquifer types to be consistently identified across the country. Three main aquifer types were identified:

- Sedimentary porous rock aquifers with intergranular porosity associated with river valleys and coastal lowlands
- Fissured aquifers of karst formations within limestone rocks
- Rocks with localised flow comprised of fractured rocks and clay sediments

The Hydrogeological Map also displays the type, potential aquifer yield and lithology of aquifers across Timor-Leste. The combination of aquifer type with potential yield is valuable for prospectivity, indicating where usable groundwater resources are likely to occur.

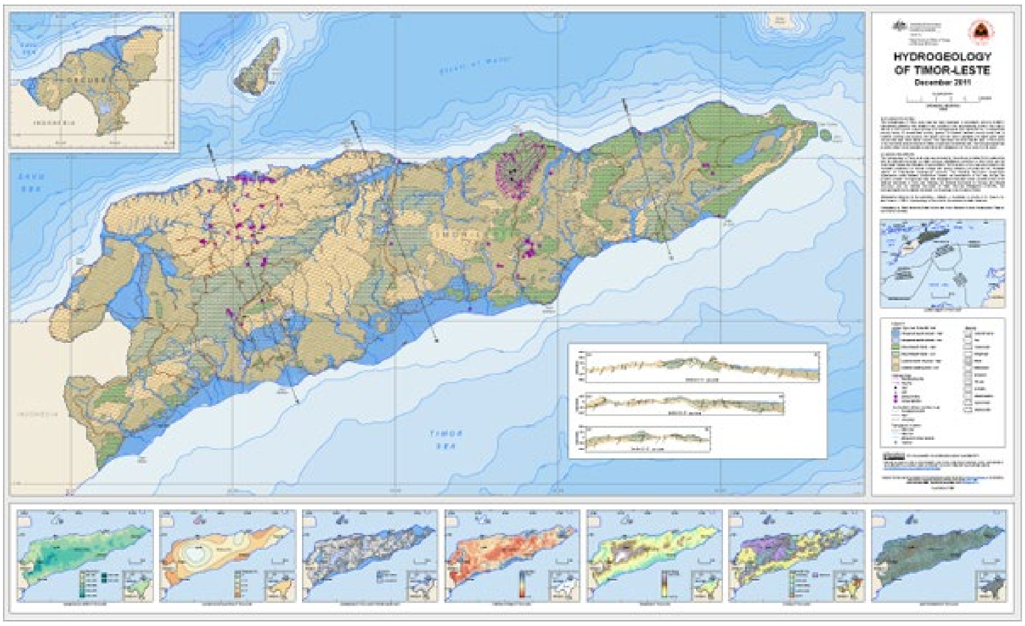

Figure 242: Timor-Leste Hydrogeological Map (Source: Geoscience Australia)

A vulnerability assessment of climate change impacts on groundwater has also been undertaken[301] that indicates the two principal climate change hazards with the potential to impact on groundwater: 1) changes in rainfall; and 2) sea-level rise. While little change is predicted for total annual rainfall, the predicted prolonged dry season will place additional pressure on groundwater resources by extending the period of groundwater stress. The estimated sea level rise of 9 mm per

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[299] World Bank, 2018. Timor-Leste Water Sector Assessment and Roadmap
[300] Oxfam, 2021. Timor-Leste's most destructive floods in recent memory worsened by climate change. Available at: https://www.oxfam.org/en/press-releases/timor-lestes-most-destructive-floods-recent-memory-likely-worsened-climate-change
[301] Wallace, L. *et al.*, 2012. Vulnerability assessment of climate change impacts on groundwater resources in Timor-Leste. Prepared for the Australian Government Department of Climate Change and Energy Efficiency

year is much greater than the average tectonic rise of Timor of 0.5 mm per year. Increases in the sea level are likely to cause seawater to move landward and intrude into aquifers. The vulnerability of the three aquifer types against these two principal climate change hazards is shown in the figure below.

Overall Aquifer Vulnerability

Aquifer Type	Vulnerability to Rainfall Changes	Vulnerability to Sea Level Rise
Intergranular (Large Catchments) Intergranular (Small Catchments)	Medium (PI = H, AC = H) High (PI = H, AC = L)	Medium (PI = H, AC = H) High (PI = H, AC = L)
Fissured (Topographic High) Fissured (Topographic Low)	High (PI = H, AC = L) Medium (PI = M, AC = M)	Low (PI = L, AC = M) Medium (PI = L, AC = L)
Localised (Topographic High) Localised (Topographic Low)	High (PI = H, AC =L) Medium (PI = M, AC = M)	Low (PI = L, AC = M) Medium (PI = L, AC = L)

Vulnerability Classes: High = higher potential impact + lower adaptive capacity; Medium = comparable potential impact and adaptive capacity; Low = lower potential impact + higher adaptive capacity. PI – Potential Impact; AC – Adaptive Capacity.

Figure 243: Aquifer vulnerability in Timor-Leste (Source: Australian Government Department of Climate Change and Energy Efficiency)

Current status of ocean observations

Local ocean data is not currently collected and what information exists is derived from low resolution satellite sources, unverified by sea surface observations. Given that there is no tide gauge data available for Timor-Leste, the Wyndham (Western Australia, since 1984) record is used as the closest available gauge. Long-term locally monitored sea-surface temperature data are also unavailable.[302]

Observational network documented in 2014

In 2014, the “Seeds of Life” project provided information on weather stations in Timor-Leste. As can be seen in the figure below, only two manual stations (at Dili and Baucau Airport) are attributed to DNMG. The remaining mix of 80 weather stations and rain gauges were managed by the Ministry of Agriculture or their partners or the Directorate of Water Quality and Control (now the National Directorate of Water Resources Management – DNGRA).

The Seeds of Life project activities ceased at the end of June 2016. In the following years, several of the documented stations have become defunct. Without ongoing funding, it is unclear how many of the documented stations are still in operation; but none appear to be reporting data to WMO.

A list of latitude, longitude and elevation values are provided for each weather station and rain gauge. All CIMEL and Hobo type weather stations are automatic weather stations. GSM and Satellite refers to the ability to transmit data to the internet with daily updates. Data may be requested by contacting the relevant departments.

[302] CSIRO. 2010. Climate change in Timor-Leste – a brief overview on future climate projections. Available at: http://www.cdu.edu.au/itl/documents/East-Timor-review-for%20submission%20to%20DCCEE.pdf

ID	Latitude	Longitude	Elevation	Location	District	Operator	Type
1	-8.54808	125.52766	11	Dili Airport	Dili	DNMG	Manual
2	-8.47895	126.39900	525	Baucau Airport	Baucau	DNMG	Manual
3	-8.71917	125.57167	900	Aileu	Aileu	ALGIS	CIMEL 405
4	-8.83170	125.59810	1500	Maubisse	Ainaro	ALGIS	CIMEL 405
5	-8.99889	125.50361	812	Ainaro	Ainaro	ALGIS	CIMEL 420
6	-8.57940	126.38661	612	Fatumaca	Baucau	ALGIS	CIMEL 420
7	-8.92250	125.18140	135	Maliana	Bobonaro	ALGIS	CIMEL 420
8	-9.31860	125.26000	22	Suai	Covalima	ALGIS	CIMEL 420
9	-8.59110	125.56890	460	Dare	Dili	ALGIS	CIMEL 405
10	-8.74940	125.40000	1165	Ermera	Ermera	ALGIS	CIMEL 420
11	-8.45190	127.01400	375	Fuiloro	Lautem	ALGIS	CIMEL 420
12	-8.53190	126.00530	25	Manatuto	Manatuto	ALGIS	CIMEL 420
13	-9.16660	125.71660	30	Betano	Manufahi	ALGIS	CIMEL 405
14	-8.53836	125.68453	982	Hera	Dili	ALGIS	Manual
15	-8.72340	125.43432	982	Gleno	Emera	ALGIS	Manual
16	-8.92495	125.39885	1165	Atsabe	Emera	ALGIS	Manual
17	-8.58697	125.34950	52	Liquica	Liquica	ALGIS	Manual
18	-8.98912	126.06158	69	Natarbora	Manatuto	ALGIS	Manual
19	-8.61661	125.63850	975	Acumau	Aileu	SoL	Hobo Micro
20	-8.70451	125.56480	980	Quintal Portugal	Aileu	SoL	Hobo Standard
21	-8.73364	125.56070	925	Seloi Malere	Aileu	SoL	Hobo Micro
22	-8.83692	125.61240	1316	Urulefa	Ainaro	SoL	Hobo Standard
23	-8.89135	125.59658	1667	Aituto	Ainaro	SoL	Hobo Micro
24	-8.90146	125.52087	2203	Hatobuilico	Ainaro	SoL	Hobo GSM
25	-8.53510	126.34650	690	Darasula	Baucau	SoL	Hobo Standard
26	-8.64255	126.37929	836	Venilale	Baucau	SoL	Hobo Micro
27	-8.63033	126.66427	309	Baguia	Baucau	SoL	Hobo GSM
28	-8.94717	125.20537	163	Ritabou	Bobonaro	SoL	Hobo Micro
29	-8.96925	125.04325	551	Balibo	Bobonaro	SoL	Hobo Micro
30	-9.28451	125.09632	688	Fohorem	Covalima	SoL	Hobo GSM
31	-8.26482	125.60496	6	Maumeta	Dili	SoL	Hobo Satellite
32	-8.49582	127.02705	358	Fuiloro	Lautem	SoL	Hobo Micro
33	-8.54236	126.83355	409	Luro	Lautem	SoL	Hobo Micro
34	-8.67051	125.32979	919	Fazenda Algarve	Liquica	SoL	Hobo Micro
35	-8.73720	125.13956	22	Loes	Liquica	SoL	Hobo Standard
36	-8.74928	125.90888	1005	Laklubar	Manatuto	SoL	Hobo GSM
37	-9.00091	125.65174	550	Same	Manufahi	SoL	Hobo Micro
38	-9.02642	125.92083	101	Dotik	Manufahi	SoL	Hobo Micro
39	-9.16303	125.71850	9	Betano	Manufahi	SoL	Hobo Standard
40	-9.20623	124.37433	29	Pante Macassar	Oecussi	SoL	Hobo Satellite

41	-8.74562	126.38180	648	Ossu	Viqueque	SoL	Hobo Micro
42	-8.86711	126.36533	51	Viqueque	Viqueque	SoL	Hobo Micro
43	-8.61269	126.29880	88	Vemase	Baucau	JMP	Hobo GSM
44	-8.47092	126.50960	10	Seical	Baucau	JMP	Hobo GSM
45	-8.67554	125.99143	135	Cribas	Manatuto	JMP	Hobo GSM
46	-9.01090	126.00900	21	Sahen	Manufahi	JMP	Hobo GSM
47	-9.09777	125.70060	32	Caraulun	Manufahi	JMP	Hobo GSM
48	-8.74878	126.70591	6	Irabere	Viqueque	JMP	Hobo GSM
49	-8.61583	125.66694	874	Remexio	Aileu	DNCQA	Rain gauge
50	-8.65314	125.63892	1243	Liquidoe	Aileu	DNCQA	Rain gauge
51	-8.87833	125.61528	2015	Flexa	Ainaro	DNCQA	Rain gauge
52	-8.59356	126.20353	82	Waigae	Baucau	DNCQA	Rain gauge
53	-8.56028	126.41556	490	Darasula	Baucau	DNCQA	Rain gauge
54	-8.57472	126.43722	262	Gariuai	Baucau	DNCQA	Rain gauge
55	-8.60278	126.55944	635	Quelicai	Baucau	DNCQA	Rain gauge
56	-8.62833	126.65278	461	Baguia	Baucau	DNCQA	Rain gauge
57	-9.03583	125.32444	794	Bobonaro	Bobonaro	DNCQA	Rain gauge
58	-9.17813	125.26616	850	Lolotoe	Bobonaro	DNCQA	Rain gauge
59	-9.18298	125.05334	208	Baer	Covalima	DNCQA	Rain gauge
60	-9.15899	125.44964	90	Zumalai	Covalima	DNCQA	Rain gauge
61	-8.55833	125.57194	15	Dili EDTL	Dili	DNCQA	Rain gauge
62	-8.26305	125.60107	10	Atauro	Dili	DNCQA	Rain gauge
63	-8.64487	125.43849	777	Railaco	Ermera	DNCQA	Rain gauge
64	-8.75288	125.32426	1087	Fatubessi	Ermera	DNCQA	Rain gauge
65	-8.83361	125.42500	1045	Lete Foho	Ermera	DNCQA	Rain gauge
66	-8.54178	126.83332	403	Luro	Lautem	DNCQA	Rain gauge
67	-8.70990	126.82800	388	Iliomar	Lautem	DNCQA	Rain gauge
68	-8.52056	127.00472	375	Los Palos	Lautem	DNCQA	Rain gauge
69	-8.64368	127.01516	66	Lore	Lautem	DNCQA	Rain gauge
70	-8.47343	127.14074	353	Moshes	Lautem	DNCQA	Rain gauge
71	-8.39139	127.25694	355	Tutuala	Lautem	DNCQA	Rain gauge
72	-8.61361	125.20583	32	Maubara	Liquica	DNCQA	Rain gauge
73	-8.66448	125.33163	1019	Fazenda	Liquica	DNCQA	Rain gauge
74	-8.55583	125.90833	175	Laclo	Manatuto	DNCQA	Rain gauge
75	-8.74917	125.90889	1100	Laclubar	Manatuto	DNCQA	Rain gauge
76	-8.86000	125.93889	680	Soibada	Manatuto	DNCQA	Rain gauge
77	-8.82250	125.70528	1179	Turiscai	Manufahi	DNCQA	Rain gauge
78	-9.27801	124.41099	177	Noe-Heno	Oecussi	DNCQA	Rain gauge
79	-9.35212	124.38418	474	Oesilo	Oecussi	DNCQA	Rain gauge
80	-8.83778	126.21111	108	Lacluta	Viqueque	DNCQA	Rain gauge
81	-8.74472	126.38444	660	Ossu	Viqueque	DNCQA	Rain gauge
82	-8.81100	126.56800	6	Bebui	Viqueque	DNCQA	Rain gauge

Figure 244: List of latitude, longitude and elevation values for weather stations and rain gauges in Timor-Leste in 2014. (Source: Seeds of Life, 2014)

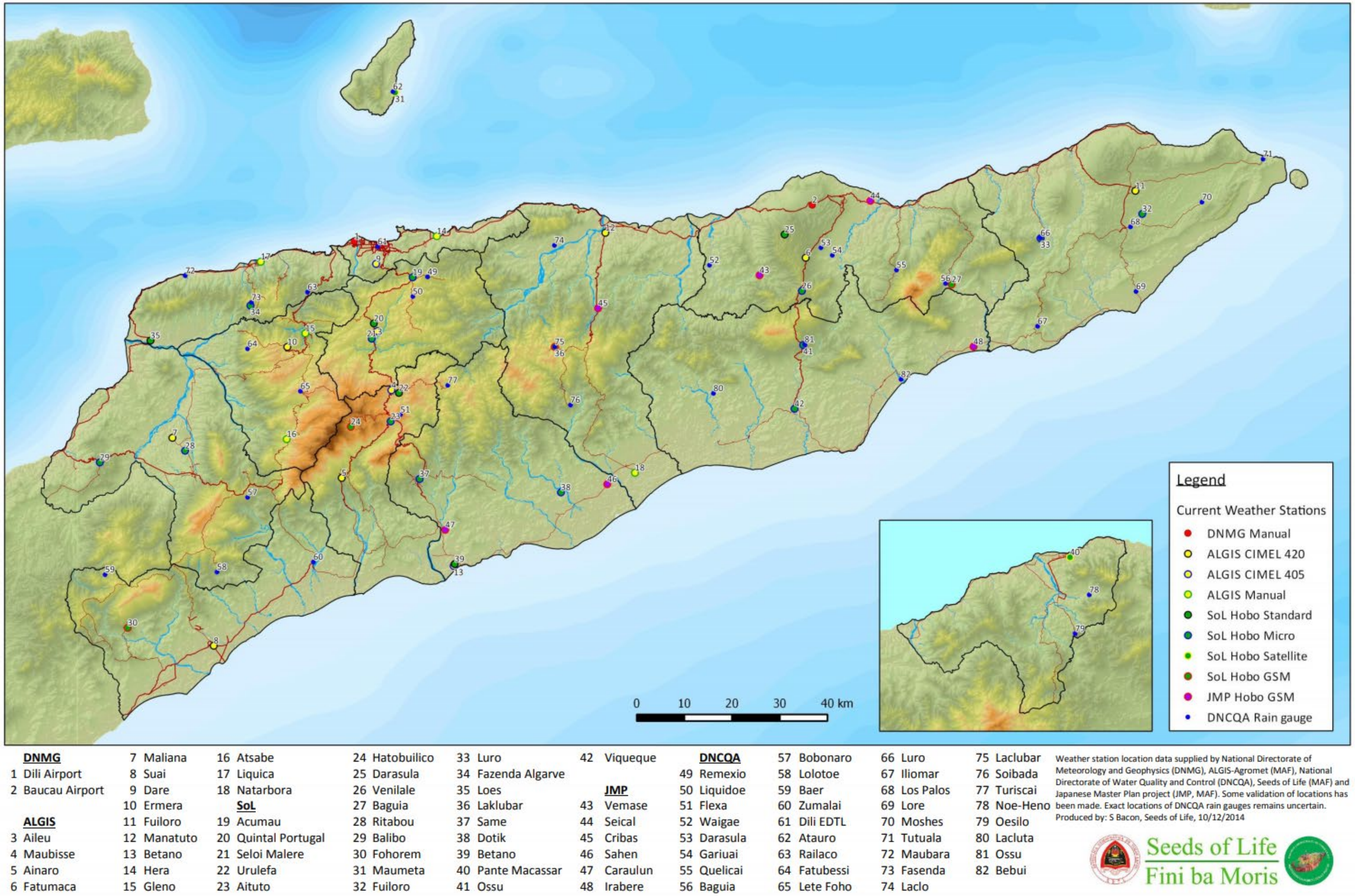

Figure 245: 2014 list of weather stations in Timor-Leste (Source: Seeds of Life)

6.1.4 – Modelling and Prediction

There is no overall forecasting or modelling system in place in Timor-Leste. The National Directorate for Meteorology and Geophysics (DNMG) does not have capacity to undertake weather and climate modelling or prediction. There is also no capacity to undertake hydrological or hydraulic forecasting.

Since 1999, the Regional Specialised Meteorological Centre (RSMC) in Darwin, Australia, has provided direct assistance to Timor-Leste through the provision of daily forecasts for the capital Dili and for the Dili aerodrome. A range of services for Timor-Leste's defence forces is also provided, as well as formal arrangements with regard to tropical cyclone warnings (see Section 6.1.5 below).[303] As such, whilst Timor-Leste does not have in-country capacity to analyse weather and climate processes, there is some provision to forecast both rapid and slow-onset hydrometeorological hazards in time for early warnings to be issued for the small number of locations with good historical data records.

The Centre for Climate Change and Biodiversity (CCCB) in the Faculty of Agriculture at the National University of Timor-Leste (UNTL) provides some climate change-related training to relevant ministries, such as crop modelling by using the Decision Support System for Agrotechnology (DSSAT). The CCCB does not have access to advanced climate change models, such as the Climate Model Intercomparison Project 5 (CMIP5).

The GEF-funded UNDP project "Strengthening Community Resilience to Climate-induced Disasters in the Dili to Ainaro Road Development Corridor, Timor-Leste (DARDC)" (2014 – 2018) proposed to establish a flood early warning system in the upper river in Aileu. This included six Automatic Weather Stations (AWS). As of May 2019, establishment of landslide monitoring in two places was ongoing. Similarly, of the two water monitoring stations, one was completed, and the establishment of the other was still ongoing. The Terminal Evaluation (TE) consultants for the project reported that the AWS stopped functioning after three months of operation and no initiation was taken to repair them until the issues were raised by the TE consultants with the project Director. The equipment has a warranty of two years.[304] As such, the flood early warning system is expected not to be operational.

6.1.5 – Multi-hazard early warnings

Timor-Leste has a reasonably well-established early warning system (EWS) for tsunami and earthquakes due to linkages to existing systems in the region, but this risk is low on the hazard map.

Cyclone tracking and early warning information is available from the Australian Bureau of Meteorology (BoM) and other international bodies calculating the frequencies of cyclonic events. BoM issues a Special Advisory for Timor-Leste, which provides guidance to the Government of Timor-Leste – including their emergency management organisations, and to the Australian agencies operating in Timor-Leste. The special advisory is issued whenever there is a significant risk of a tropical cyclone producing gale force winds over Timor-Leste, within 36 hours, or when a tropical low is forecast to produce significant weather impact within 36 hours. The advisories are issued at 6-hourly intervals.[305]

For hydrological-related disasters (floods, landslides, etc.) there is no remote sensing data, no useable weather data and no linkage with satellite-based systems.[306]

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[303] Australian BoM, 2013. Australian Bureau of Meteorology involvement with humanitarian agencies and projects. Available at: https://slideplayer.com/slide/751095/

[304] Rijal, A.R. and Bali, B., 2019. Strengthening Community Resilience to Climate-induced Disasters in the Dili to Ainaro Road Development Corridor, Timor-Leste (DARDC). Terminal Evaluation Report

[305] Commonwealth of Australia, 2020. Australian Bureau of Meteorology Tropical Cyclone Service Level Specification. Available at: http://www.bom.gov.au/cyclone/tropical-cyclone-knowledge-centre/warnings/2020-21_Tropical_Cyclone_Service_Level_Specification.pdf

[306] International Organization for Migration, 2010. Early Warning System for Disaster Risk Management for Timor-Leste

Overall, there is no systematic and established EWS for hydrometeorological hazards in Timor-Leste and disaster risk management is fragmented.

The National Disaster Management Directorate (NDMD) has established a hydrometeorological hazard warning and action matrix. However, the question of who will respond to alerts, relay messages, and prioritise response actions remains an issue in many districts. It has been noted that "locations that have received NGO or global financial and technical support are more likely to have stronger EWS protocols".[307]

	A. Floods	B. Landslide	C. Strong Winds
1. Warning	Floods are likely in your area. Wait for further information	Landslides are likely in your area. Wait for further information	Strong winds are likely in your area. Wait for further information
2. Prepare	Prepare to evacuate your area. Wait for further information.	Prepare to evacuate your area. Wait for further information.	Prepare to evacuate your area. Wait for further information.
3. Act	Evacuate to higher ground or evacuation centre now.	Evacuate to higher ground or evacuation centre now.	Evacuate to evacuation centre now.
4. Recover/ return	It is safe to return to your home Listen for further information	It is safe to return to your home Listen for further information	It is safe to return to your home Listen for further information

Figure 246: Hydrometeorological hazard warning and action matrix (Source: Timor-Leste NDMD)

While informal coordination around early warning takes place and there is a Government EWS working group, coherent approaches and understanding about EWS are lacking in Timor-Leste, particularly amongst disaster risk reduction agencies working in community-based disaster risk reduction. These include UN agencies (such as FAO and IOM), international NGOs (including Mercy Corps, CARE, Oxfam, PLAN, World Vision, Caritas, and Child Fund), and local organisations (CVTL,[308] RHTO,[309] ASRRD,[310] Fraterna[311] and others).

In the absence of a functional end-to-end early warning system in Timor-Leste, many organisations have conducted basic early warning work at community level. Without access to useable data or an authoritative source of weather and climate advice and warnings, this work has been ad hoc and informal, and agencies have not been able to coordinate their activities or integrate them into a broader national system.

[307] Timor-Leste, 2019. Disaster Management Reference Handbook
[308] Cruz Vermelha de Timor-Leste: Red Cross
[309] Ra'es Hadomi Timor Oan: the Disabled People's Organisation
[310] Asosiasaun Serbisu Redusaun Risku Dezaster: Association for Disaster Risk Reduction
[311] Fraterna: local environmental / disaster response NGO

Outcome of stakeholder consultations

At the *suco* level, stakeholder consultations[312] reported the following:

- Apart from the traditional early warning practice drills, there is no early flood warning plan for the community. Using traditional knowledge, men monitor water level rise on riverbanks and initiate warning messages to every household.
- There is no siren, no bells or whistles used for flood warning. Disseminating the message alone does not fully protect the community. The men in the village have also constructed stone walls to divert the water from the village. This practice saves lives, but it does not save their animals, which are their valuable possessions both economically and traditionally.
- The community advises that early warnings for flooding would be most useful a day or two days ahead so that they can have sufficient time to save their animals.

Legal provision with respect to Standing Orders on Disasters (SOD)

In the absence of a Disaster Risk Management (DRM) Law, the 2008 National Disaster Risk Management Policy, which is under revision, serves as the legal and policy framework for DRM in general and climate information and EWS in particular in Timor-Leste.

The current National DRM Policy includes provisions of an SOD. For example:

- The second of the Policy's 4 objectives is to "Develop and maintain early warning systems, monitoring, coordination, and operational preparation plans…";
- Policy 2 of the NDRM Policy provides clear policy and guidance for Regional EWS, Monitoring and Analysis including sources of information for forecast and EW, most of which is available outside Timor-Leste;
- Policy 3 provides guidance on disaster reporting and communication to communities including roles and responsibilities of concerned agencies such as the NDMD, its National Disaster Operation Centre (NDOC), local authorities, mass media, and others;
- Policy 4 on Principles and Responsibilities for effective EWS clearly identifies problems related to EWS emphasizes the importance of ensuring vulnerable population's awareness of hazards and the role of Government to "issue hazard warnings for its national territory in a timely and effective manner".

The 2019 Disaster Management Reference Handbook (updated from 2016 version) further articulates these policies, guidance and roles and responsibilities. For example:

- Expanding from the NDRM Policy, the Handbook provides more comprehensive sources of forecast and early warning information that can be used for climate services and EWS in Timor-Leste (pages 44 – 48).

The Handbook also expands on specific roles and responsibilities of key Government institutions including:

- the Inter-Ministerial Commission for Disaster Risk Management (CIGD), which is comprised of the Vice-Prime Minister (National Coordinator) and representatives of concerned Ministries;

[312] Annex 7 (Summary of Consultations and Stakeholder Engagement Plan) and Annex 8 (Gender Assessment and Gender Action Plan)

- the NDMD and its NDOC, Departments of Preparedness and Formation, Prevention and Mitigation, Response and Recovery;
- the Crisis Management Centre (CIGC); and
- Disaster Management Committees at Districts, Sub-district, and village/suco levels.

Roles and responsibilities for specific hazard early warnings and information sharing (such as flood and storm) are also further specified for:

- the NDMC
- National Directorate of Meteorology and Geophysics (DNMG)
- Joint Australia Tsunami Warning Centre (Bureau of Meteorology)

The DRM Handbook is also more explicit about the link of DRM with climate change and the National Adaptation Action Plan (NAPA). Subsequently, drought has been emphasised as a key risk in Timor-Leste.

6.1.6 – Dissemination and communication

Timor-Leste has limited channels and means for disseminating and communicating weather and climate information, and early warnings. Early warning systems (EWS) and other emergency communications have been codified into policy at the national level, but implementation is uneven at municipality/district and *suco* (village) level. Lack of budget, limitations in the communications network, transportation difficulties and shortages in human resources have all contributed to slowing the roll-out of EWS and emergency communications. [313]

Communication channels and infrastructure

Public radio covers nearly the entire territory, with three stations having nationwide coverage. Around 18 community stations also operate, often with funding from international agencies and NGOs. Public television is available but has smaller coverage. There are three nationwide stations with satellite coverage; two with terrestrial coverage, mostly in Dili; and two cable stations.[314, 315]

Fixed-line and fixed broadband penetration in Timor-Leste is extremely low, mainly on account of limited fixed-line infrastructure and the expansion of mobile connectivity. In 2018, the Government of Timor-Leste contracted Timor Telecom to construct a national terrestrial fibre network, in efforts to enhance e-government services. The project was completed in 2019 and has contributed to an increase in the number of fixed broadband subscribers. This number is expected to develop steadily through to 2026, although market penetration is expected to remain very low compared to other nations.[316]

The country has experienced rapid growth in mobile broadband penetration in the past few years, in which the rising proportion of mobile subscribers having smartphones has been the key driver. Very

[313] Timor-Leste, 2019.
[314] BBC, 2018. East Timor profile – media. Available at: https://www.bbc.co.uk/news/world-asia-pacific-14952882
[315] CIA, 2021. The World Factbook. Broadcast Media. Available at: https://www.cia.gov/the-world-factbook/field/broadcast-media/
[316] Research and Markets, 2021. Timor-Leste (East Timor) – Telecoms, Mobile and Broadband – Statistics and Analyses. Available at: https://www.researchandmarkets.com/reports/4051018/timor-leste-east-timor-telecoms-mobile-and?utm_source=BW&utm_medium=PressRelease&utm_code=r5pcfw&utm_campaign=1263225+-+Timor+Leste+(East+Timor)+Telecoms%2c+Mobile+and+Broadband+Statistics+and+Analyses+2019&utm_exec=chdo54prd

strong growth in the mobile broadband market is predicted to 2023.[317] The percentage of the population covered by at least a 3G mobile network is high at 97 percent.[318] In January 2021, around 45 percent of the population in Timor-Leste were internet users.[319] Whilst significant progress has been made in improving mobile broadband access in Timor-Leste, affordability remains a challenge[320] and mobile charging capabilities (information on which is unavailable) cannot be assumed.

Outcome of stakeholder consultations

At the *suco* level, stakeholder consultations[321] elucidated the following:

- Information is mostly based on local knowledge.
- Rural communities do not understand the function of an EWS.
- There is no early warning system for floods in villages. Current weather information is received through TV for those who have access to television. Radios are preferable to TV because they are cheaper, but the quality of radios is not good, and the repair of radios can be costly for villagers.
- Women think that radios are good, but it is best if the message is relayed through the suco and through a person–person contact.
- The women's groups in the community do church activities and community work but their groups have no role in dissemination of weather-related warnings to their members.
- Few men, women and youths have access to mobile phones. Some households have access to TV and radios and very few read the newspapers. Most preferred media for men is radio; for women TV; and for youth mobile phone. Although mobile phones are good communication devices, they are expensive to own.
- No training has been provided to the community on early warning systems or disaster risk reduction. They have no access to services at the municipality level including early warning systems.

Reaching people at the "last mile" is often the most intractable obstacle to effective delivery of early warnings that give timely, authoritative, understandable warnings with appropriate advice on actions. Civil society organisations including Timor-Leste Red Cross (Cruz Vermelha de Timor-Leste – CVTL), churches and development NGOs are translating scientific information for their local communities and providing practical advice. There is scope to build on these existing communication channels.

6.1.7 – Preparedness and response

Disaster risk management efforts are generally limited to responding as there is no overall systematic process for disaster management that ranges from preparedness and mitigation to rehabilitation and reconstruction.[322] Local communities across Timor-Leste have limited resources that can be set aside

[317] Research and Markets, 2021. Timor-Leste (East Timor) – Telecoms, Mobile and Broadband – Statistics and Analyses. Available at: https://www.researchandmarkets.com/reports/4051018/timor-leste-east-timor-telecoms-mobile-and?utm_source=BW&utm_medium=PressRelease&utm_code=r5pcfw&utm_campaign=1263225+-+Timor+Leste+(East+Timor)+Telecoms%2c+Mobile+and+Broadband+Statistics+and+Analyses+2019&utm_exec=chdo54prd
[318] UNESCAP, 2019. Asia-Pacific Information Superhighway (AP-IS) Working Paper Series. Regulatory Policies and ICT Trends: Insights from Timor-Leste
[319] Kepios, 2021. Digital 2021: Timor-Leste. Available at: https://datareportal.com/reports/digital-2021-timor-leste
[320] Timor-Leste, 2019. Disaster Management Reference Handbook
[321] Annex 7 (Summary of Consultations and Stakeholder Engagement Plan) and Annex 8 (Gender Assessment and Gender Action Plan)
[322] Timor-Leste, 2019. Disaster Management Reference Handbook

to mitigate risks and provide livelihood protection. Hence, capacity to effect DRR remains highly constrained. [323] Timor-Leste relies heavily on international agencies to support disaster risk management, and to participate in disaster response.

The National Disaster Management Directorate (NDMD) is responsible for providing disaster risk management, coordination and technical support to the Government and community in Timor-Leste. Amongst others, it functions as the country's centre for disaster risk reduction (DRR) activities and develops strategies for DRR, including preparedness and response plans.

At the district (municipal) level – the basic unit for risk management in Timor-Leste – District/Municipal Disaster Management Committees (DDMCs/MDMCs) are composed of district representatives of key government and non-government agencies. During emergencies, the functions of the DDMCs/MDMCs are to:

- Coordinate the rapid assessment surveys of affected areas and analysis of results;
- Coordinate district financial resources to provide the most effective response to identified needs; and
- Recommend the timing and content of requests for national support and the logistical information needed for effective delivery.

At the sub-district level, the Sub-District Administrator is responsible for emergency and DRR activities. With each *suco* (village), the Suco Chief (Xefe) and village leaders (elders, traditional leaders and village councils) provide further support for emergency and DRR activities.

In addition, Timor-Leste Red Cross Society (Cruz Vermelha de Timor-Leste – CVTL) was legally recognized as an auxiliary to the Government in 2005. CVTL plays a key role in disaster risk management, including participating in national emergency planning and national and district-level disaster simulation exercises. Involvement of CVTL is key for the preparedness and response capacities of NDMD and District Disaster Management Committees. The International Federation of Red Cross and Red Crescent Societies (IFRC) supports CVTL through technical advice, coordination and knowledge sharing, as needed, working before, during and after disasters and health emergencies to meet the needs and improve the lives of vulnerable people.[324]

6.1.8 – Financing for climate services and disaster risk management

The National Directorate of Meteorology and Geophysics (DNMG), under the Ministry of Transport and Communication, is responsible for the provision of climate services in Timor-Leste. In 2019, the annual state budget for DNMG was USD 299,000 – of which USD 232,000 was allocated to goods and services; and USD 67,000 on salaries and wages.[325] In 2018, the total annual state budget for DNMG was USD 165,000.

As with the national budget for climate services, the budget for disaster risk management varies from year to year. In 2018, the National Disaster Management Directorate (NDMD) was allocated USD 920,000 – of which USD 594,000 was for public transfers; USD 245,000 for goods and services; and USD 81,000 for salaries and wages.[326] In 2017, NDMD received USD 1.5 million from the annual state budget; the majority of which (USD 847,000) was allocated to goods and services. In addition, funding

[323] McWilliam, A. *et al.,* 2020. International Journal of Disaster Risk Reduction. Disaster Risk Reduction, modern science and local knowledge: Perspectives from Timor-Leste
[324] Timor-Leste, 2019. Disaster Management Reference Handbook
[325] Government of Timor-Leste, 2020. Annual State Budget 2019
[326] Government of Timor-Leste, 2019. Annual State Budget 2018

for disaster management is allocated directly to each of the 12 municipalities.[327] Timor-Leste also allocates funding for disaster relief and response to other sectoral ministries, namely environment, health, education and public works.[328]

The Central Fiscal Authority (the Treasury) is responsible for the management of disaster relief funds and must authorise expenditure of such funds in the event of a disaster, upon request by the National Disaster Coordinator. The National Disaster Risk Management Policy states that the District Administrator should ideally have access to a small contingency amount to be used for emergency response needs.[329] A state of emergency must be declared for international agencies to access additional funding to respond to a specific disaster event. Lack of awareness of the severity of an extreme weather event has limited foreign disaster relief operations in the past, and the need to develop threshold criteria to declare a state of emergency has been highlighted.[330]

External finance is critical to Timor-Leste for climate change programming and disaster risk management, on account of its highly limited financial capacity as a newly independent country, Least Developed Country and Small Island Developing State – as well as to compensate for its declining oil and gas revenues. The National Directorate for Climate Change (NDCC), under the Secretary of State for the Environment in the Ministry of Economic Affairs, provides support, facilitates funding and implements projects as part of the government's response to drought. In 2019, the annual state budget for NDCC was USD 197,000 – of which USD 110,000 was allocated to goods and services.[331] However, national ownership over climate funding is limited as most financial flow is 'off-budget' via development partners and NGOs. A 2018 study by WaterAid highlighted that there is a "lack of clarity and transparency in climate finance disbursement. Ministries do not have standardised procedures for expenditure, and there is still some ambiguity around the roles of ministries and working groups in coordinating climate change responses across government." Despite this, the "process of GCF accreditation, including readiness support, is triggering important discussions about procedural changes that might facilitate climate-related fund disbursement through the national budget."[332]

[327] Government of Timor-Leste, 2018. Annual State Budget 2017
[328] National Disaster Management Directorate, 2010. National progress report on the implementation of the Hyogo Framework for Action (2009-2011) - Interim
[329] Government of Timor-Leste, 2008. National Disaster Risk Management Policy 2008
[330] Sagar, V.C. *et al.* 2018. NTS Report No. 8. Integrating a disaster response architecture in Timor-Leste: Opportunities and Challenges
[331] Government of Timor-Leste, 2020. Annual State Budget 2019
[332] WaterAid, 2018. Accessing climate finance for sustainable water, sanitation and hygiene services in Timor-Leste

6.2 – IDENTIFIED NEEDS AND PRIORITIES FOR CLIMATE INFORMATION AND EARLY WARNING SERVICES

6.2.1 National priorities and needs

> ***"The need for enhancing our early warning systems and building our resilience against climate-related hazards is greater than ever before. As COVID-19 cases continue to increase daily (including among the displaced), the pandemic is putting a severe strain on our already fragile economy. This has diminished our already limited capacity to invest in early warning systems."***
>
> Dr. Julião dos Reis, Acting Executive Secretary of Timor-Leste National Designated Authority (NDA) for the GCF, May 2021

National systems are at the core of countries' capacity to address the challenges of weather and climate extremes, variability and climate change, and to manage current and projected disaster risks. [333] For its national system to be effective, Timor-Leste needs multiple actors (including national and sub-national governments, public and private sector entities, academics, civil society and communities) to work in coordinated and complementary roles to manage risks, according to their functions and capacities, and supported by relevant scientific and local knowledge. This needs to be facilitated by national strategies, coordination mechanisms or platforms that are multi-sectoral and inter-disciplinary in nature.

National priorities related to climate change

Timor-Leste is committed to addressing environmental and climate change issues and has fully engaged with international frameworks governing these issues. National priorities have been communicated in a variety of policies, strategies and programme documents, as outlined below.

Since independence in 2002 Timor-Leste has made important international commitments, including ratifying the following:

- United Nations Framework Convention on Climate Change (UNFCCC)
- Kyoto Protocol
- Paris Agreement
- Kigali Amendment to the Montreal Protocol
- United Nations Convention on Combating Desertification (UNCCCD)
- United Nations Convention on Biological Diversity (UNCBD)
- Vienna Convention and its Protocol.

Timor-Leste has developed major policy documents relating to climate change adaptation and in March 2019 agreed a Country Programme [334] with the Green Climate Fund that captures the

[333] Lal, P.N. *et al.*, 2012. National systems for managing the risks from climate extremes and disasters. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC)

[334] Timor-Leste, 2019. Timor-Leste GCF Country Programme. Available at: https://www.greenclimate.fund/document/timor-leste-country-programme

Government's prioritised strategy for addressing climate change. The Country Programme explicitly prioritised this Project in its original form (with WMO as the Accredited Entity).

Green Climate Fund Timor-Leste Country Programme (2019)

Timor-Leste's Green Climate Fund Country Programme notes that "[a]s an LDC, Timor-Leste's ability to pursue climate change adaptation and mitigation actions is dependent on the provision of capacity building, finance, and technology transfer, in particular, sufficient, predictable and sustainable finance. Funding is required to amongst other things support national research and development efforts as well as to building human and institutional capacity."[335] It notes that "Climate change is expected to have a range of significant impacts in Timor-Leste, including altering rainfall patterns, altering the onset of seasons, sea level rise, and increasing the intensity and the frequency of extreme climate events. These impacts are all expected to have negative impacts on agriculture, health and water resources."[336]

"It is expected that climate change impacts such as increased air temperature, changes in rainfall pattern and intensity, etc. will decrease and degrade agriculture productivity and the livelihoods of the communities. Climate change is also expected to impact domestic water supply, increase costs of water treatment, and increase frequency of flooding. The later impact is likely to have significant health impacts, such as increasing water-borne, vector-borne diseases and other diseases and infections. Climate change is also expected to impact infrastructure, including electricity and telecommunications infrastructure, roads, bridges and buildings like public buildings, schools and hospitals."[337]

The Country Programme outlines Timor-Leste's priorities for achieving low emissions and climate resilient development, as detailed below:

Adaptation

- Build climate proof and environmentally sustainable infrastructure to protect water resources, including enhancing water harvesting, distribution and management systems;
- Implement integrated sustainable land management to promote fixed/permanent agriculture, reduce crop burning, reduce erosion, and increase soil fertility;
- Reforest degraded lands and provide a sustainable fuel wood source to areas with high vulnerability; and develop integrated agroforestry and watershed management;
- Improve physical infrastructure and natural vegetation methods to prevent landslides in hill sites, roads and riverbanks that are made vulnerable by climate change;
- Enhance government and community strategies to respond to drought exacerbated by climate change; and
- Maintain mangrove plantations and promote awareness raising to protect coastal ecosystems from impacts of sea level rise.

Mitigation

- Reduce GHG emissions from the waste sector, including through improved management of landfill, composting, recycling and resource recovery; and

[335] https://www.greenclimate.fund/sites/default/files/document/timor-leste-country-programme.pdf
[336] https://www.greenclimate.fund/sites/default/files/document/timor-leste-country-programme.pdf
[337] Ibid.

- Climate-smart agriculture.[338]

All of Timor-Leste's adaptation priorities require reliable local-scale climate data to inform decision making. High resolution data is needed from an observation network that is recording climate phenomena in Timor-Leste's varied ecosystems to ensure that predictions and modelling are relevant to the specific circumstances of the population.

This Project will provide the required climate data. It will also make an important contribution to the implementation of climate-resilient agriculture. "There are several ongoing programs and projects underway within the GFCS from local to global scales for improving the management of climatic risks in agriculture, such as early warning systems and agricultural advisories for farmers, policy planners, industry and other stakeholders. The prerequisites for these services are managed and maintained state-of-the-art systems for measuring and recording weather variables; standardised data exchange protocols; systems for data storage, assimilation and dissemination; short, medium and extended range weather forecasts; and seasonal climate forecasts at desired spatial and temporal scales. Good quality and reliable weather and climate data are essential for climate risk assessment and mapping of crop distribution, phenology, yield potential and vulnerability indicators, including adaptation capacity, land suitability and surface and groundwater availability. Fortunately, advanced tools such as automatic weather stations, global circulation models, regional climate models, numerical weather prediction models, and downscaling techniques are more widely available to address stakeholder needs for value-added information."[339]

The key stakeholders for the Green Climate Fund in Timor-Leste are the Ministries of Finance, Social Solidarity, Agriculture and Fisheries and Public Works, and the Secretary of State for Environment. The Asian Development Bank, United Nations Development Programme, Food and Agriculture Organization, United Nations Environment Programme and GIZ are also stakeholders, as well as the local NGOs, Permaculture Timor-Leste (PERMATIL), Haburas Foundation and Raebea o Hiam Health.

National Disaster Risk Management Policy (2008)

The National Disaster Risk Management Policy[340] emphasises the geographical vulnerability of Timor-Leste to disasters induced by climatic change, and the serious socio-economic impacts on people and infrastructure. The Policy prioritises the prevention of natural disasters, proposing the following:

- Promote studies of the identification of risks zones;
- Create early warning systems, particularly relating to rains and droughts;
- Conduct training and capacity building of human resources in the area of disaster risk management;
- Be able to provide immediate response when disaster occurs; and
- Establish inter-sectoral coordination mechanisms to respond to natural disasters.

This Project proposes to directly address the second and fifth priorities and would support the UNDP Project in achieving the other three priorities.

National Adaptation Programme of Action (NAPA) on Climate Change (2010)

[338] Climate-Smart Agriculture (CSA) is an integrative approach to address the challenges of food security and climate change. (CCAFS and UNFAO, 2014)
[339] Managing Climatic Risks to Combat Land Degradation and Enhance Food security: Key Information Needs: P.K. Aggarwal, W.E. Baethegan, P. Cooper, R. Gommes, B. Lee, H. Meinke, L.S. Rathore and M.V.K. Sivakumar. World Climate Conference 3, Procedia Environmental Sciences 1 (2010) 305–312 Available online at www.sciencedirect.com
[340] https://www.preventionweb.net/files/22114_microsoftword15500nationaldisasterr.pdf

The NAPA was based on Timor-Leste's Strategic Development Plan 2011–2030[341] and developed to identify national priorities for addressing climate change adaptation and to monitor the implementation of adaptation measures. The NAPA prioritises community awareness, increased monitoring and risk forecasting, and support for the adaptation of government policies and strategies to improve climate change resilience among vulnerable groups.

Environmental Basic Law (Decree Law No. 26/2012 of 4 July 2012)

Timor-Leste's Environmental Basic Law recognises that the environment and natural resources require "balanced and sustainable management so that citizens can be afforded a higher and better quality of life within a framework of sustainable development". In the context of climate change, Article 34 states that "[t]he State shall implement the measures necessary for climate change adaptation and mitigation in terms of reducing greenhouse gas emissions…and minimizing the negative effects of the impacts of climate change on biophysical and socioeconomic systems".

Timor-Leste's Initial National Communication under UNFCCC (2014)

The Initial National Communication describes the national processes used in developing the report and identifies Timor-Leste's sources of and contribution to greenhouse gas emissions in the atmosphere. It identifies some key adaptation actions relevant to Early Warning Systems:

- Strengthening capacity of national and local institutions as well as communities in managing climate risks through the development of an effective climate information system (improving the skills of climate forecasters) including the development of early warning system and decision support system tools for policy makers; and
- Development and enhancement of sectoral capacity to coordinate the implementation of adaptation actions and also to integrate climate change into strategic planning in moving towards sustainable development and poverty reduction.

The Project will contribute directly to the achievement of the first action and will generate data and information needed for effective implementation of the second.

Timor-Leste Intended Nationally Determined Contributions (2016)

Section 4.1 of the INDC highlights the country's vulnerability to climate change, focusing on climate-related hazards such as flood, drought, storm, landslide and wildfires, and their impact on the loss of human lives and livelihoods, the country's economic infrastructure and its environmental resources. The INDC identifies priority measures for adaptation in food security, water resources, health, natural disasters, forestry, biodiversity, coastal ecosystem resilience, livestock production and physical infrastructure. The Project directly addresses the priority aspects under the Adaptation column in the table below.

Mitigation	Adaptation
GHG coverage - CO_2, CH_4, N_2O Mitigation will focus on: **transportation** (energy-efficiency/RES), **agriculture** (biogas and composting in livestock management, reducing slash and burn practices and focusing on climate-smart agriculture), **land use change and forestry**	Focus is on the following priority adaptation areas: **Food security—**integrated agroforestry/watershed management, integrated

[341] http://www.searo.who.int/timorleste/publications/Home_NATIONAL_STRATEGIC_DEVELOPMENT_PLAN_2011-2030.pdf

(rehabilitation, conservation, cultivation in shrubs-covered area – 27.4% of total land area, interest in REDD+), and **energy** (fuel wood substitution for households with biomass; adopting hydro, solar, wind, also for rural electrification); **waste** (management of landfills and landfill gas, compost resource recovery and recycling, improved incineration technology, phase out HCFCs).	sustainable land management, building resilience of rural livelihoods. **Water resources—**Integrated Water Resource Management, climate-proofed infrastructure, drought-response, improved water distribution, and reduced water waste and pollution by industry, including coffee processing. **Health—**integrated disease surveillance and early warnings for endemic and epidemic climate-sensitive diseases such as malaria and dengue, promoting evidence-based decision-making, establishing health clusters, developing community health services. **Natural disasters**—EWS in areas vulnerable to floods, storms, integrate climate risk information into traditional DRR/DRM. **Forestry, biodiversity and coastal ecosystem resilience**—reduced burning, erosion, increased soil fertility, reforestation of degraded land, maintaining mangrove plantations, ecosystem-management approach, community awareness. **Livestock production—**improved planning and legal framework to streamline climate action. Improved **physical infrastructure,** protecting coastline. Priority aspects: • Mainstreaming adaptation into planning; • Fostering longer-term climate-resilient development strategies, awareness-raising, and capacity-building; and • Building resilience to increasing ocean acidification, sea level rise, more frequent extreme rainfalls, intensive tropical cyclones.

Table 6: Based on Timor-Leste's INDCs, 2016; Timor-Leste's NAPA, 2010.

Timor-Leste Second National Communication (SNC) to the UNFCCC (2020)

The Project will directly address the following adaptation needs identified in the SNC: i) Increase the number of weather stations in Timor-Leste; ii) Assist, encourage and warn people who are at risk from natural disaster; iii) Promote early warning systems; and iv) Education and public awareness. In addition, it will contribute to an enabling environment for "integrating consideration of climate change to develop policies and programmes" and for "budget allocation within relevant Ministries [to] reflect the more vulnerable populations".

Timor-Leste's National Adaptation Plan (2021)

The Project is identified as a priority adaptation project in Timor-Leste's National Adaptation Plan (NAP). In addition, the Project will contribute to the achievement of the following priorities and outcomes: i) Strengthening the capacity of national, local institutions and communities in managing climate risks; ii) Reduce the vulnerability of farmers and pastoralists to increased drought and flood events; iii) Improve institutional and community capacity to prepare for and respond to climate change-induced natural disasters; iv) Integrate climate risk information into traditional disaster risk reduction and management; v) Enhance government and community strategies to respond to drought exacerbated by climate change; vi) Establish surveillance for health early warning systems and response mechanisms for climate-related health risks.

UN Sustainable Development Cooperation Framework (UNSDCF) Timor-Leste (2021 – 2025)

The UNSDCF reflects the shared commitment of the Government of Timor-Leste and the United Nations development system to support and accelerate the country's progress towards achievement of the SDGs and national development priorities. The Project is fully aligned with Outcome 6 on "Sustainable management of natural resources and resilience to climate change", which identifies "*Strengthening early warning system and capacities*" as a specific priority.

Engagement with civil society organisations

The Project will support an existing group of Government ministries and UN agencies responsible for coordinating early warning, climate change adaptation, and disaster risk reduction, expanding the group to include NGOs/CBOs and enabling the group to convene regularly. The following agencies will be invited to establish a coherent approach to and understanding of EWS in Timor-Leste—UN agencies (such as FAO and IOM), international NGOs (including Mercy Corps, CARE, Oxfam, PLAN, World Vision, Caritas, and Child Fund), and local organisations (CVTL[342], RHTO[343], ASRRD[344], Fraterna[345] and others). Existing ad-hoc early warning related work at the community level will benefit from improved coordination and integration into a broader national framework.

National priorities related to water resources management[346]

Water resources management in Timor-Leste is governed by:

- National Constitution – Article 6, point f and Article 139 number 1
- Decree-Law n.6/2015 – Organic Law of VI Constitutional Government
- Decree-Law n.20/2016 – Organic law of MOPTC
- Decree Law No. 3/2016 on The Statutes of the Municipal Administrations and Municipal Authorities
- Environmental Decree-Law n.26/2012
- Decree Law No. 4/2004 on Water Supply for Public Consumption
- National Strategic Development Plan 2011-2030
- National Basic Sanitation Policy, 2012.
- Sustainable Development Goal (SDG) 6

In addition, the following draft legislations and policies have also been prepared:

- National Water Resources Management Policy – draft 2017

[342] Cruz Vermelha de Timor-Leste: Red Cross
[343] Ra'es Hadomi Timor Oan: the Disabled People's Organisation
[344] Asosiasaun Serbisu Redusaun Risku Dezaster: Association for Disaster Risk Reduction
[345] Fraterna: local environmental / disaster response NGO
[346] World Bank, 2018. Timor-Leste Water Sector Assessment and Roadmap

- Proposed Decree-law for Water Resources Management – draft 2017
- National Policy in Public Water Supply, draft 2017

The National Water Resources Management Policy set out:

- The Government of Timor-Leste's responsibilities, intentions, objectives and strategies for water resources management.
- A general framework and direction for national water resources management plan until 2030.
- Guidance to inform public officials, water resource managers and all stakeholders in the formulation and implementation of legislation, regulation, policies, strategies, plans and actions for water resources management.

The legal and policy framework for water resources is designed to support the development of water resources and sets out the obligations of water users to obtain an entitlement to abstract water. The framework clarifies the rights to use public water, restrictions on those rights, and priorities for water usage. The decree law and policy are important for addressing water management issues in Timor-Leste. However, their approval is pending, and implementation will require considerable technical assistance to be effective.

National needs for climate information and early warning services

The Government is responsible for the provision of public goods such as ensuring the economic and social well-being, safety and security of its citizens from disasters, and hence is responsible for the delivery of weather and climate services and management of climate-related disaster risks.[347] Given the baseline low capacity of Timor-Leste to provide weather and climate services, and effective disaster risk management – in part due to its status as a newly independent country, Least Developed Country, and Small Island Developing State – there is a need for Timor-Leste to leverage the technical expertise of international partners in its national capacity building efforts, particularly those who have longstanding experience and expertise in-country. Regional partners can provide specialised knowledge and advice to develop and sustain capacities in countries that share similar geographical environments, as well as encourage linkages with international organisations. International partners can provide international coordination, standardisation, support and convening power, and foster exchange of data and knowledge between individual countries and regions. This is especially needed in the context of climate information and early warning services (CIEWS), given that weather and climate information are a global public good.

The national needs of Timor-Leste are further outlined below, based on the four key elements of early warning systems identified in the WMO Multi-Hazard Early Warning Systems (MHEWS) Checklist.[348]

Disaster risk knowledge

Timor-Leste needs comprehensive weather, water and climate data and information, and knowledge on all dimensions of disaster risk – including hazards, exposure, vulnerability and capacities. Risks need to be recognised as differential and dynamic; and need to be mainstreamed alongside climate change considerations and integrated into national policies, strategies, frameworks and legislation, as well as into environmental management. Decision-making and planning needs to be risk-informed and based on robust evidence, and credible information on disaster loss and damages needs to be available.

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[347] Lal, P.N. *et al.*, 2012. National systems for managing the risks from climate extremes and disasters. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC)

[348] WMO, 2018. Multi-hazard Early Warning Systems: A Checklist

The need to strengthen capacity from national to community level in managing climate risks (floods, drought, landslides) is identified as the first adaptation priority in Timor-Leste's National Adaptation Plan (NAP).[349] Furthermore, Timor-Leste's Second National Communication highlights that "further assessment of the most vulnerable areas or people that have been impacted by climate change is needed as the budget allocation within relevant Ministries should reflect to the more vulnerable populations and be included as allocated budget lines".[350]

Detection, monitoring, analysis and forecasting of the hazards and possible consequences

Timor-Leste needs multi-hazard monitoring, impact-based forecasting and decision support systems underpinned by integrated weather, water, climate and ocean observations covering the entire country. Monitoring and detection of climate-related hazards needs to be in real time or near real time, and forecasts and warnings need to be provided 24 hours a day, 365 days a year. This needs to be supported by robust data management, including processes for quality control and efficient data sharing – particularly with regard to meteorological and hydrological data.

Timor-Leste's Initial National Communication identifies the "development of an effective climate information system (improving the skills of climate forecasters) including the development of early warning system and decision support tools for policy makers" as a key adaptation action.[351] Its Second National Communication asserts that "the availability of climate and weather observation is essential" and that "there is a need to increase the number of weather stations in Timor-Leste to at least once in each district".[352] Its National Adaptation Plan identifies the need to "begin to establish a comprehensive 30-year record of hydrometeorological data to facilitate improved downscaling of global projections in the future" as a priority action in the near-term (2020 – 2022).[353] Finally, Timor-Leste's Flood Response Plan (2021) highlights the need for "strengthening the capacity and performance of hydrometeorological observation" and to "improve national capacity for flood monitoring and early warning systems".[354]

Considering the country's baseline low capacity, a stepwise integrated technical, infrastructural and institutional capacity building approach will be required.

Priorities for the National Directorate for Meteorology and Geophysics

The national entity responsible for the detection, monitoring, analysis and forecasting of weather and climate hazards in Timor-Leste is the National Directorate for Meteorology and Geophysics (DNMG) – although its mandate needs to be formalised. Informed by extensive stakeholder consultations (Annex 7), the priorities identified by DNMG are outlined below.

The tables below provide details of the equipment and improvements needed for the DNMG observational network.

No.	Location	Latitude	Longitude	Type	Status
1	Liquica	-8.58997	125.347	New AWS	Proposed Equipment
2	Ermera	-8.74995	125.3998	New AWS	Proposed Equipment
3	Manatuto	-8.51337	126.0283	New AWS	Proposed Equipment

349 Timor-Leste, 2021. Timor-Leste's National Adaptation Plan
350 Timor-Leste, 2020. Second National Communication under the UNFCCC
351 Timor-Leste, 2014. Timor-Leste's Initial National Communication under UNFCCC
352 Timor-Leste, 2020. Second National Communication under the UNFCCC
353 Timor-Leste, 2021. Timor-Leste's National Adaptation Plan
354 UN RCO Timor-Leste, 2021. Timor-Leste Joint Appeal and Flood Response Plan

4	Same	-9.009	125.6481	New AWS	Proposed Equipment
5	Viqueque	-8.88262	126.372	New AWS	Proposed Equipment
6	Lospalos	-8.44539	126.9886	New AWS	Proposed Equipment
7	Atauro	-8.24421	125.6062	New AWS	Proposed Equipment
8	Baucau	-8.47934	126.3972	New AWS	Proposed Equipment
9	Maliana	-8.9696	125.2102	New AWS	Proposed Equipment
10	Dili	-8.5496	125.5249	New AWOS	Requires upgrade from AWS to AWOS
11	Suai	-9.3007	125.2854	New AWOS	Proposed equipment. A site has already been established.
12	Suai	-9.299	125.283	New Manual Station	Proposed Equipment

Table 7: Proposed additions to the observational network in Timor-Leste (Source: DNMG)

No.	Location	Latitude	Longitude	Type	Status
1	Dili	-8.556	125.56	Manual Station	Requires calibration and maintenance. Based on previous procurements, which were undertaken with a total budget of 41 K for the two systems. It was proposed that BMKG technicians would do the work by contact with the bidder.
2	Baucau	-8.47	126.46	Manual Station	Requires calibration and maintenance
3	Oecusse	-9.3	124.29	AWOS	Requires calibration and maintenance
4	Dare	-8.592	125.58	AWS	Requires calibration and maintenance and ingesting into CliDE to be WMO compliant
5	Madabeno	-8.64	125.572	AWS	Requires calibration and maintenance and ingesting into CliDE to be WMO compliant
6	Liurai	-8.758	125.538	AWS	Requires installation of equipment and then data will require ingesting into CliDE to be WMO compliant
7	Aituto	-8.901	125.592	AWS	Requires calibration and maintenance and ingesting into CliDE to be WMO compliant
8	Vila	-8.996	125.505	AWS	**Active** but requires calibration and maintenance and ingesting into CliDE to be WMO compliant
9	Cassa	-9.134	125.544	AWS	**Active** but requires calibration and maintenance and ingesting into CliDE to be WMO compliant

Table 8: Proposed improvements for the observational network in Timor-Leste (Source: DNMG)

The Government of Timor-Leste is proposing to upgrade Dili Airport and a new terminal will be built where the current AWS (red box below) is located. This presents a good opportunity to move the current AWS to a new location south of the ConocoPhillips' current site (blue box below) and upgrade the AWS to an AWOS. Upgrade of the AWS to an AWOS requires the addition of a ceilometer and visbility meter.

Figure 247: Original and proposed sites for upgrade of AWS (red box) to AWOS (blue box) at Dili Airport

In addition, the installation of an AWOS at Suai Airport is needed to support aviation and weather forecasting. The airport layout is provided in the figure below. In order to provide a back-up for the proposed Suai AWOS and to ensure uninterrupted climate data, a manual station at Suai is also needed.

Figure 248: Proposed locations of new AWOS and manual station at Suai Airport

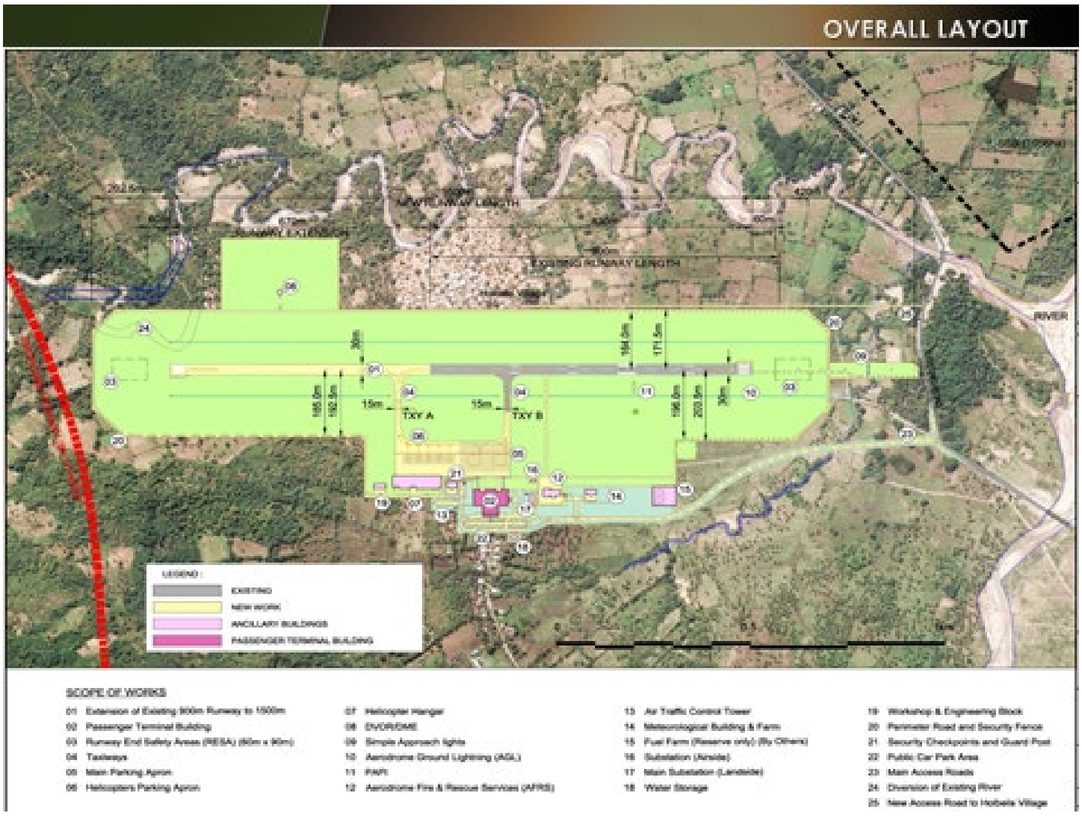

Figure 249: Overall layout of Suai Airport

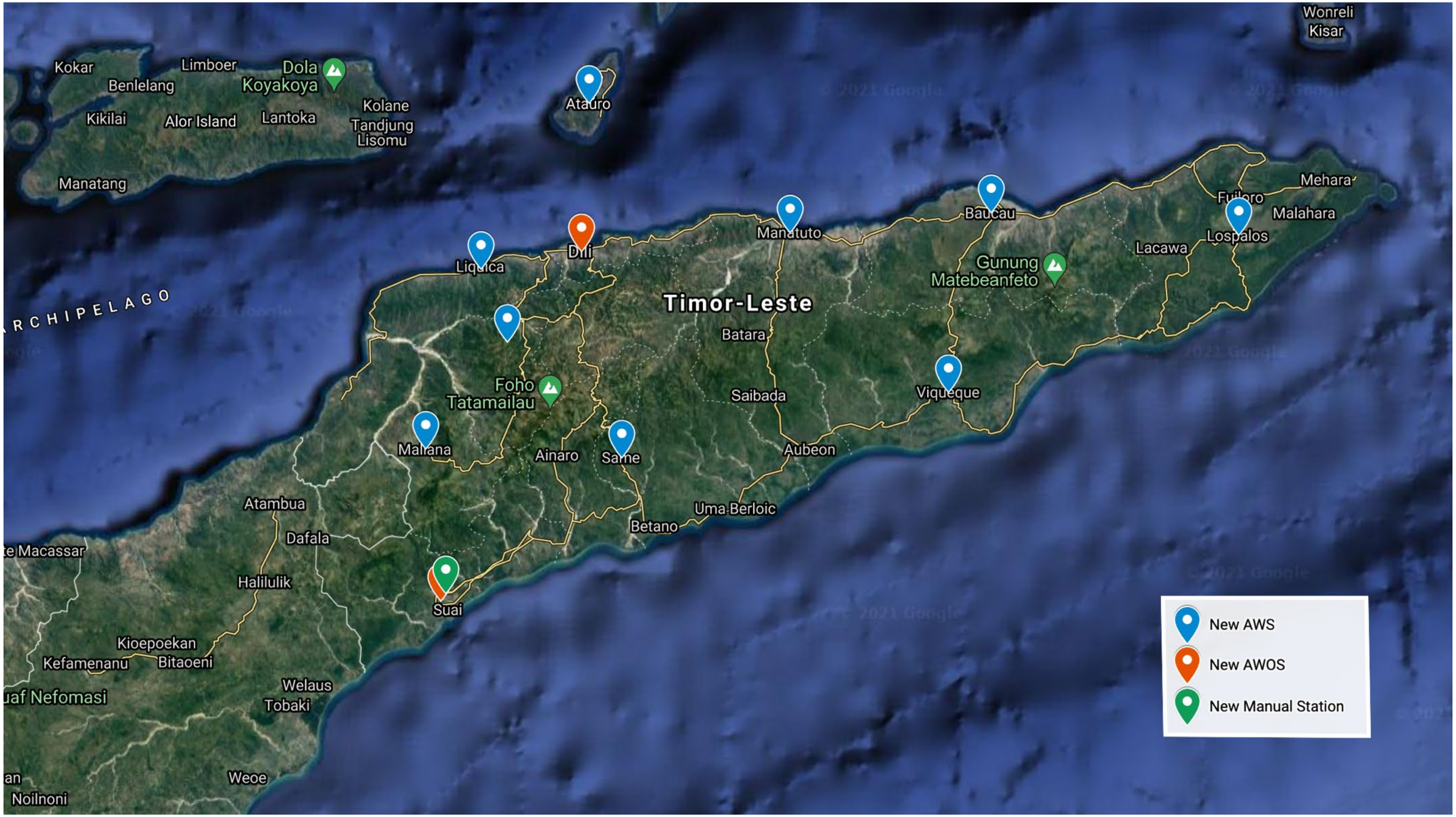

Figure 250: Proposed new hydrometeorological observation network for DNMG

Given that the current methodology for maintaining and upgrading the DNMG network is expensive and unsustainable, a staged process of support and training is needed over the lifetime of the Project to ensure that DNMG are able to sustainably operate and maintain their own network.

Key training requirements for DNMG are identified below:

- Contract for site inspections and calibration support with an international technician for at least the first 2 – 3 years of the Project.
- A comprehensive programme of training for current and future technicians to ensure they are able to upgrade and maintain the DNMG network, including support from WMO and its network.

Specific needs for flood monitoring and flood forecasting

In alignment with the WMO Flood Forecasting and Early Warning Tool "Fundamental Considerations in Flood Forecasting and Early Warning",[355] the identified needs for Timor-Leste are outlined below:

- *Meteorological knowledge associated with flood warning falls into two broad areas, namely the climatology behind flooding and the operational meteorology involved* – With regard to operational meteorology, there is a need to establish capacity in the use of weather data and remote sensing data (including satellite imagery) and in forecasting and modelling. The need for a focus on technical capacity building is also identified in the Summary of Stakeholder Consultations (Annex 7).
- *Hydrometeorological statistics* – There is a need to establish capacity to generate hydrometeorological statistics, primarily for rainfall but also evaporation. However, this first requires useable weather data (see below).
- *Real-time hydrometeorological data* – Automatic Weather Stations (AWS) and Automated Weather Observing Systems (AWOS) need calibration and maintenance, as well as ingestion of data into the climate data management system, in order to be WMO compliant. Assessment of the impacts of severe flooding in April 2021, which caused significant damage to infrastructure in Timor-Leste,[356] is also needed with regard to the hydrometeorological observation network. Furthermore, the need to improve the rainfall observation system in Timor-Leste has been recommended in a paper on a flood risk index analysis for Cuha river basin, which specifically highlighted the data gap for hourly rainfall observations.[357]
- *Hydrological information* – There is a need for a centralised database for water resources data and information to ensure accessibility and inter-compatibility across different organisations. Capacity building and training on IT and database operations is needed so that existing data can be analysed and converted into knowledge and water resource management actions. Moreover, systematic processes are needed for quality control and efficient data sharing.
- *Nature of risks and impacts* – There is a need for systematic hazard, risk and vulnerability assessments and analysis, and improved availability and consistency in risk mapping. There is also a need to better understand the socio-economic and environmental impacts of disasters.

[355] WMO, 2013. Integrated Flood Management Tools Series. Flood Forecasting and Early Warning
[356] UN RCO Timor-Leste, 2021. Timor-Leste: Floods. Situation Report No. 6 (As of 21 April 2021) https://reliefweb.int/sites/reliefweb.int/files/resources/TL%20April%20Flood%20Response%20Situation%20Report%206%20%2821%20Apr%2021%29%20%28final%29.pdf
[357] Araujo, A., 2016. Flood Risk Index Analysis for Cuha River Basin, Timor-Leste

This is particularly pertinent given the current State of Emergency in Timor-Leste. Flood and drought monitoring and warning systems need to be established.

- *Institutional and legal aspects* – There is a need for systematic strengthening and coordination among sector institutions – particularly the National Directorate for Meteorology and Geophysics (DNMG) and the National Directorate for Water Resource Management (DNGRA) – as well as strategic planning with clear results frameworks. Meteorological and hydrological data collection programs need to be coordinated to avoid duplication of efforts and missed opportunities.

Warning dissemination and communication

Timor-Leste needs communication and dissemination systems effective to the last mile to ensure that its entire population receives timely, accurate and actionable warnings in advance of impending hazard events. The utilisation of multiple communication channels is needed to extend the reach of information dissemination, ensure redundancy of the system, and to reinforce the warning message. Moreover, warnings need to be impact-based and tailored to the differential vulnerabilities, risks and needs of subpopulations.

The need to strengthen capacity and performance of hydrometeorological warning dissemination is identified as a priority response activity in Timor-Leste's 2021 Flood Response Plan.[358]

Preparedness and response capabilities

Timor-Leste needs to focus on a multi-hazard integrated disaster risk management (DRM) approach that includes high levels of disaster preparedness, disaster risk reduction and early action. Building disaster preparedness capabilities in particular is need to i) increase efficiency; ii) decrease costs; iii) enhance national and local ownership; iv) increase resilience; and v) reduce the humanitarian carbon footprint.[359] This needs to be underpinned by enhanced risk awareness and education, such that people understand their risks, trust the national warning service, and know how to react to warning messages. In addition, the establishment of innovative mechanisms such as Forecast-based Financing is needed to complement longer-term disaster risk reduction and enhance effectiveness of DRM.

Timor-Leste's National Adaptation Plan identifies the strengthening of "national capacities for climate change responsive disaster risk reduction and disaster risk management" as an adaptation priority, as well as the need for a "comprehensive approach to raising awareness about climate change physical processes, impacts, and adaptation across all sectors".[360] The need to strengthen capacity for disaster risk management at all levels is also identified as a priority in Timor-Leste's 2021 Flood Response Plan.[361]

6.2.2 Identified climate information and early warning services needs for sectors

Public sector investments are particularly important in Timor-Leste as the country remains highly vulnerable to economic and environmental shocks, while also suffering from a very weak private sector environment. Timor-Leste's private sector currently falls short due to predominantly being made up of small, informal firms with low productivity; poor firm performance due to political instability, corruption, poor access to credit and unreliable electricity supply; poor integration of

[358] UN RCO Timor-Leste, 2021. Timor-Leste Joint Appeal and Flood Response Plan
[359] OECD, 2017. Financing Preparedness
[360] Timor-Leste, 2021. Timor-Leste's National Adaptation Plan
[361] UN RCO Timor-Leste, 2021. Timor-Leste Joint Appeal and Flood Response Plan

domestic firms in the global export market with less than 5% of Timorese firms having internationally recognized quality certifications in 2015; and scarce foreign direct investment.[362]

Both the COVID-19 pandemic and recent severe flooding have led to losses of human life and undermined the country's economic growth and recovery.[363] Whilst Timor-Leste was initially successful in containing COVID-19, cases started to increase rapidly in March 2021. Combined with the significant impacts of nationwide floods and landslides in April 2021, the two national emergencies have caused economic activity in Timor-Leste to weaken. The recovery of Timor-Leste following the recent emergencies and future projected disasters relies on development and growth in both the public and private sector, but with the specific responsibility of the Government and the public sector.

As the economy remains vulnerable to climate shocks, fiscal support should be tailored to the specific needs of the country and develop climate resilience across various sectors of the economy. Specifically, there is strong evidence to support that public spending should focus on human capital (including education and health), productive sectors (such as agriculture) and investments in socio-economic infrastructures (such as schools, health facilities and water and sanitation).[364] Enhancing preparedness through investments in early warning systems (EWS) and climate resilience infrastructure is crucial to improve the resilience of Timor-Leste, given recent climatic events and the projected increase in the frequency and severity of extreme weather events and climate change impacts. Historical evidence shows that public sector investments that lead to higher standards of living for the population and higher incomes can reduce fragility levels. This suggests that, in the context of climate change, public sector investments that build climate change resilience into human capital, productive sectors and socio-economic infrastructure will place Timor-Leste on a path of sustainable recovery, growth and development.[365]

The identified needs of the Global Framework for Climate Services (GFCS) five priority sectors in Timor-Leste are discussed below. Each sector will first be discussed according to the specific context and stakeholders in Timor-Leste, and second in alignment with the four key elements of early warning systems identified in the WMO Multi-Hazard Early Warning Systems (MHEWS) Checklist.[366]

Agriculture and food security

Agriculture is one of the most important economic sectors in Timor-Leste, contributing to 17.5% of non-oil GDP and 90% of the country's non-oil exports.[367] However, Timor-Leste's rugged terrain and varying rainfall pose chronic challenges to agriculture, leading to low agricultural productivity and yields. Despite the agricultural sector employing 65% of the population, about 70% of the rural population suffers from food insecurity.[368] The high rate of food insecurity makes a large share of the population extremely vulnerable to food loss and exacerbated food insecurity as climate change impacts manifest.[369] A thriving agricultural sector is vital for Timor-Leste's ambitions to reduce poverty, enhance food security and promote economic growth across the country, and specifically in

[362] IGC (2021). *Timor-Leste's drivers of growth and sectorial transformation.* London, United Kingdom: International Growth Centre

[363] World Bank (2021). *Timor-Leste Economic Report: Charting a New Path*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

[364] World Bank (2021). *Timor-Leste Economic Report: Charting a New Path*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

[365] IGC (2021). *Timor-Leste's drivers of growth and sectorial transformation.* London, United Kingdom: International Growth Centre

[366] WMO, 2018. Multi-hazard Early Warning Systems: A Checklist

[367] World Bank (2018). *Timor-Leste Water Sector Assessment and Roadmap*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

[368] FAO (2016). *Final evaluation of the project Establishing a sustainable National Information and Early Warning System (NIEWS) on Food Security in Timor-Leste*. Rome, Italy: Food and Agriculture Organization of the United Nations

[369] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

rural areas. The Government of Timor-Leste[370] aims to improve national food security, reduce rural poverty, promote environmental sustainability of natural resources and support a transition away from subsistence farming towards commercial farming. However, the agricultural sector and food security remain threatened by the expected increase in frequency and/or severity of climate-induced natural disasters over the next decade. Specifically, the yields of some of the most common crops in Timor-Leste, such as maize, are vulnerable as the frequency of extreme rainfall events increases.[371]

Key stakeholders in Timor-Leste's agricultural and food security sectors specifically include the Ministry of Agriculture and Fisheries (MAF) and the Food and Agricultural Organization of the United Nations (FAO). The MAF is the government department in Timor-Leste that has the responsibility to ensure development of the rural sector. The Ministry works to develop a sustainable, competitive and prosperous agricultural sector that subsequently can reduce poverty, ensure food and nutrition security, and promote employment and economic growth within the agricultural sector. [372] FAO has been working in Timor-Leste since 1999. The organization is guided by its Country Programming Framework, which specifies five priority areas. Firstly, to support the improvement of institutions and coordination mechanisms for policies, laws and regulations, as well as programmes and plans to ensure 100% equitable access to food for all. Secondly, to strengthen the national capacity for agricultural data collection, analysis, management and publications. Thirdly, support improved farming livelihoods, food availability and diversity of household diets. Fourthly, to support smallholder fishing and agriculture households to become more resilient in the face of climate change. Fifthly, to support the renewal, realignment and development of Timor-Leste's cash crop economy.[373]

Disaster risk knowledge

The agriculture sector is one of the most vital sectors in Timor-Leste, but climate change and natural hazards threaten food security.[374] As such, the agricultural sector needs comprehensive information on disaster risk, including sector-specific information on hazards, exposure, vulnerability and capacity. The availability of disaster risk information can help decision-makers in the agriculture and food security sector to improve their understanding of climate impacts on agricultural development and food systems, and their estimates of populations at risk (i.e. risk mapping).[375]

Identified needs in Timor-Leste include:

- Ensure provision of climate inputs to, and participation in, vulnerability mapping
- Conduct hazard mapping and crop zonation mapping
- Achieve enhanced, better-coordinated collection and international exchange of climate and food security data and derived products to complement the analysis of seasonal perspectives for crop production[376]

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[370] Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste

[371] FAO (2021). *Programmes in Timor-Leste*, viewed 14 July 2021. <http://www.fao.org/timor-leste/programmes-and-projects/en/>

[372] Devex (2021). *Ministry of Agriculture, Forestry and Fisheries (MAFF - Timor-Leste)*, viewed 14 July 2021. <https://www.devex.com/organizations/ministry-of-agriculture-forestry-and-fisheries-maff-timor-leste-133132>

[373] FAO (2021). *Programmes in Timor-Leste*, viewed 14 July 2021. <http://www.fao.org/timor-leste/programmes-and-projects/en/>

[374] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

[375] WMO (2014). *Agriculture and Food Security Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[376] FAO (2016). *Final evaluation of the project Establishing a sustainable National Information and Early Warning System (NIEWS) on Food Security in Timor-Leste*. Rome, Italy: Food and Agriculture Organization of the United Nations

- Strengthen the knowledge base on the effect of climate change on nutrition security, malnutrition, and associated adaptation needs[377]
- Improve research and knowledge management capacities to support climate-smart agriculture and resilient land management[378]

Detection, monitoring, analysis and forecasting of the hazards and possible consequences

The agriculture sector needs appropriate and timely weather, water and climate information at relevant spatial and time-scale data points for decision-makers to make better-informed decisions. At short time scales, such information can be help Timor-Leste to address problems triggered by climate extremes (e.g., droughts, heatwaves). At long time scales, such information is needed to address long-term agricultural and food security risks associated with climate change, such as changes in monthly and seasonal rainfall which affect agricultural yields.[379]

Identified needs in Timor-Leste include:

- Improve data collection and the use of meteorological, agrometeorological, and climatic information in analysis on, and forecasting of, the agricultural sector. Specifically, there is a need to record rainfall levels across Timor-Leste[380]
- Improving the reporting of yield, area and production statistics in Timor-Leste[381]
- Integrate climate information into insurance, credit provision, crop monitoring and yield forecasting[382]
- Develop early warning systems and weather monitoring systems in Timor-Leste that can mitigate the impact of climate variability on the agricultural sector[383]

Warning dissemination and communication

The agricultural sector needs to establish reliable warning dissemination and communication mechanisms to provide needs-based information and feedback to the National Directorate for Meteorology and Geophysics (DNMG), the Ministry of Agriculture and Fisheries (MAF) and agriculture extension services. The agricultural sector also needs reliable, timely, locally understandable climate information with response options to farmers, considering inputs credit, market and financial aspects. This can help to increase farm productivity, bridge yield gaps and reduce risks.

Identified needs in Timor-Leste include:

- Establish reliable communication mechanisms to provide needs-based information and feedback mechanisms

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[377] FAO (2016). *Final evaluation of the project Establishing a sustainable National Information and Early Warning System (NIEWS) on Food Security in Timor-Leste*. Rome, Italy: Food and Agriculture Organization of the United Nations

[378] Secretary of State for the Environment (2020b). *Timor-Leste's National Adaptation Plan*. Dili, Timor-Leste: Government of Timor-Leste

[379] World Bank (2021). *Timor-Leste*, viewed 16 July 2021. <https://climateknowledgeportal.worldbank.org/country/timor-leste/climate-sector-agriculture>

[380] FAO (2016). *Final evaluation of the project Establishing a sustainable National Information and Early Warning System (NIEWS) on Food Security in Timor-Leste*. Rome, Italy: Food and Agriculture Organization of the United Nations

[381] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

[382] WMO (2014). *Agriculture and Food Security Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[383] FAO (2016). *Final evaluation of the project Establishing a sustainable National Information and Early Warning System (NIEWS) on Food Security in Timor-Leste*. Rome, Italy: Food and Agriculture Organization of the United Nations

- Support farmer associations, NGOs, Timor-Leste Red Cross Society (CVTL) village volunteers by developing information channels that the farmer community can easily understand and grow to trust[384]
- Develop and consistently use common and local languages in climate and agricultural risk information dissemination[385]
- Produce information that can be accessed in times when agricultural user decisions are needed, such as extreme droughts and locust infestations, which have the potential to damage crops and contribute to food loss[386]
- Set up a national information system at the suco level which can provide data on food security, agricultural and rural livelihoods to decision-makers[387]

Preparedness and response capabilities

The agricultural sector needs to reduce the vulnerability of farmers and pastoralists to the increased drought and flood events[388] by strengthening the preparedness and response capabilities of users of climate and agricultural information from national to local level.[389] Preparedness and response capabilities are essential to recognise, understand, appropriately interpret and apply available climate information in Timor-Leste. The agricultural sector needs to respond to the evolving needs of the agricultural and food security community by developing and working to mainstream climate services into core agricultural functions.

Identified needs in Timor-Leste include:

- Develop a distribution plan for the provision of nutritious food baskets for the temporarily displaced in the event of a natural disaster, with special food for identified vulnerable groups (e.g., infants, children, pregnant and lactating women, the elderly and those with pre-existing health conditions)[390]
- Educate and raise awareness on sustainable agriculture and forest management[391]
- Incorporate climate change into agriculture sector planning and management practices[392]
- Mainstream climate change considerations into agriculture sector regulatory frameworks[393]
- Ensure that Timorese farmers are at the centre of analysis of climate impacts to enhance the local understanding of how climate-related hazards can affect farming productivity[394]

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[384] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance
[385] WMO (2014). *Agriculture and Food Security Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization
[386] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance
[387] FAO (2016). *Final evaluation of the project Establishing a sustainable National Information and Early Warning System (NIEWS) on Food Security in Timor-Leste*. Rome, Italy: Food and Agriculture Organization of the United Nations
[388] Secretary of State for the Environment (2020a). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF
[389] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance
[390] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office
[391] Secretary of State for the Environment (2020a). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF
[392] Secretary of State for the Environment (2020b). *Timor-Leste's National Adaptation Plan*. Dili, Timor-Leste: Government of Timor-Leste
[393] Secretary of State for the Environment (2020b). *Timor-Leste's National Adaptation Plan*. Dili, Timor-Leste: Government of Timor-Leste
[394] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

Health

The overall health of Timor-Leste's population is low, with 20% of children being chronically malnourished and over 50% of children under the age of five suffering from stunting. Communicable diseases such as respiratory diseases, diarrhoea and malaria are the most common source of death in Timor-Leste, accounting for 60% of total deaths.[395] Respiratory and diarrheal disease are also the primary factors causing the high rates of child mortality in Timor-Leste, where 4.4% of all children under five fail to survive.[396] Air pollution poses further health risks. The annual mean concentration of PM2.5 in Timor-Leste is 19 $\mu g/m^3$, which exceeds the "safe" maximum of 10 $\mu g/m^3$ recommended by the World Health Organization.[397] PM2.5 is a significant contributor to ill health, including cardio- and cerebrovascular disease, respiratory illnesses, and lung cancer.[398] The Government of Timor-Leste[399] aims to achieve a healthier population by 2030, achieved through comprehensive, high-quality health services to all Timorese people. A healthier population is subsequently expected to reduce poverty rates, raise income levels and improve national productivity. However, the path to a healthier population is threatened and likely to become even worse by climate change. Climate change is expected to induce mortality rates due to higher frequencies of extreme weather events and increasing the risk of malnutrition and cardiovascular, respiratory and infectious diseases. Rising temperatures, higher flood risks and heat waves will further reduce agricultural production and subsequently increase the risk of child mortality and malnutrition.[400]

Key stakeholders in Timor-Leste's health sector specifically include the Ministry of Health, supported by the District Health Services, Community Health Centres, Health Posts and outreach activities, as well as the Cruz Vermelha de Timor-Leste (Red Cross of Timor-Leste, CVTL), the International Federation and Red Cross and Red Crescent Societies (IFRC) and the World Health Organization (WHO). The IFRC, and CVTL as its National Society, have been proactively tackling the humanitarian needs of vulnerable people in Timor-Leste. Specifically, the CVTL aims to save lives and improve the quality of life for the most vulnerable by improving health, disaster risk reduction, community resilience to natural disasters, youth education and organizational development.[401] The Ministry of Health in Timor-Leste has also worked closely with the WHO. The WHO has been a part of developing policies and arranging health services required in the country. The WHO has played a catalytic role in Timor-Leste for the formation of the future direction of health development, health authorities and formulating health policy, planning and health regulations.[402]

Disaster risk knowledge

The health sector needs comprehensive information on disaster risk, including a specific focus on health-related hazards, exposure, vulnerability and capacity. The availability of disaster risk information can help the Ministry of Health, the District Health Services, Community Health Services

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[395] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

[396] UNICEF (2021). *Country profiles Timor-Leste*, United Nations Children's Fund, viewed 23 June 2021, <https://data.unicef.org/country/tls/>

[397] IAMAT (2021). Timor-Leste General Health Risks: Air Pollution, viewed 17 July 2021. < https://www.iamat.org/country/timor-leste-/risk/air-pollution>

[398] IPCC (2014). *Human health: impacts, adaptation and co-benefits. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Social Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, USA

[399] Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste

[400] WHO (2015). *Climate and Health Country Profile – 2015, Timor-Leste*. Geneva, Switzerland: World Health Organization

[401] IFRC (2019). *IFRC Timor-Leste Program Overview 2019.* Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies

[402] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

and other key stakeholders in Timor-Leste to improve their understanding of the linkages between climate change and health. The health community needs to work closely with climate service providers to advance the health research agenda and enhance disaster risk knowledge regarding the impact of climate change on health, including in terms of the economic costs of impacts and adaptation.[403]

Identified needs in Timor-Leste include:

- Integrate climate change considerations into health sector planning and regulatory frameworks[404]
- Support the establishment of an independent expert process to assess health-climate linkages[405]
- Identify evidence-based guidelines for the use of climate services in healthcare by filling the knowledge gaps of the role of climate hazards on health outcomes[406]

Detection, monitoring, analysis and forecasting of the hazards and possible consequences

The health sector in Timor-Leste needs to improve the detection, monitoring, and analysis of climate data at various time scales and geographical areas in order to forecast how climate extremes will impact human vulnerabilities. Climate and health information can be used to identify possible consequences in the seasons ahead and make projections of longer-term health outcomes.

Identified needs in Timor-Leste include:

- Collect climate information, such as local precipitation patterns and surface air temperature, which is directly related to user needs and health risks such as malaria and other climate-induced diseases[407]
- Enhance surveillance and risk assessment of communicable diseases in all affected areas following a natural disaster for early detection and response[408]
- Monitor for post-disaster illnesses and diseases through surveillance and supportive supervision[409]
- Improve data analysis, modelling and prediction of health risks, such as malaria[410]
- Digitalize historic health and climatic data to improve access to health and climate datasets
- Incorporate data on population, rural vs urban residency, migration, nutritional status etc. into health forecast services[411]

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[403] WMO (2014). *Health Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[404] Secretary of State for the Environment (2020b). *Timor-Leste's National Adaptation Plan*. Dili, Timor-Leste: Government of Timor-Leste

[405] WMO (2014). *Health Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[406] World Bank (2021). *Timor-Leste*, viewed 16 July 2021. <https://climateknowledgeportal.worldbank.org/country/timor-leste/climate-sector-agriculture>

[407] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

[408] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

[409] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

[410] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

[411] WMO (2014). *Health Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

- Provide tailored health services through facilitating collaboration between the weather, climate and health communities[412]

Warning dissemination and communication

The health sector needs to establish reliable warning dissemination and communication mechanisms that include information on climate-related hazards to health. The health sector also needs communication strategies at the national, subnational and local levels to ensure coordination of warning issuers and dissemination channels. In turn, this will enhance the quality of information delivered to the health community and the actual uptake of climate information within health services.

Identified needs in Timor-Leste include:

- Strengthen EWS and surveillance of communicable diseases that are prone to outbreaks, particularly in the aftermath of a natural disaster[413]
- Ensure that health sector actors communicate how extreme weather events and climate change can impact health outcomes, such as the causal effect of extreme heat on amplified levels of air pollutants, which can exacerbate heart and blood vessel disease[414]

Preparedness and response capabilities

Timor-Leste needs to enhance the capacity of the health sector and communities to anticipate and respond to changes in the distribution of climate-sensitive diseases.[415]

Identified needs in Timor-Leste include:

- Increase awareness on public health risks and prevention associated with various natural disasters, as well as prevention methods such as community mobilization and communication for behavioural change[416]
- Develop professional training programs regarding the use of climate information in public health decision-making processes
- Strengthen primary health care services to build capacity of local communities to increase their resilience to climate-related health risks[417]
- Strengthen response capabilities of the health sector through ensuring verification and quality assurance of climate products that are used for health responses[418]

Energy

Fossil fuels account for 90% of the total primary energy supply in Timor-Leste in 2017, with only 10% of the total energy supply coming from renewable sources.[419] However, 90% of the power requirements for rural communities are met using biomass fuels, such as wood fuel, for heating and

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[412] Secretary of State for the Environment (2020b). *Timor-Leste's National Adaptation Plan*. Dili, Timor-Leste: Government of Timor-Leste
[413] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office
[414] World Bank (2021). *Timor-Leste*, viewed 16 July 2021. <https://climateknowledgeportal.worldbank.org/country/timor-leste/climate-sector-agriculture>
[415] Secretary of State for the Environment (2020a). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF
[416] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office
[417] WHO (2015). *Climate and Health Country Profile – 2015, Timor-Leste*. Geneva, Switzerland: World Health Organization
[418] WMO (2014). *Health Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization
[419] IRENA (2017). *Energy profile Timor-Leste.* Abu Dhabi, UAE: International Renewable Energy Agency

cooling applications. The electricity sector in Timor-Leste is inadequate and of low quality, only providing electricity to a third of the population and only for approximately six hours per day. Only the central areas of Dili and Baucau have access to electricity most hours of the day, although there are regular outages. The Government of Timor-Leste[420] aims to ensure electricity for all citizens 24 hours per day through investments in new power plants and improved transmissions and distribution systems, alongside expansions of renewable energy systems. Access to electricity is essential for the country's development, supporting a healthy and well-educated society that is interconnected to the rest of the world. However, climate change and related impacts are linked to negative effects on Timor-Leste's energy sector, with disruptions on both the demand and supply sides. Climate change is expected to increase the energy demand as the rising average global temperature will increase the need for heating and cooling appliances, which is the predominant use of energy in Timor-Leste. Climate change is also expected to reduce the capacity for energy supply, as changing precipitation patterns will cause local floods that disrupt power transportation lines and distribution networks.[421]

Key stakeholders in Timor-Leste's energy sector include a range of actors at various levels of society. At the national level, the Ministry of Petroleum and Mineral Resources is responsible for the design and execution of energy policies and management of oil resources in Timor-Leste, as approved by the Council of Ministers. The Ministry is also responsible for drafting and proposing policy and legislation for the sector.[422] Additionally, at the national level, the Secretariat of State for Energy Policy is responsible for the national development of renewable energy in Timor-Leste. The Secretariat has already developed an action plan for renewable energy, which is expected to have a significant impact on the quality of life for the population, as well as have positive impacts on job sources and government revenue.[423] At the district level, the state-owned company 'Electricidade de Timor-Leste' (EDTL) has a monopoly of electricity supply in Dili and 11 district capitals.[424]

Disaster risk knowledge

The energy sector needs disaster risk information to identify relevant meteorological and climate phenomena for specific energy infrastructure and energy systems in Timor-Leste.[425]

Identified needs in Timor-Leste include:

- Provide ancillary datasets of electricity grids, distances to coasts, elevations, populated centres etc., to expand disaster risk knowledge on the exposure and vulnerability of the energy sector to climate extremes[426]
- Expand research into how climate-related disasters can impact specific energy installations and technologies[427]

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[420] Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste

[421] World Bank (2021). *Climate by Sector > Energy,* viewed 23 June 2021, <https://climateknowledgeportal.worldbank.org/country/timor-leste/climate-sector-energy>

[422] gpm.gov.tl (2021). Minister of Petroleum and Mineral Resources, viewed 14 July 2021. <https://www.gpm.gov.tl/en/minister-of-petroleum-and-mineral-resources/#.YO7t4-hKiMp>

[423] Timor-leste.gov.tl (2010). *Timor-Leste invests in Renewable Energies,* viewed 14 July 2021. <http://timor-leste.gov.tl/?p=3827&n=1&lang=en>

[424] DLA Piper (2015). *RENEWABLE ENERGY IN THE ASIA PACIFIC*. Melbourne, Australia: DLA Piper

[425] WMO (2014). *Energy Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[426] WMO (2014). *Energy Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[427] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

- Expand energy-related risk knowledge by developing new parameterizations for high-resolution numerical models that can better integrate energy-specific features, such as wind turbines and solar plants[428]

Detection, monitoring, analysis and forecasting of the hazards and possible consequences

The energy sector needs *in-situ* and satellite driven high-resolution meteorological data for the assessment of energy-related resources and risks. The access to historical datasets with meteorological and climate variables will improve the detection, monitoring, analysis and forecasting capabilities of the energy sector and can be used to predict demand, insurance and energy efficiency. Moreover, the energy sector needs forecasting tools to improve site-specific and sector-specific information for energy, and to strengthen linkages between the energy sector and short-term, seasonal and longer-term climate variations.

Identified needs in Timor-Leste include:

- Collect data on energy systems, air quality, greenhouse gas emissions and other environmental factors across time and space[429]
- Obtain detailed site-specific and historical datasets that can link extreme climate events to energy supplies and demand[430]
- Establish forecasting tools to allow the energy system to adapt to meteorologically influenced energy demand and to guide long-term decisions in the energy sector

Warning dissemination and communication

The energy sector needs improved communication methodologies to effectively convey warnings to the energy sector at various lead times and predict energy demand at various timescales. Specifically, there is a need for a User Interface Platform (UIP) that can provide estimates on climate risk, communicate the interpretation of datasets and provide support for the installation, operation and maintenance of meteorological instruments in the energy sector.[431]

Identified needs in Timor-Leste include:

- Improve communication methodologies to effectively convey climate warnings at various lead times to the energy sector
- Provide tailored tools that can disseminate specific information to energy subsectors, such as heating and cooling, wind gusts, water temperature and river flows
- Increase interactions among energy traders/insurers and between meteorologists/climatologists[432]

Preparedness and response capabilities

The energy sector needs capacity development to improve the preparedness and response capabilities to natural hazards. In turn, enhance capabilities support the energy sector to tackle possible impacts

[428] WMO (2014). *Energy Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization
[429] Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste
[430] Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste
[431] WMO (2014). *Energy Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization
[432] WMO (2014). *Energy Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

from incoming severe climatic events and ensures that appropriate weather and climate services are in place to facilitate the development of renewable energy systems and energy efficiency.[433]

Identified needs in Timor-Leste include:

- Strengthen the preparedness of local communities and government organizations by organizing regular workshops, summer schools, regular webinars, and regular international conferences on the link between climate hazards and the energy sector[434]
- Improve energy efficiency at the supply side (fossil fuel combustion), transportation and the demand side (households and commercial buildings)[435]
- Increase the use of renewable energy, including biomass, biogas, hydropower, solar PV, wind turbines, etc.[436]
- Increase the amount of electricity generated from renewable energy sources as a means to adapt to climate change and climate change mitigation[437]
- Identify win-win energy systems which can mitigate greenhouse gas emissions, adapt to climate change, and facilitate economic development and poverty alleviation.
- Integrate climate and weather information into net-zero energy plans and enhance support for renewable energy use[438]

Disaster risk reduction

Timor-Leste is the 7th most disaster-prone country in the world, predominantly impacted by droughts and floods, which exacerbates poverty and malnutrition in the country.[439] The vulnerability of Timor-Leste to climate-related disasters is evident from the devastating impacts of the recent tropical cyclone (Seroja), heavy rains, flooding and associated landslides that occurred between 29th March and April 2021, which affected a total of 33,835 households and caused at least 41 fatalities.[440] In 2015 and 2016, the El Niño-induced drought impacted over 120,000 people across the country, of which 400,000 people were directly and severely affected.[441] Droughts in Timor-Leste have shown to harm the water and sanitation systems, food security, health and livelihoods of local communities. However, despite the negative impacts from droughts, many citizens reported a lack of response and recovery following the El Niño drought and few communities could access government or external actor assistance.[442]To address disaster risks, the Government of Timor-Leste has committed to various international treaties, such as the UNFCCC's Paris Agreement, and has developed a disaster risk management plan as a part of their National Adaptation Plan. However, government commitments

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433 Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste

434 WMO (2014). *Energy Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

435 Secretary of State for the Environment (2020). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF

436 Secretary of State for the Environment (2020). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF

437 Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste

438 Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste

439 CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

440 UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

441 UNSDG (2016). *Timor-Leste: El Niño Impact, UN Resident Coordinator's Office Situation Report No. 3*. New York, United States: United Nations Sustainable Development Group

442 Cook, A.D.B., Suresh, V., Nair, T. and Foo, Y.N. (2019). Integrating disaster governance in Timor-Leste: Opportunities and Challenges. *International Journal of Disaster Risk Reduction*, 35, pp. 1-12

are limited due to insufficient staff capacity and a lack of local acknowledgement regarding the need for climate risk management. Climate change is expected to exacerbate the risk and frequency of natural disasters in the next decades, directly affecting food and agriculture, with the greatest harms for coastal regions. Climate change is also expected to increase the risk of injury and deaths, damage to natural resources and displacements of local communities.[443]

Key stakeholders in Timor-Leste's disaster risk management sector includes a range of actors across various levels of the society. Specifically, at the national level, the National Disaster Management Directorate (NDMD) is responsible for providing disaster risk management coordination and technical support to the government and communities in Timor-Leste. At the district level, the District Disaster Coordinator (DDC) is responsible for disaster response decision-making, response observations and disaster risk reduction. At the sub-district level, the Sub-District Administrator (SDA) is responsible for emergency and disaster risk reduction activities, seeking assistance from the DDC or at national level as required. Within each village, there is a Suco Chief, as well as village leaders (elders, traditional leaders and village councils), who provide further support for emergency and disaster risk reduction activities. In addition, Timor-Leste Red Cross Society (Cruz Vermelha de Timor-Leste – CVTL) was legally recognized as an auxiliary to the Government in 2005. CVTL plays a key role in disaster risk management, including participating in national emergency planning and national and district-level disaster simulation exercises. Involvement of CVTL is key for the preparedness and response capacities of NDMD and District Disaster Management Committees. The International Federation of Red Cross and Red Crescent Societies (IFRC) supports CVTL through technical advice, coordination and knowledge sharing, as needed, working before, during and after disasters and health emergencies to meet the needs and improve the lives of vulnerable people.[444]

Disaster risk knowledge

The disaster risk reduction sector needs risk assessments that determine the nature and extent of climate risk by analysing potential hazards, exposed assets and conditions of vulnerability (including causalities, construction damages, crop yield reductions and water shortages). Disaster risk knowledge needs to include information on the exposure and vulnerability of local communities to natural hazards across time and space to develop a comprehensive picture of dynamic risks.[445] Although historic and real-time databases do not provide a perfect prediction of the losses associated with future hazards, given the projected increase in climate variability and extreme events, they are an essential tool for the National Disaster Management Directorate (NDMD) to quantify the vulnerability of the population and to assess future risk.

Identified needs in Timor-Leste include:

- Identify how natural disasters adversely affect women, men, boys and girls differently. Specifically, identify how groups including women, children, people with disabilities and the elderly experience exacerbated impacts due to existing vulnerabilities[446]

[443] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

[444] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

[445] WMO (2014). *Disaster Risk Reduction Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[446] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

- Conduct multi-sectorial assessment and household assessment to inform the short, medium and longer-term shelter needs in relation to natural hazards and to help inform efforts to resettle people to disaster-safe areas[447]
- Support analysis of gender-sensitive and inclusive sectoral assessment data, ensuring specific data on sex, age, disability and people with special needs[448]
- Target investments at applied research to understand the correlation between climatic regimes and extreme event patterns, and to quantify the financial and social risks at seasonal, annual and decadal time frames[449]
- Translate environmental variables into disaster risk variables in order to establish causality between extreme climate events and loss and damage.
- Incorporate relevant climate observations, statistical analyses, forecasts and projections of weather and climate-related extremes into risk assessments[450]

Detection, monitoring, analysis and forecasting of the hazards and possible consequences

The disaster risk reduction sector needs historical and real-time databases to make predictions about future natural hazards and associated consequences in Timor-Leste. Both short-term and seasonal weather forecasts are needed to build reliable deterministic or probabilistic risk scenarios and, in turn, to strengthen disaster risk reduction efforts in Timor-Leste.

Identified needs in Timor-Leste include:

- Conduct real-time monitoring of evacuation centres, consolidations of evacuation centres, including maps, locations, demographics, needs and intentions of displaced persons[451]
- Conduct real-time monitoring of hazards, meteorological and hydrological conditions[452]
- Collect *in-situ* and space-based earth system observation networks and observations of exposed assets; collect remotely sensed ancillary data collected over study sites and develop archives of real-time data records and metadata[453]
- Target investments at operational climate services that include analysis, forecasts and projections of climate regimes and the probabilities/scenarios related to extreme weather patterns[454]

Warning dissemination and communication

There are communication gaps in Timor-Leste's disaster risk reduction sector that pose significant challenges to the effective management of natural disasters, conflicts and climate change adaptation.

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[447] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office
[448] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office
[449] WMO (2014). *Disaster Risk Reduction Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization
[450] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance
[451] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office
[452] WMO (2014). *Disaster Risk Reduction Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization
[453] WMO (2014). *Disaster Risk Reduction Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization
[454] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

The disaster risk reduction sector needs effective communication and dissemination systems to ensure that people and communities across Timor-Leste can receive warnings in advance of an impending hazard and to facilitate national and regional coordination and information exchange.[455]

Identified needs in Timor-Leste include:

- Target investments to ensure that all stakeholders are engaged in the implementation of climate services and to establish coordination and information channels for relevant climate and non-climate inputs[456]
- Improve access to climate-relevant information by establishing a dissemination plan that includes media, politicians, NGOs, news agencies, foreign embassies, etc.[457]
- Ensure that warnings are issued from a pre-determined source and disseminated through pre-established channels in a simple and timely fashion to authorities and the public[458]

Preparedness and response capabilities

The disaster risk reduction sector urgently needs to strengthen its preparedness and response capabilities, as essential phases in a comprehensive approach to disaster management. In particular, proactive preparedness is needed to ensure a balance between the reduce of risk and the enhancement of community resilience. Innovative means to plan and fund such efforts – such as Forecast-based Financing – are required to enhance effectiveness and reduce costs.

Identified needs in Timor-Leste include:

- Enhance capacity development by strengthening institutional capacities to enhance resilience of communities in coastal regions and the capital Dili, which is at high risk of flooding from sea-level rise[459]
- Invest in the development of early warning systems and contingency planning which can help the government plan for extreme weather events, such as drought, floods and associated landslides[460]
- Implement loss accounting systems to provide decent, adequate and dignified shelters to vulnerable households affected by floods or other natural disasters[461]
- Safeguard the health, security, privacy and dignity of women and men, boys and girls affected by natural disasters through the provision of emergency shelter and non-food item assistance.
- Address displacement needs from natural disasters and provides solutions to diminish the risk of protracted displacement [462]

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455 CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

456 WMO (2014). *Disaster Risk Reduction Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

457 CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

458 WMO (2014). *Disaster Risk Reduction Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

459 CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

460 CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

461 UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

462 UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

- Provide support in evacuation centres for the relocation of children, families and vulnerable groups who are unable to return to their homes following a natural disaster. The evacuation centres need to be safe for women, children and vulnerable groups in terms of safety, lighting and privacy for toilets and showers, and sleeping arrangements[463]
- Conduct regular real-time monitoring of recovery processes and households at the suco level[464]

Water Management

Timor-Leste's water and sanitation infrastructure are of low quality following the damages suffered during the violence for independence, including damaged pumping stations, transmission pipes, valves and tanks. The low quality of water resource management makes diarrheal illnesses easy to obtain, putting the health of the population at risk of a major cause of death. Water and sanitation management systems are harmed by water shortages in dry seasons, as it reduces access to both drinking water and sanitation facilities. Water resource management systems are also increasingly harmed by extreme rainfall during wet seasons that, through flooding and damage to sewage systems, induces the spread of bacterial diarrhoea and typhoid fever.[465] Only 66% of the population has access to a clean water source, such as piped water, hand pumps, water tanks or water bottles. One-third of the population must walk over 10 minutes to access a water source and 96% of urban households outside Dili do not have access to safe water 24 hours per day.[466] The Government of Timor-Leste aims to build a water resource system that can provide the whole population with access to clean water and sanitation by 2030. However, climate change is expected to have negative impacts on Timor-Leste's water management as sea-level rise, projected increases in extreme rainfall events, and greater precipitation variability will increase the risk of flooding and droughts. Climate change also risks intensifying storm events and heatwaves, which will damage coastlines, freshwater and groundwater sources, thereby threatening the domestic water supply for urban centres.[467] Recent evidence of the increasing effects of climate change includes the heavy rainfall between 29 March and 4 April 2021 in Timor-Leste, resulting in flash floods and landslides across all 13 municipalities in the country. The event led to a total of 44 recorded fatalities and over 30,000 households affected.[468]

Key stakeholders in Timor-Leste's water resource management sector specifically includes the National Directorate for Water Supply (DNSA), the National Directorate for Basic Sanitation (DNSB), the National Directorate for Water Resources Management (DNGRA), the National Directorate for Meteorology and Geophysics (DNMG) and the National Directorate for Disaster Risk Management (NDMD). The DNSA and DNSB are responsible for the management, regulation, and oversight of activities related to water supply and sanitation systems.[469] At the sub-national level, the DNSA is responsible for ensuring piped water in urban areas.[470] The DNGRA has the mandate for hydrology

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463 UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

464 UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

465 CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

466 Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste

467 WMO (2018). *Multi-hazard Early Warning Systems: A Checklist*. Geneva, Switzerland: World Meteorological Organization

468 UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

469 World Bank (2018). *Timor-Leste Water Sector Assessment and Roadmap*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

470 World Bank (2015). *Water Supply and Sanitation in Timor-Leste.* Washington, DC: International Bank for Reconstruction and Development / The World Bank

and hydraulics and is responsible for monitoring and research on the quality and volume of water resources. The DNGRA is primarily focused at the national level on developing law and policy and implementing monitoring programs, for hydrometeorology and seawater intrusion. The majority of the Directorate staff work throughout the municipalities supporting the National Hydrometeorological Monitoring Program. Water Resources staff of the Municipal Water, Sanitation Service and Environment Services (SMASA) coordinates that program for their respective municipalities. Meanwhile, the responsibility for flood forecasting lies with DNMG. The NDMD is the main focal point to prevent water-related natural disasters and to provide assistance and protection to communities in the event of a natural disaster.[471] At the community level, community water management groups have the primary responsibility of securing water to communities, but with the oversight and technical input provided by the DNSA.[472] In addition, the GCF-funded UNDP project “Safeguarding communities and their physical assets from climate-induced disasters in Timor-Leste” (FP109) is addressing key elements of hydrology and hydraulics in Timor-Leste – including flood risk mapping, flood modelling and forecasting for major river basins.

Disaster risk knowledge

The water management sector needs comprehensive information on climate-related risks to water resources development, surface water resources and groundwater – including hazards (namely extreme rainfall or drought), exposure, vulnerability and capacity. Research and development on climate and water applications are essential for the support and creation of new products that suit the needs of the water community.[473]

Identified needs in Timor-Leste include:

- Ensure regular monitoring and assessments for climate risks in flood-prone communities[474]
- Further analyse and detect areas that are prone to flooding as water damages, such as flooding, has shown to have a history of causing collapsed roads, destruction of infrastructure and putting lives at risk[475]
- Undertake dynamic flood hazard mapping and risk assessment
- Produce detailed studies on specific water resource issues to further water resource development and reduce the vulnerability to climate change and associated fluctuating public water supplies[476]
- Determine water resources availability and water demand under a range of water demand and climate scenarios; conducted at a national scale, with downscaling to priority areas[477]

Detection, monitoring, analysis and forecasting of the hazards and possible consequences

The water management sector needs monitoring systems to estimate the impact of water-related hazards on the local community, it also needs forecasting and warning services to project incoming

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[471] World Bank (2018). *Timor-Leste Water Sector Assessment and Roadmap*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

[472] World Bank (2015). *Water Supply and Sanitation in Timor-Leste.* Washington, DC: International Bank for Reconstruction and Development / The World Bank

[473] WMO (2014). *Water Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[474] UNRCO (2021). *Timor-Leste: Floods.* Geneva, Switzerland: UN Resident Coordinator’s Office

[475] (Government of Timor-Leste, 2010)

[476] World Bank (2018). *Timor-Leste Water Sector Assessment and Roadmap*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

[477] World Bank (2018). *Timor-Leste Water Sector Assessment and Roadmap*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

water-related climate hazards. There are frequently gaps and mismatches between the nature and distribution of climate observing systems and networks for water monitoring in Timor-Leste, which highlights the need for improvements to the climate-water interface and extending it to meet user needs and ensuring high-quality data.[478]

Identified needs in Timor-Leste include:

- Develop meteorological and hydrological models that are designed to produce probabilistic output for risk analyses[479]
- Research, modelling and prediction to make quantitative climate predictions on various time-scales spatial scales
- Facilitate joint work between the climate and water actors to improve both the quality and reliability of water products and services, hence improving the utility and confidence in climate services
- Water sector stakeholders need to inform climate service providers of the needs for specific variables and information, and the format and presentation of items, gaps and opportunities[480]

Warning dissemination and communication

The water management sector needs communication systems for frequent and harmful water-related climate hazards in Timor-Leste, such as floods, and multiple channels to disseminate climate-related information to the water management sector.[481] Improvements in climate communication and dissemination channels will enhance the access of high-quality information available to the water community, which subsequently allows the sector to conduct risk assessments and planning.

Identified needs in Timor-Leste include:

- Build a dialogue between users of climate services, the water sector and those responsible for the observation, research and information system components
- Improve climate literacy in the user community through various public education initiatives and online training programmes; Improve water literacy of climate service providers, to ensure that climate service providers better understand the decision-making context of water managers[482]
- Prevent water-borne disease outbreaks following natural disasters through community mobilization for water, hygiene and sanitation behavioural change communication[483]

Preparedness and response capabilities

The water community needs to promote integrated water resource management to guarantee water access in a climate change context[484]. Specifically, the water community needs to establish causality

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[478] World Bank (2018). *Timor-Leste Water Sector Assessment and Roadmap*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

[479] WMO (2014). *Water Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[480] UNRCO (2021). *Timor-Leste: Floods.* Geneva, Switzerland: UN Resident Coordinator's Office

[481] World Bank (2018). *Timor-Leste Water Sector Assessment and Roadmap*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

[482] WMO (2014). *Water Exemplar to the User Interface Platform of the Global Framework for Climate Services*. Geneva, Switzerland: World Meteorological Organization

[483] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

[484] Secretary of State for the Environment (2020a). *Second National Communication*. Dili, Timor-Leste: Government of Timor-Leste, UNEP, GEF

between the water regime and climatic and human interventions in order to support the construction and management of dams and embankments. There is a need to facilitate greater resilience of Timor-Leste in the context of climate change and water-related disasters as proposed by the National Adaptation Program of Action (NAPA) for Climate change who promotes more integrated water resource management to guarantee water access in a climate change context[485].

Identified needs in Timor-Leste include:

- Develop and implement water and environmental policies, water and flood management policies, and water management regulations and laws as a response to rising sea-level rise which increases the risk of flooding in coastal and low-lying regions of Timor-Leste[486]
- Incorporate climate resilience into water sector planning and regulatory frameworks[487]
- Enable the collection and dissemination of information and knowledge on good practices regarding drought mitigation, preparedness and response.
- Additional secure water sources are needed to increase the coverage of water access and reduce vulnerabilities to water shortages following droughts or extreme climate events[488]
- Implement risk management and emergency preparedness practices and procedures, such as ensuring access to safe drinking water and sanitation that can trigger water-borne diseases[489]
- Promote community engagement and hygiene practices based on a deeper contextual understanding of the social and cultural norms[490]
- Improve water, hygiene and sanitation services in schools and health centres through improving drinking water safety and quality, rehabilitation of water supply facilities, water storage, gender-sensitive sanitation facilities and provision of handwashing stations[491]

6.2.3 Identified CIEWS needs for communities and individuals

Given the vulnerability of Timor-Leste to climate variability and change, and the limited coping capacity of its population, there is an urgent need to better integrate weather and climate information into societal decision-making processes. Communities, especially those most vulnerable, are fundamental to people-centred multi-hazard early warning systems. Local stakeholders need to be actively involved in all aspects of the establishment and operation of early warning systems, be aware of the hazards and potential impacts to which they are exposed, and have the capacity to take actions that minimise loss and damage, and reduce risks.

Stakeholder consultations specifically identified the need to strengthen *suco*-level understanding of and access to risk information and warnings associated with hydrometeorological hazards. Forecast and early warning information needs to be provided in a way that is accessible to local communities, and trust in DNMG and NDMD, as information providers, must be established. However, ensuring that information is accessible and understandable is not sufficient to guarantee uptake. Information needs

[485] CFE-DM (2016). *Timor-Leste Disaster Management Reference Handbook*. Hickam, Hawaii: Center for Excellence in Disaster Management & Humanitarian Assistance

[486] Government of Timor-Leste (2010). *Timor-Leste Strategic Development Plan 2011-2030.* Dili, Timor-Leste: República Democrática de Timor-Leste

[487] Secretary of State for the Environment (2020b). *Timor-Leste's National Adaptation Plan*. Dili, Timor-Leste: Government of Timor-Leste

[488] World Bank (2018). *Timor-Leste Water Sector Assessment and Roadmap*. Washington, DC: International Bank of Reconstruction and Development / The World Bank

[489] UNRCO (2021). *Timor-Leste: Floods.* Geneva, Switzerland: UN Resident Coordinator's Office

[490] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

[491] UNRCO (2021). *Joint Appeal & Flood Response Plan Towards Recovery, Timor-Leste.* Geneva, Switzerland: UN Resident Coordinator's Office

to be provided at the right time for decision making and at the appropriate spatial scale to ensure relevance to the local context. In particular, weather and short-term climate information (i.e., hours to seasons timescales), as well as information on impacts and risks, to inform actions that can immediately reduce the impacts of extreme weather events. In addition, local information channels and traditional knowledge should be leveraged as a means to improve communication at the community level.

Key requirements include translation in local languages (e.g. Tetum), the provision of verbal communications given the high levels of illiteracy, use of multiple communication channels (e.g. television, SMS, local and community radio, agriculture extension workers) and ensuring that forecasts and warnings are disseminated in a consistent and timely manner with impact information so that individuals can take appropriate action. This should be based on understanding of last-mile connectivity (which population groups can be reached by different communication channels) and the differential vulnerabilities and needs of specific population groups – particularly those who are marginalised and/or vulnerable, such as women, youth, elderly people and people with disabilities.

Socioeconomic development in Timor-Leste is curbed by the inability to prepare for and respond appropriately to climate-related hazards. There is a need to establish capacity of communities and individuals to shift from reactive responses to proactive, risk-informed anticipatory actions that improve preparedness and reduce disaster risk. Such actions must be underpinned by enhanced risk education. Communities across Timor-Leste need to better understand climate hazards and risks, and knowledge is needed on the availability and use of early warnings, and how forecasts and warnings can inform effective disaster risk management. Timor-Leste's Second National Communication[492] highlights that improving *suco*-level climate risk management capacity in key sectors such as agriculture and water is needed as part of efforts to reduce vulnerability of the *sucos.* The need to conduct public awareness and training was identified as a priority during stakeholder consultations.

Finally, the Gender Assessment (Annex 8) details the need for a gender responsive – and, where possible, gender transformative – approach throughout project development, implementation, monitoring and evaluation, and this needs to start at the community level. Women and men need to be encouraged to equally participate and actively engage in the development and implementation of early warning systems and disaster risk management. Warning dissemination and communication needs to take into account gender norms, behaviour patterns and information preferences; and preparedness and response actions need to be tailored to the differential needs and capacities of women and other vulnerable groups.

Specific needs identified in the Joint Appeal and Flood Response Plan (May 2021)[493]

Extreme rainfall across Timor-Leste from 29 March to 4 April 2021 resulted in flash floods and landslides across all 13 municipalities, with the capital Dili and surrounding low-lying areas the worst affected. The disaster impacted Timor-Leste at the individual, household and community levels.

The residual humanitarian needs include:

- Emergency health needs of injured persons
- Health needs of those with pre-existing conditions and pregnant and lactating women
- Psychosocial needs, including of children
- Prevention of disease outbreaks, and of further spread of COVID-19
- Safe water, temporary latrines, hygiene/dignity kits and materials for cleaning up

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[492] Timor-Leste, 2020. Second National Communication under the UNFCCC

[493] UN RCO Timor-Leste, 2021. Timor-Leste Joint Appeal and Flood Response Plan

- Flood, cooking materials and cooking stoves/firewood
- Temporary shelter and/or shelter materials
- Management of remaining evacuation centres, including protection and prevention of sexual and gender-based violence

In order to transition to recovery of the affected communities, the early recovery needs of affected persons need to be frontloaded, including:

- Agricultural livelihood needs – such as seeds, agricultural inputs, fertilizers and agricultural tools
- Non-agricultural livelihood needs
- Renovation of community assets – such as embankment, market facilities, and irrigation infrastructure
- Renovation of health and education facilities
- Reconstruction of damaged shelters

In addition, identified community-specific needs include:

- Promote community-based hazard awareness, preparedness and disaster risk reduction
- Increase awareness on public health risks and prevention associated with flooding
- Enhance community capacity for disaster preparedness and response

The identified needs, spanning multiple sectors, demonstrate the necessity for coordinated and integrated approaches to strengthen local capacities in disaster risk management and enhance their preparedness in the face of future climate shocks. This must be informed by enhanced risk knowledge, climate information and data, and ensuring that data meets the unique needs of women, girls, men, boys and marginalised groups.

6.2.4 Summary needs assessment

The table below provides an overall summary of the needs of Timor-Leste, based on the four key elements of early warning systems identified in the WMO Multi-Hazard Early Warning System (MHEWS) Checklist.[494]

Key element of MHEWS	Summary Needs for Timor-Leste
Disaster risk knowledge	• Comprehensive data and information on key weather, water and climate-related risks (including hazards, exposure, vulnerabilities and capacities). • Dynamic multi-hazard mapping that integrates near real-time weather, water and climate data • Mainstreaming of climate and disaster risk knowledge into government, sectoral and household-level decision making and planning • Integration of data from various sector sources with climate data • Systematic collection, sharing and assessment of weather, water and climate risk information and data, and data on disaster loss and damage • Integrated platform for weather, water and climate-related data, information and analytics

[494] WMO, 2018. Multi-Hazard Early Warning Systems: A Checklist

	• Standardised data and information, disaggregated by sex, age and disability (where possible) • Established process to maintain, regularly review, and update data • Risk information on vulnerable groups (hazard, exposure, differential vulnerability) used to inform appropriate disaster risk management
Detection, monitoring analysis and forecasting of the hazards and possible consequences	• Legislation to mandate the responsibilities of the National Directorate for Meteorology and Geophysics (DNMG) in the provision of weather and climate services and formalise its relationship with other agencies, such as the National Directorate for Water Resources Management (DNGRA) • Surface-based observation network in compliance with the WMO Global Basic Observing Network (GBON) – thereby facilitating access to the proposed Systematic Observations Financing Facility (SOFF) to ensure long-term sustainability • Monitoring data to be received, processed and available in standardised format in real time or near real time • Routine maintenance and calibration of observation and monitoring infrastructure to ensure optimal operation of the system • Capacity building and training for DNMG on operation, calibration and maintenance of monitoring equipment, and Quality Management Systems (QMS) • In-country capacity to undertake data analysis, modelling, prediction and forecasting for weather, water and climate – including impact-based forecasting and early warning • Sector-specific climate information, decision support tools and advisories • Early forecasting of key climate-related hazards (e.g., floods and drought) and their potential impacts
Warning dissemination and communication	• Clarification of functions, roles and responsibilities of each actor in relation to EWS and inclusion in standard operating procedures • Regular coordination, planning and review meetings between EWS stakeholders • EWS centres operational 24/7 and staffed by trained personnel • Communication strategies to ensure coordination across warning issues and dissemination channels, as well as to build credibility and trust in warnings (particularly at the community level) • Early warnings tailored to the different risks and needs of specific population groups (including differential vulnerabilities and capabilities) and reaching the entire population • Feedback mechanisms to verify that warnings have been received and to correct potential failures in dissemination and communication
Preparedness and response capabilities	• Strengthened capacities from national to community level to prepare for and manage climate risks – in particular, floods, droughts and landslides • Increased coordination between different sectors (e.g., health and disaster risk management) that need to be ready to respond to extreme events in a timely manner • Disaster preparedness measures, including plans and standard operating procedures, that account for the differential needs, vulnerabilities and capacities of population groups

	• Disaster preparedness and contingency plans informed by scientific data and climate projections • Early action and response options linked to the provision of funding to support them – i.e., Forecast-based Financing • Participatory analysis of historical emergency and disaster events, and incorporation of lessons learned into preparedness and response plans, and into capacity-building strategies • Increased awareness and education on weather, water and climate-related hazards and climate change impacts in communities, sectors and government • Increased awareness on how warnings will be disseminated, which sources are reliable and how to respond • Tailoring of awareness and education campaigns to the specific needs of different population groups

Table 9: Summary needs assessment for climate information and early warning services (CIEWS) in Timor-Leste

6.3 – BARRIERS TO EFFECTIVE CLIMATE INFORMATION AND EARLY WARNING SERVICES

Post-disaster assessments and consultations with stakeholders reveal persistent barriers to the effective use of early warnings, that is, the generation of reliable and authoritative advice, and the reception and understanding of that advice by everyone who needs it. Key barriers for Timor-Leste are:

- Lack of legislative, regulatory and policy frameworks for climate services and disaster risk management, as also highlighted in the 2030 Agenda for Sustainable Development and its Sustainable Development Goal (SDG) 13, target 13.b, which aims to "*Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States*".
- Inadequate observation networks and sector-specific climate information (e.g. for agriculture and disaster response), as also recognised under the Paris Agreement Article 7, 7c, which stresses the need for "*Strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making*".
- Limited communication and use of climate hazard and risk information, as also recognised by the Sendai Framework on Disaster Risk Reduction, which highlights in I, 14 that "*there is a need to address existing challenges and prepare for future ones by focusing on monitoring, assessing and understanding disaster risk and sharing such information...and enhancing multi-hazard early warning systems...*" and in III, 19g that "*Disaster risk reduction requires a multi-hazard approach and inclusive risk-informed decision-making based on the open exchange and dissemination of disaggregated data…*".
- Limited capacity and funding to prepare for and manage climate risks, as also recognised in the Paris Agreement Article 11, 1, which emphasises the need to "*enhance the capacity and ability of developing country Parties*" and facilitate "*access to climate finance, relevant aspects of education, training and public awareness, and the transparent, timely and accurate communication of information*".

7 – EXISTING AND/OR PREVIOUS PROJECTS AND INITIATIVES FOR CLIMATE ACTION IN TIMOR-LESTE

7.1 – INTERNATIONAL AGREEMENTS, STRATEGIES AND FRAMEWORKS

The proposed Project is aligned with the Sustainable Development Goals, the Paris Agreement and the Sendai Framework.

The development of effective multi-hazard early warning systems (MHEWS) contributes to the achievement of several of the UNDP **Sustainable Development Goals** (SDGs), but particularly to Goal 13: Climate Action, and its objective: *To improve education, awareness raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning*. Target 13.1 advises countries to "*Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries*".

The **Paris Agreement** in Article 7, Sub-paragraph 7(c) calls for "*strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making*".[495]

The **Sendai Framework for Disaster Risk Reduction 2015–2030** [496] is a non-binding voluntary agreement that recognises that the State has the primary role to reduce disaster risk, but that responsibility should be shared with other stakeholders including local government, the private sector, and other stakeholders. It has seven Global Targets, of which one is: *Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.* In paragraph 33 b) the Framework stresses that it is important "*To invest in, develop, maintain and strengthen people-centred multi-hazard, multisectoral forecasting and early warning systems, disaster risk and emergency communications mechanisms, social technologies and hazard-monitoring telecommunications systems; develop such systems through a participatory process; tailor them to the needs of users, including social and cultural requirements, in particular gender; promote the application of simple and low-cost early warning equipment and facilities; and broaden release channels for natural disaster early warning information*". The Sendai Framework's Seven Global Targets calls for efforts to "*substantially increase the availability and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030*."

Global Framework for Climate Services[497]

The proposed Project draws on guidelines developed by the World Meteorological Organization as a means to ensure effective end-to-end provision of climate services from observation and data collection to delivery of usable advice. A component of the Project will be the development, through facilitated stakeholder workshops, of a National Framework for Climate Services (NFCS) specific to the requirements of Timor-Leste.

"The Global Framework for Climate Services (GFCS) accelerates and coordinates the technically and scientifically sound implementation of measures to improve climate-related outcomes at national, regional and global levels. As a framework with broad participation and reach, GFCS enables the

[495] https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[496] https://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf
[497] WMO. Global Framework for Climate Services (GFCS). Available at: https://gfcs.wmo.int/

development and application of climate services to assist decision-making at all levels in support of addressing climate-related risks."

Formed as the principal outcome of the 2009 World Climate Conference 3, the GFCS:

- Provides the international mechanism for coordinated actions to support and enhance the quality, quantity and application of climate services;
- Builds where appropriate on existing efforts, focusing on meeting user needs to provide the greatest benefits possible from knowledge about the climate;
- Provides widespread social, economic and environmental benefits through more effective climate and disaster risk management;
- Supports research in the development and implementation of climate change adaptation measures, many of which will require climate services not currently available;
- Aims to link the outputs of scientific research to the products generated by service providers that will then serve the practical needs of end users;
- Benefits climate change mitigation activities by providing information that supports the development of renewable energy infrastructure and other mitigation measures such as reforestation; and
- Aims to ensure that every country is better equipped to meet the challenges of climate variability and change.

The implementation of GFCS has five components (Figure 124):

- Observations and Monitoring;
- Climate Services Information System;
- Research, Modelling and Prediction;
- User Interface Platform; and
- Capacity Development.

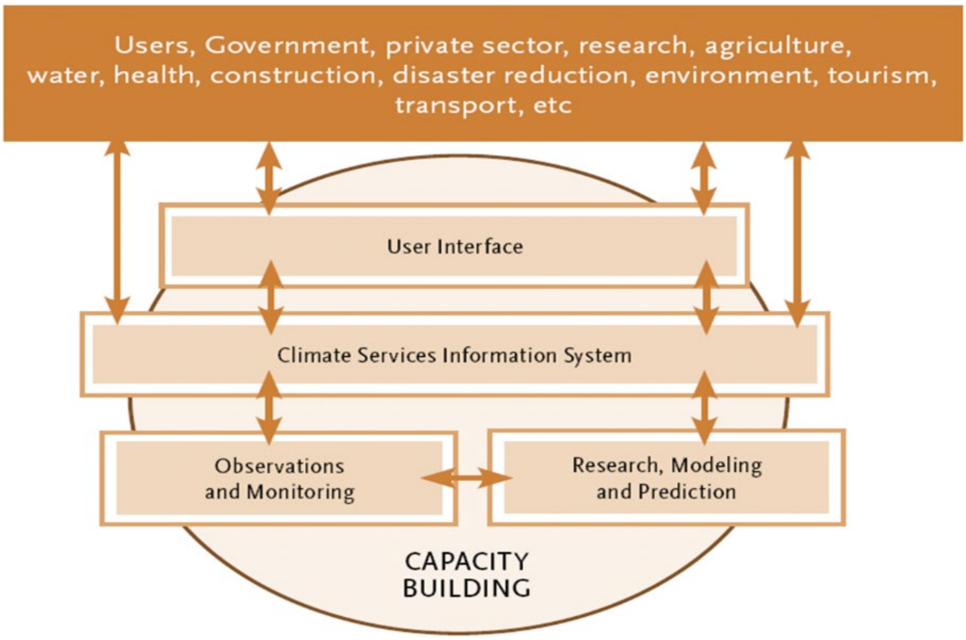

Figure 251: Components of Global Framework for Climate Services

The GFCS focuses on developing and delivering services in five priority areas, which address issues basic to the human condition and present the most immediate opportunities for bringing benefits to human safety and wellbeing:

- Agriculture and Food Security
- Disaster Risk Reduction
- Energy
- Health
- Water

National Framework for Climate Services

The widespread and effective use of climate services requires significant interaction among many organisations and people, including government, civil society, communities, partners and donors, and must involve decision makers, climate experts and sector disciplines. While there is a significant improvement in climate predictions, there is still a need to improve the use of climate information to better address user needs.

WMO has provided "Step-by-step Guidelines for Establishing a National Framework for Climate Services"[498] for NMHSs to develop climate services at the national level. The document outlines a three-phased approach:

1. Assessing the baseline on climate services (What are the capacities of the country in the five pillars? What is the country's state of readiness to implement an NFCS? Who are the key stakeholders/users/clients/partners? What climate services are currently provided?);

2. Organising a national stakeholder consultation workshop on climate services – a national dialogue should be established between the NMHS and the users;

3. Developing a national strategic plan and action plan for the NFCS.

The NFCS is also built upon the five components of the GFCS.

7.2 – INITIATIVES SUPPORTING EARLY WARNING SYSTEMS IN TIMOR-LESTE

In the absence of a functional end-to-end early warning system in Timor-Leste, several organisations have included ad-hoc early warning related work at the community level, but these efforts have not been coordinated or integrated into a broader national system. Short term assistance has been provided in the past to the DNMG and other Government agencies engaged in climate services and disaster risk reduction, but again without managing to clarify roles and formalise responsibilities. Activities that have made or are making a lasting impact, and with which the proposed Project will collaborate, include the following projects.

The UNDP GCF Project ***Safeguarding rural communities and their physical assets from climate induced disasters in Timor-Leste***: this project is helping Timor-Leste agencies to climate proof the essential small scale rural infrastructure—roads and bridges, water supplies and sanitation, flood defences—upon which rural populations rely, targeting the six most vulnerable municipalities (15% of total population).

It will conduct vulnerability assessments of high-risk communities, which will provide a baseline measure of food insecurity and related information. FAO, MAF and this Project will work with extension officers to introduce the use of climate forecasts in making farming decisions, and the Project will also address the need for early warnings of extreme events.

[498] WMO, 2018. WMO-No. 1206. Step-by-step Guidelines for Establishing a National Framework for Climate Services

The vulnerability assessments will inform the proposed Project's priorities for early warning systems development. In turn, this Project will benefit the UNDP GCF Project's climate-related hazard risk assessments in the future by providing improved access to good quality climate data and information—this will significantly enhance the utility of the risk assessments. Collaboration with the UNDP project will be integrated at all levels, including through support for regular meetings of the group of Government ministries and UN agencies responsible for coordinating early warnings, climate change adaptation and disaster risk reduction.

Key outputs of the proposed Project that will add value to the UNDP GCF project are outlined in the table below.

Key outputs in UNEP FP	Added value to UNDP FP109 ("Safeguarding rural communities and their physical and economic assets from climate induced disasters in Timor-Leste")
Enhanced observations and monitoring underpinning climate information and early warning services	Permanent strengthening of the Met Service DNMG to provide **high spatiotemporal resolution weather and climate data** from Automatic Weather Stations and Radar will underpin UNDP's **climate hazard, risk and vulnerability mapping**
Multi-hazard impact-based forecasting and **DSS** for disaster risk reduction	Will provide an **evidence base for strategic, climate risk-informed decision making**, planning, risk screening and project prioritization for the UNDP-led **climate-resilient infrastructure** and **de-risking of investments**
Enhanced **fire risk mapping** and **fire event management**	Will **reduce the risk of wildfire damage and destruction to small-scale rural infrastructure** funded under the UNDP project
Re-establishment of the **National Disaster Operations Centre** (NDOC)	Will enable timely emergency responses to **minimise impacts of climate hazards on critical infrastructure** funded under the UNDP project
Increased **public awareness** and **education** on climate hazards, risks and early warning	Will **equip communities with scientific knowledge, understanding and timely warnings** to **safeguard the rural infrastructure and assets** funded by the UNDP project
Integrated Community-Based Risk Reduction (working with Timor-Leste Red Cross Society (CVTL))	Will build the capacity of communities to adopt **climate-resilient livelihood practices** and reinforce UNDP's **climate-proofing** activities
Forecast-based Financing (FbF)	Will **minimize climate-induced loss and damage to infrastructure** and help **safeguard the rural infrastructure and assets** supported by the UNDP project

Table 10: Added value of the proposed Project to the approved GCF country portfolio – UNDP FP 109

The AE understands that critical elements of hydrology and hydraulics are already covered in the UNDP GCF project, which is undertaking flood risk mapping, flood modelling and forecasting for major river basins. The proposed Project will build on their outputs and address the critical gap of integrating the observation data from monitoring stations (including hydrometric and hydrological) maintained by various agencies including, but not limited to, DNMG, the National Directorate for Water Resources Management (DNGRA), the Agriculture and Land-use Geographic Information System (ALGIS), and the Ministry of Agriculture and Fisheries (MAF). The proposed Climate Data Informatics System (CDIS) for DNMG will host all hydrological data along with weather and climate data in a single platform for easier access, quality control, and generation of derived products.

The UNDP GCF project is addressing hydrology and hydraulics needs in Timor-Leste as follows:

- *Hydrological modelling* – Rainfall-runoff models of all upstream catchments that feed into the main basins will be developed to simulate runoff responses. Rainfall-runoff modelling will be based on catchment physical data (topography, land use, soils, geology) and rainfall event characteristics (observed rainfall time series data and statistical rainfall parameters).

Catchment-scale topographic LiDAR data is available for the whole of Timor-Leste and is held by the Ministry of Finance. For rapidly responding sub-catchments, such as those in steep upstream catchments, rainfall-runoff modelling will require sub-daily rainfall and flow data (e.g. hourly) for calibration. If sub-daily rainfall data is not available, UNDP proposes to use a standard distribution to derive the hyetographs for rainfall-runoff modelling.

- *Hydraulic modelling* - A hydraulic model of each floodplain will be developed to route the flood hydrograph through the channel and floodplain of the study basin. The hydraulic model will need to be calibrated and verified in tandem with the hydrological model until good agreement is reached between modelled and observed levels and flows at key gauging locations or observed flood extent maps derived from historical flood surveys and satellite imagery.
- *Flash flood hazard mapping* – Flash-flood prone areas will be identified using meteorological criteria (rainfall amounts and intensities), geomorphologic criteria, hydraulic modelling, risk assessment and vulnerability analysis.
- *Modelling the impacts of climate change on catchment hydrological response* – The impact of climate change will be modelled using a perturbation approach that applies simple step changes to observed meteorological time series.

The JICA GCF Project ***Community-based Landscape Management for Enhanced Climate Resilience and Reduction of Deforestation in Critical Watersheds***: this project aims to promote community-based sustainable natural resource management to decrease deforestation and forest degradation. Key outputs of the proposed Project that will add value to the JICA GCF project are outlined in the table below.

Key outputs in UNEP FP	Added value to JICA SAP021 ("Community-based Landscape Management for Enhanced Climate Resilience and Reduction of Deforestation in Critical Watersheds")
Enhanced observations and monitoring underpinning climate information and early warning services	Permanent strengthening of the Met Service DNMG to provide **high spatiotemporal resolution weather and climate data** from Automatic Weather Stations and Radar will underpin JICA's capacity building to **understand climate hazards, risks and drivers of natural resource degradation**
Agriculture Stress Index System (ASIS) and **Early Warning for Agriculture**	**Sector-specific impact-based forecasts** and **action-oriented early warnings** will **facilitate climate-resilient agriculture** and **sustainable natural resource management** funded by the JICA project and **prevent maladaptation**
Air Quality Monitoring System	Will enable Timor-Leste to **monitor GHG and PM2.5** emissions to conduct **Impact Assessments** and assess the **effectiveness of mitigation** supported by the JICA project
Enhanced **fire risk mapping** and **fire event management**	Will **reduce the risk of wildfire damage and destruction to natural environments** where JICA is supporting climate-resilient agriculture, reforestation and sustainable forest management activities
Increased **public awareness** and **education** on climate hazards, risks and early warning	Will **equip communities with scientific knowledge, awareness and understanding** to **sustainably manage natural environments** supported by the JICA project
Integrated Community-Based Risk Reduction (working with Timor-Leste Red Cross Society (CVTL))	Will improve **community-level disaster risk reduction** to **maximise the effectiveness of community-based natural resource management** supported by the JICA project
Forecast-based Financing (FbF)	Will **mitigate climate impacts to natural resources and ecosystems** and help **bolster climate-resilient livelihood actions** supported by the JICA project

Table 11: Added value of the proposed Project to the approved GCF country portfolio – JICA SAP 021

JICA has been supporting sustainable development in Timor-Leste for over two decades and continues to provide support through technical cooperation projects, expert advisory, and partnerships. With relevance to the water sector, support from JICA includes hydrological and hydraulic surveys, water supply improvement and community-based integrated watershed management. The installation of monitoring equipment for hydrometeorological hazards (including river monitoring) is a priority project for 2021 – 2025.[499]

Climate change research and modelling: the Timor-Leste Government has recommended that academic institutions such as the National University of Timor Lorosa'e (UNTL) Climate Change Centre have better access to UNFCCC climate change scenarios and apply them to establish or improve drought and flooding predictions in support of the DNMG. The Centre for Climate Change and Biodiversity (CCCB) in the Faculty of Agriculture of UNTL is already providing some climate change related training to relevant ministries, such as crop modelling by using DSSAT (the decision support system for agrotechnology). The proposed Project will give the CCCB access to climate change models such as CMIP5 (Coupled Model Intercomparison Project Phase 5) and provide related training on interpreting the outputs. The Project will arrange for a technical partner agency to provide intensive training on climate modelling to CCCB staff in the first year so that they can enhance the accuracy of their trainings to relevant ministries and stakeholders.

The ***Integrated Community-Based Risk Reduction*** (ICBRR) program managed by the Cruz Vermelha de Timor-Leste (CVTL: Timor-Leste's Red Cross National Society) protects and supports communities and households whose health, safety and livelihoods are most vulnerable to climate-related hazards. The proposed Project will enable CVTL to scale up community-based disaster risk management approaches, establish community-based early warning systems, train additional facilitators, conduct an annual coordination meeting with related organizations and manage two climate change conferences over the term of the Project. CVTL will conduct multiple capacity building and awareness workshops with communities as the entry points for supporting enhanced preparedness. CVTL will draw on key lessons from previous pilot projects—particularly that individual communities face complex sets of risks, which are inter-connected and best tackled together in a systematic, integrated way.

EWS stakeholder group meetings: The Project will support an existing group of Government ministries and UN agencies responsible for coordinating early warnings, climate change adaptation and disaster risk reduction, expanding the group to include NGOs/CBOs and enabling the group to convene regularly. The following agencies will be invited to establish a coherent approach to and understanding of EWS in Timor-Leste—UN agencies (such as FAO and IOM), international NGOs (including Mercy Corps, CARE, Oxfam, PLAN, World Vision, Caritas, and Child Fund), and local organisations (CVTL[500], RHTO[501], ASRRD[502], Fraterna[503] and others). Existing ad-hoc early warning related work at the community level will benefit from improved coordination and integration into a broader national system.

An MoU between Indonesia and Timor-Leste for the meteorology, climatology and geophysics sector was signed in January 2016 to establish cooperation between the ***Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG)*** and the Ministry of Public Works, Transport and

[499] JICA, 2016. The Project for Study on Dili Urban Master Plan in the Democratic Republic of Timor-Leste. Available at: https://libopac.jica.go.jp/images/report/12268611.pdf
[500] Cruz Vermelha de Timor-Leste: Red Cross
[501] Ra'es Hadomi Timor Oan: the Disabled People's Organisation
[502] Asosiasaun Serbisu Redusaun Risku Dezaster: Association for Disaster Risk Reduction
[503] Fraterna: local environmental / disaster response NGO

Communication of Timor-Leste. The partnership includes providing support for calibration of meteorological and seismology equipment, human resource development, and the exchange of data and information about meteorology, climatology and geophysics. BMKG has since helped the Timor-Leste Government to calibrate 12 AWSs (Automatic Weather Stations) in 12 locations, in response to a request by the Ministry of Agriculture and Fisheries to establish a sustainable National Information and Early Warning System (NIEWS) on food security. BMKG also helped train MAF staff in the calibration and maintenance of AWSs.

The ***Climate and Ocean Support Program in the Pacific***, delivered by the Australian Bureau of Meteorology, included Timor-Leste's DNMG in some of its capacity building activities. It installed a simple, robust, open-source climate data management system (CliDE), developed as a common system for the 14 independent Pacific island countries, and it included the DNMG in training activities for some years. This Project will support DNMG to upgrade to RIMES's Climate Data Informatics System (CDIS).

The ***WMO Flash Flood Guidance System with Global Coverage Project:***[504] The Flash Flood Guidance System (FFGS) was developed to address the lack of global capacity to develop effective warnings for flash floods. The FFGS is a robust system designed to provide the products needed to support the development of flash flood warnings from rainfall events using remote-sensed precipitation (i.e., radar and satellite-based rainfall estimates) and hydrological models. To assess the threat of a local flash flood, the FFGS allows product adjustments based on the forecaster's experience of local conditions; incorporation of information, such as Numerical Weather Prediction (NWP) outputs; and in-situ observations, such as rain gauge data or local observer reports.

The ***Southeastern Asia-Oceania Flash Flood Guidance (SAOFFG) System***[505] project aims to develop and implement regional flash flood guidance and early warning systems. The approach involves the development of regional technology, training, protocols, and procedures to address the issues of mitigating the impacts of flash floods and the application of the system to provide critical and timely information by the National Meteorological and Hydrological Services (NMHSs) of the participating countries, which include Timor-Leste.

The First Steering Committee Meeting of the SAOFFG System in July 2017 reported progress in FFG basin delineation, initial model parameterization based on global datasets (soils, land cover), collection of publicly-available data from global datasets and integration of SAOFFG by system engineers. However, all development work was based on global datasets. The SAOFFG Technical Developer emphasized the need for local data, namely: i) Real-time precipitation data; ii) Historical precipitation data from rain gauges; iii) Digital spatial data on soils characteristics and landcover; iv) Historical streamflow data from stream gauges; and iv) Channel cross-sectional data.

Copernicus Emergency Management Service (EMS) Mapping:[506] The Copernicus EMS Mapping utilises satellite imagery and other geospatial data to provide free of charge mapping services in the case of natural disasters and other emergencies throughout the world. The maps are produced in two temporal modes: i) Rapid Mapping consists of the provision of geospatial information within hours or days from the activation in support of emergency management activities immediately following a

[504] https://public.wmo.int/en/projects/ffgs
[505] https://www.wmo.int/pages/prog/hwrp/flood/ffgs/saoffg/saoffg.php
[506] https://emergency.copernicus.eu/mapping/ems/emergency-management-service-mapping

disaster; and ii) Risk & Recovery Mapping consists of on-demand provision of geospatial information to support disaster management activities not related to immediate response.

In response to severe flooding in Timor-Leste in April 2021, CEMS Rapid Mapping was requested to assess the impact of the flood in the affected areas.[507] This included delineation products (to assess the geographical extent of the event) and grading products (to evaluate the intensity and scope of damage resulting from the event).

World Vision Timor-Leste has a long-term project in four municipalities: Aileu, Baucau, Bobonaro, and Covalima. WVTL has implemented DRR and disaster response projects in each of these areas and are currently targeting Bobonaro and Covalima with active drought response and drought projects funded by the Australian Humanitarian Response, New Zealand Ministry for Foreign Affairs and Trade and the Government of Germany. WVTL normally works at the community level ("aldeia" and "suco") and coordinates and cooperates at the municipality level to train local authorities on how to respond to alerts and advice.

The World Bank ***"Building Climate/Disaster Resilience Along the Dili-Ainaro and Linked Road Corridors in Timor-Leste"*** project (2015 – 2018) aimed to build the capacity of target communities and district and sector agencies in community-based disaster risk management (CBDRM) and adaptation to reduce the impact of recurring landslides and floods. The CBDRM activities included awareness-raising, development of suco disaster risk management plans and implementation of pilot community infrastructure sub-projects to reduce climate-related risks. Key lessons learned and recommendations from the project are detailed below:

- The Government of Timor-Leste's "ability to make timely policy and management decisions was the main impediment to project implementation. This is not necessarily a reflection of the professional capacity of the government personnel, but rather a systemic issue where systems and procedures inherited from the pre-independence era have not been fully transformed into a framework that fits with reality."
- Capacity building through technical support and knowledge transfer should be the core approach for countries with low delivery capacity. Pilot projects serve as proof-of-concept and showcase to build confidence. Study visits to neighbouring countries with similar development challenges, and mentoring, technical assistance and South-South learning represent low-cost capacity building solutions.
- "Entrusting the community to make development decisions is critical to building collective accountability." The community demand-driven approach is ideal for building trust and strengthening a community's social capital.
- Engagement of international professionals to support establishment of a management system and processes with a view to handing them over to national professionals mid-project is key to the design of a project management and sustainability strategy.[508]

ACP-EU NDRR Program: The "Climate and Disaster Resilience in Communities along Dili-Ainaro and Linked Road Corridors" Project (2013 – 2015) aimed to reduce the risks that Timor-Leste faces from natural disasters and minimize the losses that result to its infrastructure assets and livelihoods of poor rural farmers. The project has three main components: Hazard Risks Assessment within the Dili-Ainaro and Linked Roads districts (Ainaro, Aileu, Ermara and Manufahi); Strengthening Capacity at National

[507] https://emergency.copernicus.eu/mapping/list-of-components/EMSR507
[508] World Bank, 2019. Implementation Completion and Results Report TF01187

and District Level in Planning/Delivering Preventative Actions; and Community Based Disaster Risk Management (CBDRM) and Adaptation Projects within Districts connected by Dili-Ainaro Corridor and Linked Roads."[509]

Global Climate Change Alliance (GCCA): The GCCA support programme to Timor-Leste (2013 – 2018) aimed to improve the capacity of vulnerable populations in Timor-Leste to cope with climate change impacts through sustainable natural resource management and improved livelihood options, with a focus on forestry and agriculture. Key challenges and lessons learned are outlined below:

- "The project focused on the preparation and implementation of vulnerability assessments that are feasible and efficient in the context of Timor-Leste. These vulnerability assessments have the capacity to feed into the review of planning methodologies for integrated village development planning.
- [D]ocumentation on best practices and lessons learnt on Climate Change Adaptation in Timor-Leste fuels technical discussions with partners and other stakeholders and supported the identification of appropriate techniques.
- Capacity development activities and advisory services for key stakeholders as well as general public awareness raising campaigns are key to increase the quality of the technical dialogue and improve the overall feedback received by the project.
- Inter-institutional coordination with an effective leadership from the government is a key of success. Having a clear and realistic plan is also important to materialise coordinated actions."[510]

United Nations Office for the Coordination of Humanitarian Affairs: Natural Hazard Risks (UNOCHA, 2011) presented a map portraying the risks from earthquakes and tropical storms for Timor-Leste. The maps produced from this study show that the entire country falls under one category of the earthquake intensity that is the Modified Mercalli Intensity (MMI) scale VIII. Similarly, the whole country falls under the Saffir-Simpson scale 1 (118-153 km/h) for tropical storms. It does not appear that the study took into account local conditions in Timor-Leste, such as local site conditions, topographic slope, elevation, land use/land cover, and so on. All of these will have impact on the calculation hazard intensity at a local level.[511]

The UNDP ***"Disaster Risk Management Institutional and Operational Systems Development in Timor-Leste"*** project (2009) undertook a disaster risk and hazard map analysis for Timor-Leste. The project produced mapping products, which were made available in a Geographic Information System (GIS) called DRMInfo. The maps were divided into 'hazard' and 'element at risk' such as households, schools and bridges. Hazards covered include landslide, flood, fire, drought, tsunami, cyclone and earthquake.[512]

[509] Global Facility for Disaster Reduction and Recovery, 2015, "ACP-EU NDRR Program in the Pacific", GFDRR, July 2015
[510] GCCA, 2018. Global Climate Change Alliance support programme to Timor-Leste
[511] Asian Disaster Preparedness Centre, 2013. Timor-Leste: A country situation report on disaster risk assessment related initiatives
[512] Asian Disaster Preparedness Centre, 2013. Timor-Leste: A country situation report on disaster risk assessment related initiatives

The Project will contribute directly to Timor-Leste's achievement of progress towards these objectives, as well as facilitating meaningful reporting on that progress.

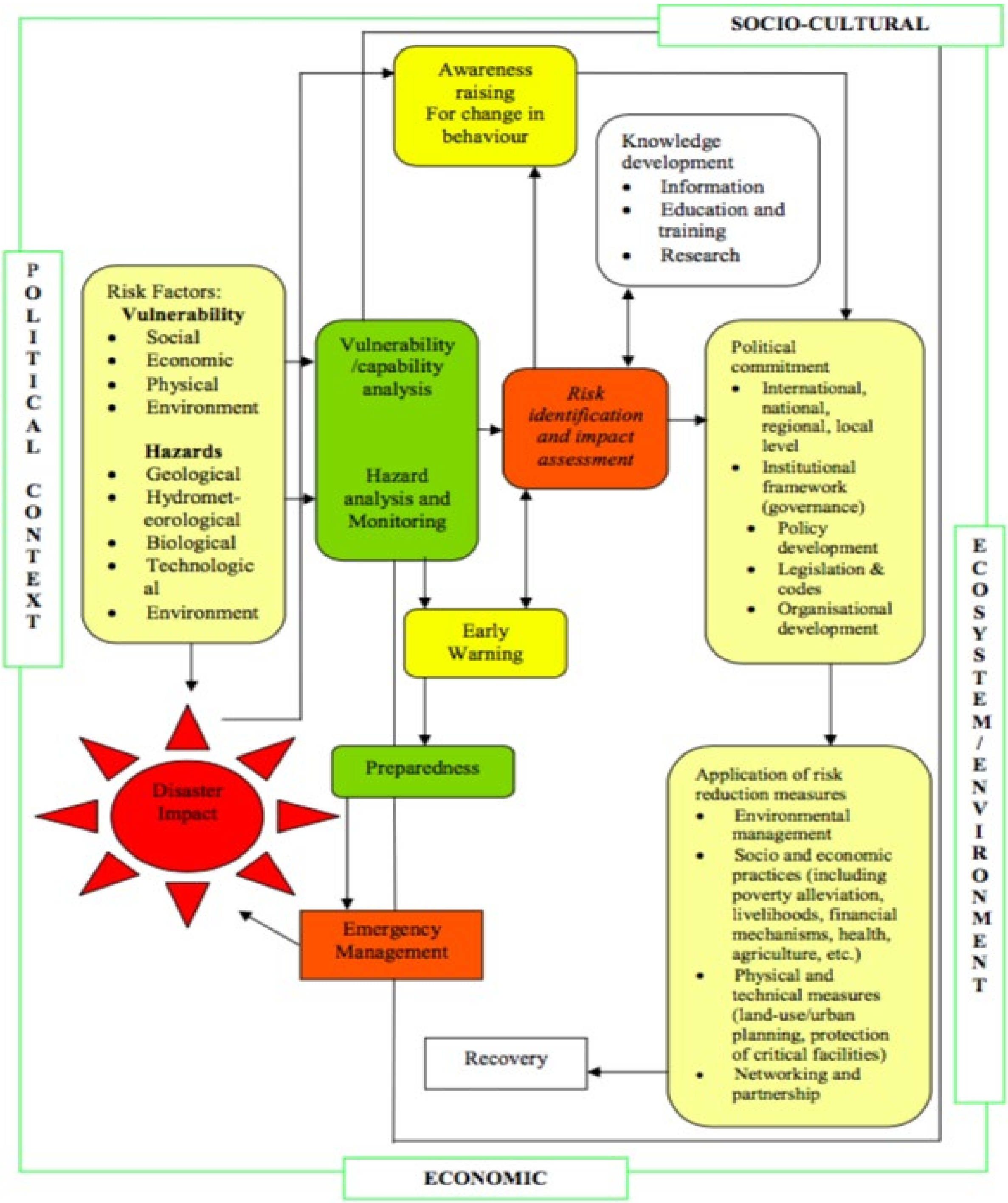

Figure 252: A framework for disaster risk reduction (Timor-Leste NDDRM Policy, 2008)

Impact					
5	Tsunami				
4	Earthquake				Drought/El Nino
3		Pandemic		Landslides	Flood
2			High Wind Fire		
1	Civil Unrest				
Likelihood	1	2	3	4	5

Figure 253: Risk matrix for Timor-Leste (Source: International Organization for Migration)

Regional Integrated Multi-Hazard and Early Warning System for Africa and Asia (RIMES)

RIMES is an international and inter-governmental institution, owned and managed by its Member States for the generation and application of early warning information, focusing on end-to-end early warnings of tsunami and hydrometeorological hazards. It provides regional early warning information and services and helps to build the capacity of its member states (which include Timor-Leste). RIMES was established on 30 April 2009 and was registered with the United Nations on 1 July 2009. RIMES operates from its regional early warning centre located at the campus of the Asian Institute of Technology in Pathumthani, Thailand.

RIMES caters to differential needs and demands of its Member States by enhancing capacities for end-to-end multi-hazard early warning, in particular: hazard monitoring, detection, analysis, prediction, and forecasting; risk assessment; potential impact analysis; generation of tailored risk information at different time scales; risk communication; and application of tailored risk information in decision-making.

RIMES has established a sub-regional hub in Papua New Guinea and in January 2018 it funded a workshop on Climate Early Warning Systems in Fiji. Several countries are currently exploring becoming either a member state or an official collaborating country. RIMES is closely associated with WMO and will work collaboratively on EWS activities.

7.3 – INITIATIVES SUPPORTING EARLY ACTION IN TIMOR-LESTE

The ***Start Fund Crisis Anticipation Window*** enables NGOs to prepare for forecasted crises and respond early to mitigate the predicted impacts. It is the first NGO funding mechanism available for anticipatory interventions. In the event of a crisis, an alert is issued by a Start Network member in order to trigger a decision on allocation of funding to the alerted crisis.[513]

[513] Start Network, 2020. Start Fund Crisis Anticipation Window. Available at: https://startnetwork.org/start-fund/crisis-anticipation-window

Alert 158 for Timor-Leste was submitted on 2 May 2017, based on a predicted 70% likelihood of drought due to a second El Niño event from November 2017. The Start Fund allocated GBP 200,000 to the alert. Anticipatory activities were implemented by five agencies: four implemented food and seed distribution and one (Oxfam) conducted an early warning system analysis and drought preparedness activities.

Figure 254: Overview of the Start Fund Crisis Anticipation Window Alert 168 for Timor-Leste (Source: Start Fund)

Based on interviews with stakeholders from the Government of Timor-Leste, the Start Network, UN agencies and the Red Cross, and analysis of available forecasting information and its use, the Oxfam Early Warning Systems Analysis generated recommendations to build a drought early warning system for Timor-Leste. Oxfam then leveraged AUD 50,000 through the Australian Humanitarian Partnership to enable recommendations to be taken forward, thus facilitating impact beyond the 45-day implementation window. The drought preparedness activities involved drought contingency planning workshops for local partner organisations. Oxfam subsequently invested GBP 32,000 (GBP 5,300 per partner) to fund implementation of the contingency plans.

Key learning points from the intervention relevant to the proposed Project are detailed below:

- "Early warning systems analysis and capacity development form parts of longer-term strategies, but can benefit from timely investment, when a specific forecast is identified. These activities have the added benefit of having longer term impact, meaning they add value even if a specific forecast does not come to fruition."
- Assessments and surveys showed that "the issues caused by drought are multi-dimensional and reach beyond food and agriculture. Access to water being a key concern. …[D]rought mitigation should seek to integrate approaches to account for this complexity."
- Qualitative reflections gathered from community members "yielded many clear recommendations in relation to improving the impact of seed distributions and mitigating

drought risk; community member perspectives should be integrated into project planning where possible and their expertise recognised."[514]

8 – METHODOLOGY

In July 2019 the proposed Project's revised Concept Note was endorsed by Timor-Leste's NDA and approved for further development by the GCF. UNEP engaged consultants to undertake the fieldwork required to revise and complete a Feasibility Study and develop a Funding Proposal.

The consultants[515] engaged an in-country Stakeholder Engagement Specialist (SES) to lead the stakeholder engagement in Timor-Leste. The SES worked in-country from 9 September 2019 to 14 December 2019 and used his wide network within Timor-Leste's Government and national and international NGOs to arrange meetings with their representatives. Consultations began from the Project outline, its agreed components and the suggested interventions and activities. Stakeholders were invited to share their knowledge and ideas and provide detailed input on potential interventions and activities for the Project.

The Stakeholder Engagement Plan (Annex 7) reports on the priority issues arising from face-to-face meetings with stakeholders. The SES met about two dozen representatives from multiple departments within Timor-Leste ministries and departments, including the Meteorological Service (DNMG), Secretary of State for the Environment, the National Directorate for Climate Change, the Director of the Centre for Climate Change and Biodiversity, and the National Directorate for Research at the Ministry of Agriculture and Fisheries. The SES also met with members of local NGOs and representatives from international organisations such as FAO, UNDP, and the Red Cross Society of Timor-Leste.

The purpose of these national consultations was to ensure ownership of the proposed Project, achieved through discussion with national, provincial, community, sector and regional stakeholders, development partners, private sector, NGOs, women, children, youth and vulnerable marginalised groups, and by identifying their priorities for EWS.

In-country work also included:

- Gender analysis and formulation of a Gender Action Plan (Annex 8): In the development and implementation of EWSs, little consideration is usually given to the differences between women's and men's situations, perceptions of threats, vulnerabilities and access to information and resources. Integrating a gender perspective can ensure better prevention and robust responses and preparedness. In order to improve the effectiveness of EWSs, the objective of this analysis was to inform the design of the Project with a specific and precise assessment of gender implications including gender roles, power relations and a disaggregation of women's and men's specific interests, needs, and priorities. These are very significant in Timor-Leste, which ranks poorly on gender equality by world standards. The Gender Action Plan provides recommendations on how to enhance the benefits of the Project for both men and women and to promote gender equality including gender-responsive activities, gender performance measures and gender-disaggregated indicators.

[514] Start Network, 2018. Case Study: Start Fund Alert 158. Timor-Leste: Anticipation of Drought 2017
[515] Pacific Science Solutions: https://pacscisol.com/

- Institutional analysis: Assessment of Project implementation arrangements, particularly the capacity of Timor-Leste's government agencies to implement the Project and operate the infrastructure. The SES also identified capacity development activities.

As the Project's scope (as defined in the Concept Note) was progressively agreed with national partners and activities were prioritised, more detailed work was undertaken, such as:

- Development of detailed costings for each proposed intervention by the requesting agency (this process is described below in the section on Budget Development).
- Economic analysis (Annex 3): Assessment of the economic benefits and potential costs of the Project on the basis of a preliminary budget outline.
- Formulation of an Operation and Maintenance (O&M) Plan (Annex 21) including development of a long-term management and monitoring plan (beyond Project completion) with indicative budget to ensure sustainable operation and maintenance of the infrastructure and equipment.
- Environmental and Social Safeguards (ESS) (Annex 6): Activities to be implemented by the Project are category C activities with low or no adverse environmental and social risks and impacts. This assessment consisted of a screening of environmental and social risks appropriate to this category and identification of mitigation and risk management measures, as necessary.

Minutes of the meetings conducted by PSS and the Stakeholder Engagement Specialist are provided in the Stakeholder Engagement Plan (Annex 7). Discussions were guided by a document provided by the consultants: a table aligning activities prioritised by Timor-Leste agencies for the original Concept Note with the agreed four components of the final approved Concept Note and their outputs.

Agencies were asked to check the activities in the table, to confirm those they wanted to keep in the proposal, and to make any corrections needed to the name of the agency, activity details, etc. For the activities nominated for retention, each agency was asked to explain each request with enough detail for it to be considered for inclusion:

- Every Activity should be within the Project's scope;
- Baseline information or information on the current situation should be provided wherever applicable;
- The Activity description should what was to be done, how, where, by whom and when;
- The justification should demonstrate how the proposed Activity will achieve all or some of the following:
    - Improve or address or eliminate a current issue;
    - Benefit Timor-Leste (or targeted groups);
    - Cost effectiveness;
    - Long-term sustainability; and
    - Contribute to the Project's objectives.

The in-country consultations had generated requests for new activities, not included in the original Concept Note, but consistent with the Project's objectives and within its scope. Each of these activities required the same information from its sponsoring agency—in some instances the Activity was to be delivered by a regional agency or other development partner, who would provide the information needed.

8.1 – SELECTION CRITERIA

The GCF finances climate resilient and low-emission projects and programs that contribute towards achieving at least one of its eight strategic impact areas—four of these are related to adaptation and four to mitigation areas—through activities that drive paradigm shifts towards low emission economic growth and climate resilience. When deciding on whether to invest in projects, the GCF seeks to strike a balance between national priorities, potential to deliver concrete climate benefits, cost considerations, and opportunities to deliver co-benefits.

The GCF has identified the following five high potential investment priorities that are particularly promising for achieving mitigation and adaptation action. These investment priorities aim to achieve cross-cutting benefits in an efficient and impactful way. The investment priority areas are as follows:

1. Enhanced resilience in Small Island Developing States;
2. Climate compatible cities;
3. Sustainable low emission, climate resilient agriculture;
4. Scaled up finance for forests and climate change;
5. Transformed energy generation and access.

The proposed Project specifically addresses the priority for enhanced resilience in Small Island Developing States.

To ensure that GCF resources achieve a paradigm shift towards climate resilient and low-emission development in an economically efficient and inclusive manner, the GCF has outlined six high-level investment criteria and activity-specific sub-criteria that all project proposals need to reflect (as shown in the following figure). When determining whether proposals reflect these criteria, the GCF uses indicators which take into consideration the context of the country.

Figure 255: GCF high-level investment criteria[516]

[516] GCF, 2018. Investment criteria indicators

The Project interventions have been designed to meet the GCF investment criteria as follows:

Impact Potential

This Project will deliver transformative impact in Timor-Leste. It will increase resilience and enhance livelihoods of the population of Timor-Leste through a paradigm shift to evidence-based decision making, and through strengthened preparedness to climate risks. This will be achieved by strengthened delivery of climate services and multi-hazard early warnings, which are crucial for building the climate resilience of Timor-Leste and its vulnerable communities. As climate-related hazards increase, the Project will enhance delivery of timely, credible, impact-based and actionable climate and weather information. Moreover, the Project will reach the "last mile" by engaging communities in the understanding and use of actionable climate information products and targeted early warning alerts. This will eventually lead to a reduction in the number of people affected by climate-related hazards.

The Project will contribute to the achievement of the following Fund-level impacts stated in the GCF Performance Measurement Framework (PMF):

A1.0 Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions.

The Project aims to improve the resilience of 1,293,119 people (51% male and 49% female). This represents the entire population of Timor-Leste who are expected to benefit from the Project's significant in-country capacity building to deliver integrated weather, water and climate information services, impact-based multi-hazard early warning systems (MHEWS), and evidence-based decision-making and planning underpinned by high-resolution data, information and risk knowledge. This includes 1,034,495 direct beneficiaries (80% of the total population), which is the estimated population most at risk from worsening climate-related hazards, particularly from drought, flooding, and landslides that are often precipitated by extreme rainfall events. People are also affected by coastal inundation, storm surges and cyclones. Both coastal populations and communities in remote inland areas are increasingly at risk from loss of livelihoods and assets as well as injury and loss of life.

The cost-benefit analysis (CBA) for EWS in Timor-Leste shows a positive net present value (NPV) of US $56.01 million with a 10% discount rate. The economic internal rate of return (EIRR) of 104.3% exceeds the discount rate, making the proposed investment economically viable. Sensitivity analysis has been used to test key parameters such as a decrease in benefits by 10% or an increase in costs of 10%. Although the EIRR decreased with those simulated cost benefit changes, the EIRR remained well above the 10% threshold in both cases (90.2% and 91.5% respectively). In addition, an even more pessimistic scenario combining a decrease in benefits by 10% and an increase in costs by 10% still results in a very high NPV and EIRR (US $46.81 million and 79.4%). The overall conclusion is that proposed EWS interventions will have substantial benefits, even if costs have been underestimated and benefits overestimated. The CBA provides positive quantitative justification for the Project, which is estimated to generate a benefit-cost ratio of 5.7:1. This suggests that each USD 10 invested will translate to benefits with a value of USD 57.

The Project aims to reduce the expected losses of lives and economic assets from the impacts of extreme climate-related disasters and is expected to achieve an overall reduction in damages and losses through increasing the safeguarding of assets (such as fishing boats and equipment, agricultural land and properties) from climate-related hazards through accurate, timely and actionable early warning services established by the Project. Actionable climate information products, particularly for agriculture, health, water and disaster management, will increase resilience and reduce the risks from climate-related hazards, thus minimising losses and damage to crops and other assets. Strengthening

DNMG with modern and cost-effective infrastructure and support for local capacity and institutional development will enable Timor-Leste to improve services to the level required to provide the evidence base for risk-informed decision making and planning, Forecast-based Financing and Early Warning Early Action.

A2.0 Increased resilience of health and well-being, and food and water security

The Project will promote multi-stakeholder climate action, bringing together actors in sectors such as public health, disaster risk management, agriculture and water resource management and empowering them with actionable knowledge to enhance their resilience to increasing climate threats. Improved understanding of climate risks to health and well-being, and food and water security, through tailored forecasting and a health sector-specific decision support system together with targeted training, awareness-raising and climate-related heath impact advisories will enable decision-makers – from government leaders to individual citizens – to take appropriate actions to keep the population of Timor-Leste safe and healthy. Continuous engagement of multiple stakeholders across the climate services value chain – for example, through the national Climate and Health Working Group – will enable identification of climate-related health, food and water security priorities and development of the most appropriate products and services to address these priorities. Moreover, the Project proposes to increase the proportion of households that have secure food and water sources through the establishment of end-to-end early warning systems for extreme climate events that threaten food production and water supplies. A high proportion of rural households are known to have very precarious incomes and resources, which are put further at risk by their lack of information about climate threats. Currently, Timor-Leste has insufficient capacity, data and infrastructure to provide adequate warnings. Furthermore, the Project will work with agriculture extension officers to introduce the use of sector-specific forecasts and early warnings to inform climate-resilient planning, and the Project will also address the need for early warnings of extreme events.

A complementary GCF-funded UNDP project “Safeguarding communities and their physical assets from climate-induced disasters in Timor-Leste” (FP109) is addressing key elements of hydrology and hydraulics, which will contribute to enhancing water security. This includes flood risk mapping, flood modelling, and forecasting for major river basins. The Project will build on their outputs and address the critical gap of integrating the observation data from monitoring stations (including hydrometric and hydrological) maintained by various agencies (including the National Directorate for Water Resource Management – DNGRA). The proposed Climate Data Informatics System (CDIS) will host all hydrological data along with weather and climate data in a single platform for easier access, quality control, and generation of derived products. The approach taken to integrate hydrology and hydraulics throughout the Project takes into account the low baseline capacity in Timor-Leste and has been carefully designed to complement FP109, rather than duplicate it. Complementarity with FP109 will be accomplished without any additional budgetary allocation. A multi-level institutional arrangement has been developed to facilitate establishment of synergy and effective collaboration. The arrangement is outlined in Section 9.

A6.0 Increased generation and use of climate information in decision-making

The Project will substantially expand the geographical coverage of weather and climate observations in Timor-Leste and its coastal waters by modernising observation and communication equipment, refurbishing and upgrading weather stations and installing additional observation equipment in compliance with Global Basic Observing Network (GBON) requirements. Additional data will be made available as information to government sector agencies and other relevant platforms (such as cloud computing).

The Project will support the development of tailored information products for communities, climate-sensitive sectors and other relevant stakeholders, with a particular emphasis on the agriculture, health, water and disaster risk management sectors. It will support DNMG and key stakeholders to translate hydrometeorological, climate and sector information into sector-relevant impact-based forecasts, which in turn will feed into sector-specific decision-support systems (DSS). The overall aim of the DSS will be to complement and improve efficiency in the dissemination of forecasts, early warning and response advisories. It will provide a means for decision makers and disaster managers to correlate between scientific parameters and potential impacts by visualising information in a user-friendly, understandable and actionable format. The Project interventions (namely Sub-Activities 2.2.3 and 2.3.3) are designed to ensure that development and operationalisation of the DSS is realistic within the budget and timescale of the Project and will be sustainable beyond the implementation period – as elaborated in Section 9.

Moreover, the Project will foster mutually beneficial partnerships between the DNMG and climate information users, so that the meteorological service understands how sectors and communities want to use information. It will support DNMG in training users to understand climate basics and apply information to planning. The National Climate Outlook Forums / Monsoon Forums, established in Year 1, will serve as the key vehicles for facilitating the use of climate information in different sectors, such as agriculture, fisheries, water and disaster management. The national Climate and Health Working Group to be established will enhance collaboration between DNMG and health professionals to co-produce health-tailored climate information; and build capacity for climate services to be institutionalised as decision tools to improve public health outcomes. The Project will also directly introduce tailored products to various audiences such as subsistence and commercial farmers, either through agricultural extension officers or directly through community outreach by DNMG.

A7.0 Strengthened adaptive capacity and reduced exposure to climate risks

The Project will establish a people-centred, impact-based multi-hazard early warning system (MHEWS), derived from a systematic needs assessment (see Section 6) of the existing situation and in partnership with organisations active in disaster risk management. Result 4 addresses an integral element of MHEWS by enhancing disaster preparedness capabilities from national to local level, whilst concurrently equipping and empowering communities with the risk knowledge to make informed decisions to better prepare for and manage the impacts of climate-related hazards. Enhanced risk knowledge contributes to strengthened resilience and adaptive capacity. The actual implementation of specific adaptation or “response” activities is beyond the scope of the Project.

The Project will develop actionable early warnings supporting the work of extension officers with subsistence and commercial farmers on restorative agriculture. It will provide training and awareness workshops to build community capacity to prepare for forecasted climate-related hazards. A targeted awareness and education campaign for women will empower them with enhanced knowledge and understanding of disaster risks to support increased participation in disaster risk management and decision making for climate resilience. The Project will work with local partners that have expertise in engaging with communities in Timor-Leste to ensure that EWS information reaches the “last mile”. In addition, the Project will introduce seasonal forecasting and generate data from ocean areas, which will support safety of life at sea, generate local-scale forecasts and monitoring of extreme events in real time, and improve communication to and from all communities through robust, reliable technology.

A8.0 Strengthened awareness of climate threats and risk-reduction processes

The Project is expected to significantly increase awareness of climate hazards and appropriate disaster risk reduction measures within the government agencies, sectors and communities. It will support sector agency officers to understand climate processes and mainstream climate awareness into policy and planning through the conduct of National Framework for Climate Services workshops, the annual National Climate Outlook / Monsoon Forum, national Climate and Health Working Group, tailored information products, sector-specific training and workshops.

The Project will work with communities and partners to develop basic understanding of climate processes and climate change, and related health and environmental risks. It will support the development of effective preparedness actions to early warnings of climate hazards, which will facilitate acceptance of the DNMG's warnings and advice, and contribute to saving lives, livelihoods, crops and assets.

The inclusion of activities that aim at building preparedness capabilities (namely Result 4) is in line with the approved GCF project FP147[517] and are included as a key element in a holistic climate information and early warning services (CIEWS) project designed to deliver transformational impact to the last mile. Such activities provide an opportunity to extend the reach of the CIEWS to the last mile – sensitising communities to the value of climate information and early warnings towards reducing the impact of climate-related hazards and providing an entry point to build trust in scientific knowledge systems and demonstrate their complementarity with local knowledge. The inclusion of Result 4 is in line with international best practices for delivering end-to-end, people-centred multi-hazard early warning systems (MHEWS) that "*empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury and illness, loss of life and damage to property, assets and the environment*", as stated in the Checklist prepared by the partners of the International Network for Multi-Hazard Early Warning Systems.[518] The need to "ensure that financing covers all segments of the EWS value chain" is also a key strategic recommendation in the WMO 2020 State of Climate Services report.

Paradigm Shift Potential

The Project will enable a paradigm shift to evidence-based planning and early action through accurate, timely and actionable climate information, impact-based forecasting, people-centred multi-hazard early warning systems (MHEWS) and Forecast-based Financing – an innovative mechanism for disaster preparedness and early action demonstrated to save lives.[519] This will result in a transformation to increased resilience to climate change threats and enhanced livelihoods, and a reduction in the damages and losses incurred through the increased frequency of climate-induced disasters, such as flooding and landslides. Avoided economic losses will result from better preparedness to extreme events due to the use of improved forecasts, early warning and early action, with sustained engagement and involvement of end-users in disaster risk management.

Potential for scaling-up and replication

The Project is expected to achieve transformational change in the understanding and use of climate information and early warnings from national to community level. The National Framework for Climate Services (NFCS) to be developed will be designed to facilitate delivery of best practice climate

[517] https://www.greenclimate.fund/project/fp147
[518] WMO, 2018. Multi-hazard Early Warning Systems: A Checklist
[519] IFRC, 2017. Forecast-based Financing: Effective early actions to reduce flood impacts. Available at: https://www.preventionweb.net/files/62642_casestudy5bangladeshfbffinal.pdf

services throughout Timor-Leste. The NFCS will facilitate the integration of climate services into relevant national policies, strategies and plans, providing a solid foundation for the uptake of climate information into decision-making and upscaling of Project interventions. This will be further complemented by development of a sustainable financial framework and business model for climate services, including budget allocation and identification of cost-recovery options, and institutional and capacity building of DNMG. To sustain forecast-based early action, a country-driven, scalable financial mechanism will be identified.

The Project's approach to development of climate products and services tailored to specific end-user needs has intrinsic replication potential, as does the development of methodologies, standard operating procedures (SOPs) and forecast-based early action mechanisms. In addition, the location of community-based interventions will be selected to optimise the spatial distribution of activities and outcomes, thereby increasing the likelihood that climate resilient approaches (e.g., community-based disaster management and preparedness actions) are observed and adopted by non-direct beneficiary communities. There is high potential for in-country scalability of community-based activities and South-South knowledge sharing (including with FP147[520]), supporting replication in other Pacific SIDS. Finally, the User Interface Platform will enable information, advice and lessons learned to be communicated to multiple stakeholders, which will facilitate the successful upscaling of Project activities across Timor-Leste.

Potential for knowledge and learning

Timor-Leste's circumstances mean that it will benefit from the lessons learnt by other SIDS in the transition to evidence-based planning and early action. Established relationships with Pacific SIDS neighbours will be useful, particularly with countries experiencing similar constraints and implementing similar programs, though from a more advanced starting point. There is potential for Timor-Leste to accelerate its progress in procurement methodologies, technology option decision-making, the development of effective communication techniques and in identifying potential business models, drawing on the experience of neighbouring SIDS.

The Project will promote robust knowledge management – including through targeted capacity building, training of trainers (ToT), mentoring, attachments and technical advisory – which will facilitate that information exchange and lesson-learning remains a priority throughout the implementation period. Engagement with RIMES, the Indonesian meteorological service (BMKG) and the Indonesian Red Cross (PMI) through this Project will enhance South-South cooperation by strengthening Timor-Leste's relationships with neighbouring countries and establishing links between DNMG and nearby national meteorological services in more developed countries. Networking with Pacific island countries engaged in similar programs and among development partners working with both Timor-Leste and Pacific countries will foster sharing of lessons with particular relevance to SIDS.

At the national and sub-national level, the National Climate Outlook Forum will function as a knowledge management platform between climate information providers and end-users to facilitate exchange of knowledge and lessons learned. The national Climate and Health Working Group will enhance this function with specific emphasis on delivering climate services for public health and well-being. Knowledge and learning will be a key focus of Project interventions – from technical training for agriculture extensionists to community-based disaster risk reduction workshops. The Project recognises the complementarity of the traditional and scientific knowledge systems, and the critical importance of integrating such knowledge for effective climate resilience at the local level. Traditional

[520] https://www.greenclimate.fund/project/fp147

knowledge provides observations and interpretations at a much finer spatial scale than climate science and with considerable temporal depth, identifying elements that may be overlooked by climate scientists.[521] Engagement with communities to develop localised Community Action Plans (CAPs) and SOPs will integrate both traditional and modern scientific climate knowledge to improve community understanding of climate science, and DNMG's understanding of how traditional knowledge is used. Involvement of communities in the development and implementation of Project interventions will ensure that decision-making is accountable and responsive to the populations affected and ensure local appropriateness of international best practices.

Furthermore, the Monitoring and Evaluation Plan and regular activity monitoring processes will be used to revise and improve the Project interventions throughout its 5-year term to ensure impact evaluation, with progress documented and publicised.

Contribution to the creation of an enabling environment

An important focus of the Project is to support the establishment of an enabling environment for long-term sustainability, which will be facilitated through the integration of climate services and MHEWS into key policies, strategies, plans and the national budget. This will provide a foundation for uptake of climate information in decision making and support sustainable service provision in the long-term, beyond the Project's duration. The National Framework for Climate Services, seasonal National Climate Outlook Forums, national Climate and Health Working Group and the new framework for financing climate services will be critical to achieving this.

Enhancing coordination and forging robust multi-stakeholder partnerships for climate services, early warning systems, disaster risk management, water resource management and public health will create an enabling environment for long-term resilience. This includes the development or strengthening of policy, legal and regulatory frameworks conducive to increased political commitment, and to awareness in public and private sectors of disaster risk reduction and management as a strategic development priority. This will promote the allocation and mobilisation of the resources required to sustain resilience building. The Project will build capacity for forecast-based early action through Forecast-based Financing and Early Warning Early Action (EWEA) for agriculture and food security. In the longer term, this will facilitate that climate-resilient early actions from national to community level are identified and funded before a climate shock and become an integral component of disaster risk reduction and management in Timor-Leste.

Furthermore, the Project contains several interventions that will emphasise and support private sector mobilisation. In particular, the User Interface Platform will provide a forum for dialogue and wider partnerships between the public and private sector, thereby creating an enabling environment for public-private partnerships and mutually beneficial cost-recovery mechanisms. The Project will identify opportunities for specialised climate information and early warning products with commercial value to catalyse private sector interest. Moreover, the new financial framework will emphasise private sector mobilisation as a means to enhance the sustainability of climate services and improve efficiency. In developing the framework, the Project will identify suitable revenue streams and effective strategies to incentivise and mobilise private sector resources.

Contribution to the regulatory framework and policies

Timor-Leste is in the process of building its legislative and regulatory framework in most sectors, since its achievement of independence in 2002, and of establishing national policies relating to

[521] UNESCO, 2012. Traditional knowledge for climate change assessment and adaptation

environmental management and disaster risk reduction. The Project presents an opportunity to clarify and formalise relationships among relevant agencies and with users of weather, water and climate data and information.

The Project will support Timor-Leste in building capacity to provide the essential high-resolution data and climate information needed to plan all nationally and internationally funded climate-sensitive investments and establish sustainable support so that strengthened capacity can be maintained. Data from the monitoring network and vulnerability assessments will allow for better understanding and anticipation of the effects of hydrometeorological and climate events and will inform the risk assessments carried out by the GCF UNDP project (FP109). The data will also support the future formulation of science-based adaptation policies, regulations and planning for adaptation to climate change, disaster risk reduction and public health management.

The integration of climate information services into key policies, decision-making and operational processes of government entities will facilitate transformational planning and programming. This will be facilitated by establishing institutional, policy, planning and regulatory frameworks to optimise coordination between DNMG and other governmental agencies. The National Climate Sector Action and Communication Plans and National Meteorological Strategy will facilitate that developed policies (e.g. the NFCS and National Meteorology Act) are being effectively applied at the national and sub-national level. Local level frameworks (e.g. gender-responsive communication strategies, Community Action Plans (CAPs) and Early Action Protocols) will support proactive climate-resilient action at the community level.

Overall contribution to climate-resilient development pathways

Timor-Leste articulated its commitment to pursuing climate-resilient sustainable development in its Intended Nationally Determined Contributions (2016) but asserted that international support will be required to increase its adaptive capacity. This Project will support climate-resilient development in Timor-Leste from national level to “the last mile”. The NFCS will provide the overarching framework to integrate climate information into evidence-based planning and decision-making for climate resilience. Building capacity of the National Disaster Management Directorate (NDMD) in EWS will ensure that coordination and technical support is available to the Government, sectors and communities to effectively prepare for climate-related hazards and support disaster risk reduction in Timor-Leste. Strengthening climate resilience will help to minimise the social, economic and environmental costs of climate impacts so that they do not hinder progress towards development goals.

The development and dissemination of targeted and actionable climate information products will be transformational in building the climate resilience of key economic sectors, particularly agriculture, health and disaster risk management, but also water management, shipping, tourism and insurance. Delivered through a suite of outreach, learning and knowledge management activities, information products will catalyse more efficient and evidence-based approaches and response actions to climate risks and prevent maladaptation. This will be transformational in building the long-term resilience of sectors and communities to climate change, but also in immediate reduction of losses of assets and livelihoods caused by climate-related hazards.

Enhanced climate information will enable resilience planning for critical infrastructure impacted by climate change and climate-related hazards, through embedding tailored and actionable climate risk information into their planning, design, construction and management frameworks. A significant focus of the Project will be to build the capacity of communities to take appropriate preparedness actions and utilise climate information to better manage disaster risks. This will be facilitated through the co-development of *suco* level Community Action Plans; enhanced community-based early warning systems, particularly to support climate resilience in agriculture, health and water management; and the development of Forecast-based Financing mechanisms for proactive preparedness to manage climate risks.

As described in Section D.1., the Project will complement the GCF-funded UNDP project FP109. A multi-level institutional arrangement has been developed to facilitate this (see Section 9). The Project will extend the application of FP109 outputs beyond the initial small-scale rural infrastructure focus by linking the UNDP-led vulnerability assessments and flood hazard maps with newly established near real-time rainfall forecasts to generate sector-specific impact-based forecasts. In a mutually reinforcing manner, the enhanced data availability facilitated by the Project will provide valuable data inputs for several activities implemented under FP109. The accuracy of the hydrological and hydraulic models developed under FP109 is dependent on the quality of the input data, and particularly the availability of high-quality rainfall data for model calibration and verification. By building the infrastructural and technical capacity of DNMG to provide high-quality data in line with WMO specifications, the Project will contribute to enhanced accuracy of FP109 outputs, which in turn will improve the inputs (namely the flood hazard maps) available for integration into the Project-developed decision-support system.

Sustainable Development Potential

The Project will create long-term social, environmental and economic benefits, as well as support gender-responsive development – as detailed below.

The Project is aligned with the Sustainable Development Goals (SDGs), the Paris Agreement, the Sendai Framework, the SAMOA Pathway, and international and national laws. With respect to the SDGs, the Project will contribute to Timor-Leste's progress towards disaster risk reduction, ecosystem protection, climate change adaptation, health and sustainable economic development. Through the proposed activities, the Project will contribute to six out of the 17 UN Sustainable Development Goals (SDGs), namely: SDG 3 – Good Health and Well-being; SDG 5 – Gender Equality; SDG 10 – Reduced Inequalities; SDG 13 – Climate Action; SDG 14 – Life Below Water; and SDG 15 – Life on Land.

The Project is also fully aligned with Outcome 6 of the UN Sustainable Development Cooperative Framework for Timor-Leste on "Sustainable management of natural resources and resilience to climate change", which identifies "*Strengthening early warning system and capacities*" as a specific priority.

Environmental co-benefits

The long-term environmental co-benefits of the Project are expected to be significant. The increased availability and use of actionable climate information can enhance natural resource management, from climate risk-informed policymaking to conservation and arresting biodiversity loss.

The Project will support Timor-Leste's national meteorological service (DNMG) to generate and deliver impact-based forecasts, decision-support systems and advisories tailored to natural resource-dependent sectors – such as agriculture and fisheries – that will facilitate the rapid identification of weather, water and climate hazards that pose environmental risks and consequently inform the safeguarding of natural resources and biodiversity. Strengthened data sharing and inter-institutional coordination with the Water Sector, as well as the provision of data inputs to enhance the accuracy of flood hazard mapping and modelling, will contribute to improved water resource management and management of hydrological risks. In addition, the establishment of marine forecasting will support improved management of coastal habitats and inform sustainable fisheries practices to minimise environmental impacts.

Air pollutants can have severe impacts on ecosystem function and contribute to biodiversity loss. For example, chemical transformations of nitrogen oxides in the atmosphere and subsequent deposition causes acidification and eutrophication of soil and water bodies respectively, which in turn affect productivity and plant growth. The Project will establish a high-resolution air quality monitoring and alerting framework that will provide multiple pathways for the Government of Timor-Leste to reduce climate change and air pollution impact through evidence-based mitigation policy and interventions.

With regard to the energy sector, detailed climate and air quality information is necessary for comprehensive environmental impact assessments and can inform energy management decisions to improve efficiency and reduce greenhouse gas emissions.

At the local level, the Project will raise awareness on weather, water and climate hazards and related risks, including to environmental health, and will build preparedness capabilities for effective early action in response to hazard warnings. Moreover, through training on the use of climate forecasts, the Project will sensitise communities to the value of climate information and early warnings towards reducing the impact of climate-related hazards, including on natural resources, ecosystems and biodiversity. This will contribute to enhanced local ownership for environmental protection and resilience building of natural environments.

At the global scale, the increased generation of essential surface-based observation data will enhance global forecasting capabilities, which in turn will improve the ability to predict and mitigate the impacts of impending environmental hazards across the world.

Moreover, the Project design emphasises alternatives to international travel, when possible. Capacity building that can be undertaken by in-country staff or delivered remotely will be the preferred option. When international travel is necessary, the Project activities will seek to consolidate the travel to avoid multiple missions. With respect to national travel, consultants will be encouraged to use low-emission vehicles, when they are available, and plan workshops in central locations to avoid unnecessary travel.

Social co-benefits including health impacts

The Project interventions have many inherent social co-benefits, particularly with regard to positive impacts on health and population well-being. Climate and health are inextricably linked. There is an increasing demand for relevant, timely and usable information about weather and climate variability, change, risks and impacts to improve decision-making for enhanced resilience. There is also an urgent need to correlate these factors with air pollution – the world's largest single environmental health risk[522] – and to enhance joint action between the meteorological, climate and health communities to understand and reduce the health risks of poor air quality. This requirement for "focusing action on upstream determinants of health, the environment and determinants of climate change in an integrated and mainstreamed approach across all sectors" is emphasised in the World Health Organization (WHO) Global Strategy on Health, Environment and Climate Change 2019.

In the case of the health sector, the Project will create an enabling environment for coordinated and sustained collaboration between climate and health experts and decision-makers to enhance understanding and application of climate knowledge for health – facilitating targeted interventions that save more lives, reduce disease burden, and enable cost savings in service delivery. The

[522] WMO, 2014. Air Quality and Human Health, a Priority for Joint Action. Available at: https://public.wmo.int/en/resources/bulletin/air-quality-and-human-health-priority-joint-action

establishment a national Climate and Health Working Group will be key in this regard. The Project will work with DNMG and the Ministry of Health to co-develop tailored forecasting and a sector-specific decision support system, together with a mobile app to extend the reach of health-related forecasts and advisories to the general public. Continuous engagement of multi-sectoral and multi-disciplinary stakeholders along the climate services for health value chain will enable identification of health priorities and development of the most appropriate services to address these priorities; increase participation and ownership; improve perceptions towards the value of climate services; build in-country capacity; and align stakeholders' objectives and expectations.[523]

A high-resolution spatiotemporal hybrid air quality monitoring system for fine particulate matter (PM2.5 / PM10) and nitrogen dioxide (NO_2) – a precursor for PM2.5 and ozone (O_3) – will be established in the capital city of Dili, with data feeding into a customised mobile application for air pollution warnings, forecasting and health impact advisory. In the longer term, the data will inform evidence-based air quality management policies and enable Timor-Leste to reduce its air pollution. Whilst its Intended Nationally Determined Contributions (INDC) do not require Timor-Leste to report on steps to reduce short-lived climate pollutants (SLCPs) – even though meeting the targets of the Paris Agreement is likely impossible without cutting SLCP emissions[524] – acting quickly to reduce SLCP emissions will benefit human health immediately and slow the rate of near-term warming.[525] Moreover, this intervention will support achievement of SDG target 11.6 *"By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality…"*, indicator 11.6.2 *"Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted)"*. It also contributes to the aims of the WMO Global Atmosphere Watch (GAW) Programme to provide information and services on atmospheric composition to the public and to decision-makers relating to urban air pollution, especially fine particles, which is affecting human health.

Moreover, the implementation of end-to-end early warning systems will contribute to reducing harm to populations and destruction of property through improved disaster preparedness capabilities. Prevention and timely action will likely lower mortality rates and contribute to the improvement of safety, particularly within isolated and/or coastal communities. This should reduce the costs associated with recovery actions, and consequently, have a positive economic impact (see economic co-benefits below).

At the community level, the Project will conduct targeted awareness-raising and education on climate-related health risks, as a key trigger in encouraging protective behaviours and increasing collective local capacity to prepare for and manage climate impacts. Moreover, the Project will build capacity to understand and use weather, water and climate forecasts and identify climate risks. This will enhance local knowledge and empower communities to increase their resilience to climate change impacts. Avoided loss of assets and livelihood sources will help to alleviate poverty in beneficiary communities through reduced loss of income. Social cohesion will be promoted through community-based interventions and co-development of localised climate risk management plans.

In addition, the Project activities will create employment opportunities for national employees, particularly through hiring local consultants who will be employed by civil society organisations and government institutions. Local businesses will also benefit, as catering services, conference venues and interpreters will be employed as part of the workshop activities. Lastly, GCF and UNEP labour

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[523] WMO and WHO, 2016. Climate Services for Health

[524] BBC, 2019. Cut air pollution to fight climate change – UN. Available at: https://www.bbc.co.uk/news/science-environment-49134175

[525] WHO, 2018. First WHO Global Conference on Air Pollution and Health. Climate change and air pollution: two sides of the same coin. Available at: https://www.who.int/airpollution/events/conference/Climate_change_background.pdf

standards will be integrated into the Project interventions, thus ensuring international best practices regarding safety and labour standards for activities that involve small-scale construction.

Economic co-benefits

The Project will contribute to reduced economic damage and loss in Timor-Leste through enhanced preparedness to extreme events and climate risk-informed decision-making and actions. High-resolution baseline data, hazard information and vulnerability assessments will be integrated into targeted early warning and decision-support systems to enhance the climate resilience of sectors and communities. Early warning systems are reported to save lives and assets worth at least ten times their cost. Just 24 hours lead-time of an impending storm or heatwave can reduce the consequent damage by 30 percent.[526] In addition, the Project will establish capacity for Forecast-based Financing (FbF) to enhance preparedness and ensure sustainable funding for pre-planned disaster risk management actions. FbF improves the efficiency of those implementing interventions[527] and has been shown to minimise damage and loss caused by climate-related hazards and reduce the need for humanitarian assistance in the aftermath.[528]

Economic gains are expected from better management of resources – for example, due to the use of impact-based forecasts in agriculture and water resources. Studies in several countries have shown that increased availability and use of weather and climate forecasts can reduce the impacts of weather variability on agricultural production by up to 30%. In the water sector, the use of forecasts to optimise water system supply operations can translate to up to 33% or more in performance improvements.[529] In the aviation and marine industries, weather data can improve supply chain efficiencies while reducing emissions and fuel usage.[530] Weather-optimised routing has been shown to reduce shipping emissions by up to 4% and reduce fuel consumption by up to 10%.[531] The Project will contribute to sustained local economies as a result of more strategic risk-informed local development planning. Improved decisions for weather events (e.g. farmers may earn higher incomes by avoiding crop losses and by tailoring their planting or harvesting decisions to a seasonal forecast) are expected to result in smoothing consumption and lower prices for food. Indirect economic benefits will be derived by the Project's contribution to food security and self-sufficiency, which will reduce the need for imports.

It should be noted that the economic benefits for the Project (see Annex 3 – Economic Analysis) are underestimated, both due to analyses having been done following conservative assumptions and because there are economic benefits that are difficult to measure and/or are derived in the long-term. For example, the use of more accurate climate forecasts will reduce income uncertainty and contribute to smoothing consumption. Most importantly, early warning systems save lives and this is arguably impossible to translate to dollar terms. In the longer term, climate-sensitive sectors will be facilitated to make better informed investments that will yield long-term economic benefits. Reducing uncertainty is also shown to have direct positive effects on individual welfare.[532] There are different methods to quantify the value of climate services – including decision theory, avoided cost calculations, partial equilibrium models, game theory, contingent valuation, benefits transfer, and

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[526] Global Commission on Adaptation, 2019. Adapt Now: A Global Call for Leadership on Climate Resilience
[527] UNEP, 2021. Adaptation Gap Report 2020
[528] WFP, 2019. Forecast-based Financing Factsheet. Available from: https://www.wfp.org/publications/forecast-based-financing-factsheet
[529] World Bank, WMO and UK Met Office, 2021. The Value of Surface-based Meteorological Observation Data
[530] Forbes, 2021. Using Weather Data Helps Businesses Address Challenges of Climate Change. Available at: https://www.forbes.com/sites/rennyvandewege/2021/05/03/using-weather-data-helps-businesses-address-challenges-of-climate-change/?sh=402e4efd1f9e
[531] European Commission, 2013. Timr for international action on CO_2 emissions from shipping. Available at: https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/marine_transport_en.pdf
[532] Alem, Y. and Colmer, J., 2015. Consumption smoothing and the welfare cost of uncertainty. Centre for Climate Change Economics and Policy Working Paper No. 138. Grantham Research Institute on Climate Change and the Environment Working Paper No. 118.

econometric models. The combination of these evaluations, provided that they do not overlap, contribute to improved understanding of the whole spectrum of potential benefits. For the Project's Cost-Benefit Analysis (Annex 3), the avoided cost calculations method was deemed most suitable as it is consistent with previous evaluations performed in Timor-Leste, and in the Pacific islands.

Gender-responsive development impact

The Project will facilitate gender-responsive development in Timor-Leste through the mainstreaming of gender considerations throughout its design, implementation, monitoring and evaluation – as detailed in the Gender Assessment and Gender Action Plan (Annex 8). This will ensure that gender concerns are addressed and that existing gender inequalities are not reinforced, thus maximising the outcomes and transformative impact of the Project.

The Project will aim to:

1. Raise gender awareness and increase understanding at national, sectoral and community level of the differential impacts of climate change on women and men.
2. Address the climate vulnerabilities of both women and men through meaningful stakeholder engagement and the delivery of climate information and early warning services tailored to the specific needs of end-users.
3. Promote the empowerment of women through equal representation and participation in planning, decision making, capacity building and skills development.

A summary of the gender-responsive strategies and actions to be incorporated and implemented in the Project is provided in section G.2.

Impact of COVID-19 on the Global Observing System – a potential co-benefit of the Project

Any lack of observations over one area negatively impact on the quality of forecast and analysis products globally. Whilst a significant portion of the global observing system is either partly or fully automated, some parts have already been severely affected due to COVID-19. Aircraft observations have drastically declined, with an overall reduction in aircraft observations of 75 – 80 % compared to normal. The decrease is close to 90% in the tropics and Southern Hemisphere, where there are already fewer observations available. The availability of surface data has decreased significantly since the beginning of the COVID-19 crisis. The main suspected cause is reliance on manned observing stations subject to lockdown. For ocean observations, the main impact has been on voluntary ship observations, which are down around 80% compared to the pre-COVID-19 baseline.[533] Thus, the COVID-19 crisis exemplifies the importance of the Global Basic Observing Network (GBON) and the Systematic Observations Financing Facility (SOFF) – namely, the transition to automation will improve reporting frequency and resilience. Through the development of a financial framework for sustainable climate services (Sub-Activity 1.1.5), the Project will engage with SOFF to ensure that Timor-Leste can benefit from its support to sustain its systematic basic observations networks as a global public good.

Impact of COVID-19 on lives, livelihoods and assets – a potential co-benefit of implementing Forecast-based Financing (FbF) and integrated disaster risk management

The vulnerability of Timor-Leste is evident from the devastating impacts of the recent tropical cyclone, heavy rains, flooding and landslides that occurred between 29th March and April 2021, and which

[533] WMO, 2020. COVID-19 impacts observing system. Available at: ttps://public.wmo.int/en/media/press-release/covid-19-impacts-observing-system

affected over 30,300 households and caused 48 fatalities.[534] In addition to causing considerable human and economic loss, the flooding and landslides significantly undermined COVID-19 response efforts as Timor-Leste struggled to contain the virus' second wave. Heavy flooding in the National Laboratory and medical storage facility led to the loss of vital medical supplies and a COVID-19 isolation facility had to be temporarily evacuated. Moreover, displaced people sheltered in improvised evacuation centres and in the homes of relatives, which likely exacerbated the spread of the virus. [535,536] The compounding impacts of weather hazard-induced disasters and the COVID-19 pandemic provide demonstrable evidence of the potential for a repeat of the "unprecedented double disaster" warned of by the UNDRR Asia Pacific COVID-19 Brief in April 2020, following the devastation of large areas of Vanuatu by Tropical Cyclone Harold.[537] In addition, the Brief emphasises "the need for countries to focus on a multi-hazard integrated disaster risk management approach that includes high levels of disaster preparedness and accelerated disaster risk reduction across sectors".[538] The dual challenge of climate change and a global pandemic highlights the relevance of the proposed Project, and the urgency required to prioritise health sector resilience, disaster risk management efforts and enhancement of multi-hazard early warning systems. Furthermore, when Forecast-based Financing is combined with early response to a climate shock and resilience or disaster risk reduction activities, the co-benefits are maximised:

- A 2018 return on investment study in Nepal on implementing the approach, found that USD 22 million can be saved when responding to an emergency of an average size (175,000 affected people). Over 20 years, USD 34 and 42 kg of CO_2 emissions can be saved per dollar invested, after deducting the investment cost.[539]
- A 2018 USAID study on Ethiopia, Kenya and Somalia indicates that early response to drought, combined with safety net transfers and resilience-building activities, could over a 15-year period save USD 4.3 billion, or an average of USD 287 million per year.[540]
- A 2015 Cost-Benefit Analysis carried out in Sudan and Nigeria shows that using a forecast-based system would lower the cost of an emergency response by 50 percent and that the net cost of a late humanitarian response is four to seven times higher than multi-year resilience-building.[541]

The above studies exemplify the economic co-benefits of implementing the Forecast-based Financing / Early Warning Early Action mechanisms proposed under this Project.

Needs of the Recipient

Timor-Leste gained independence in 2002. With a population of 1.3 million people occupying the eastern half of the island of Timor, Timor-Leste has functioned as a democratic republic since independence. While elections have generally been regarded as free and fair, and the media provided with freedom of expression, many aspects of Timor-Leste's development remain a challenge. Poverty levels remain high, with an estimated 42% of the population living in poverty in 2014, and the 2017

[534] UN Resident Coordinator's Office (RCO) Timor-Leste, 2021. Timor-Leste: Floods. Situation Report No. 10 (As of 18 June 2021). Available at: https://timorleste.un.org/sites/default/files/2021-06/TL%20April%20Flood%20Response%20Situation%20Report%2010%20%2821%20June%2021%29.pdf

[535]

[536] UN News, 2021. 5 April 2021. UN steps up response, as thousands impacted by Timor-Leste floods. Available at: https://news.un.org/en/story/2021/04/1089012

[537] UNDRR, 2020. UNDRR Asia Pacific COVID-19 Brief. Combating the Dual Challenge of COVID-19 and Climate-Related Disasters

[538] UNDRR, 2020. UNDRR Asia Pacific COVID-19 Brief. Combating the Dual Challenge of COVID-19 and Climate-Related Disasters

[539] WFP, 2019. Forecast-based Financing in Nepal: A Return on Investment Study

[540] WFP, 2018. Forecast-based Financing: Moving from crisis response to risk management

[541] WFP, 2018. Forecast-based Financing: Moving from crisis response to risk management

Human Capital Index[542] standing at 0.43 (compared to the regional average of 0.61).[543] Investment in infrastructure and human capital is heavily dependent on the petroleum sector, which accounts for the vast majority of government revenue. As natural resources are depleted, diversification will be essential for the future of Timor-Leste's economy and social infrastructure spending. The preservation of natural environmental and commercial agriculture is likely to play a key role in the diversification process.

Climate change in Timor-Leste

Timor-Leste is vulnerable to floods and landslides, earthquakes, tsunamis, and tropical cyclones, and it is also prone to severe droughts. While Timor-Leste has a medium exposure to hazards, the isolation of many of the local communities, accentuated by the topographic conditions, and poor access to infrastructure, tend to exacerbate negative impacts, making it one of the most disaster-prone countries in the world. Socioeconomic development is curbed by inability to respond appropriately to climate-related hazards.

The vulnerability of Timor-Leste is evident from the devastating impacts of the recent tropical cyclone, heavy rains, flooding and landslides that occurred between 29th March and April 2021, and which affected over 30,300 households and caused 48 fatalities within the population.[544] As of 16th July 2021, 730 people remained temporarily displaced, which corresponds to 6% of the total number of people in evacuation centres at the peak (recorded 8th April 2021). The ongoing COVID-19 pandemic is putting a severe strain on Timor-Leste's already fragile economy – estimates suggest that the economy contracted by 7 percent in 2020, the largest decline since independence[545] – and has hence diminished the country's already limited capacity to invest in early warning systems.

Monitoring and forecasting of occurrences, intensities, and evolution of extreme hydrometeorological events have been critical for humanitarian and government bodies to plan, mitigate, and manage responses to disaster, aiming at saving lives and limiting economic and environmental losses. This Project proposes to enhance climate information and knowledge services in Timor-Leste, in order to make the country more resilient to climate-related impacts and hazards. Better climate-related information and knowledge will improve security and economic livelihoods, through resilience building, and appropriate interventions addressing climate change threats, requiring tailored climate information and people-centred knowledge services covering oceans and islands across all sectors.

Further inhibiting Timor-Leste's stability is extreme weather and climate variability, including flooding and storm surges, often associated with tropical storms and extreme precipitation. Moreover, Timor-Leste is also exposed to geophysical hazards, including earthquakes, heavy rains, and landslides, as well as unsafe levels of air pollution. The aforementioned socio-economic characteristics of Timor-Leste contribute to its vulnerability. Many Timorese live close to coasts, which subjects them to storm surges, river flooding, and saltwater intrusion of freshwater resources and agricultural land. As such, developing comprehensive early warning systems should have a significant impact on both social and economic outcomes in Timor-Leste.

Underlying vulnerabilities

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[542] The Human Capital Index (HCI) quantifies the contribution of health and education to the productivity of the next generation of workers. The HCI can be used to assess how much income is forgone due to gaps in human capital.
[543] World Bank, 2019. The World Bank in Timor-Leste Overview. Available from: https://www.worldbank.org/en/country/timor-leste/overview
[544] UN Resident Coordinator's Office (RCO) Timor-Leste, 2021. Timor-Leste: Floods. Situation Report No. 10 (As of 18 June 2021). Available at: https://timorleste.un.org/sites/default/files/2021-06/TL%20April%20Flood%20Response%20Situation%20Report%2010%20%2821%20June%2021%29.pdf
[545] World Bank, 2021. Timor-Leste Economic Report: Charting a New Path

Climate change will increase the exposure of the entire population of Timor-Leste to environmental hazards; however, it will also exacerbate existing imbalances in vulnerability as a result of both geographic and socioeconomic factors.[546] The Project has been developed based on extensive stakeholder engagement, including dedicated consultations to inform the Gender Assessment and Action Plan (Annex 8), such that interventions are responsive to the needs of specific vulnerable groups in Timor-Leste.

According to the Asian Development Bank (ADB) study on asset-based measurement of living standards in least developed *sucos* (villages) in Timor-Leste, *sucos* with the lowest living standards are the most remote, have small populations, have the lowest literacy rates and are more engaged in agricultural activity. To achieve fair and inclusive development, additional focus is required to support *sucos* with lower living standards.[547] The Project includes specific interventions to develop targeted community-based early warning systems and disaster risk management and build capacities from the *suco* level upwards for improved preparedness measures to climate hazards. Around 70% of the population of Timor-Leste rely on climate-sensitive rain-fed agriculture as their primary source of income.[548] Accordingly, the Project will develop the capacities of farmers to utilise climate information, including from crop advisories, sector-specific decision support systems (DSS) and agriculture extension services.

Women in Timor-Leste are disproportionately affected by climate change due to existing inequalities and multi-dimensional social factors that influence their adaptive capacities, resilience and participation in climate action.[549] Based on the Gender Development Index (GDI), Timor-Leste is in GDI Group 5, which corresponds to countries with the lowest gender equality in human development achievements.[550] The Project has and will continue to adopt a gender mainstreaming approach throughout its development and implementation. This includes the implementation of gender-responsive actions, such as providing gender-specific needs training to DNMG staff; designated leadership roles for women's groups in early warning protocols; and ensuring that all relevant data is gender disaggregated. Further details are provided in the Gender Assessment and Action Plan (Annex 8).

Country Ownership

The Government of Timor-Leste has highlighted the critical importance of services relating to climate change, early warning systems for climate-related hazards, and disaster risk reduction in major national policy documents. These are summarised in the list below.

Dialogue on this Project began in 2015 when Timor-Leste expressed interest in the World Meteorological Organization's (WMO) proposal for a multi-country programme in the Pacific region to strengthen early warning capacity for hydrometeorological extreme events. A Concept Note was approved by GCF in 2015 for five countries—four Pacific island countries and Timor-Leste. WMO undertook an intensive consultation process during 2017 with Timor-Leste and four Pacific island countries to develop effective approaches to establishing EWSs that would reach people at the last mile with accurate, timely, actionable warnings and advice ahead of extreme climate events. Carriage of the proposal has since passed to UNEP, which has undertaken further consultation with potential users and stakeholders in Timor-Leste, as reported in detail in the Stakeholder Engagement Plan (Annex 7). Timor-Leste's National Designated Authority (NDA) for interaction with the GCF (and

[546] Thomas, K. et al. WIRES Climate Change, 2019. Explaining differential vulnerability to climate change: A social science review
[547] ADB, 2013. Least Developed Sucos – Timor-Leste
[548] Bündnis Entwicklung Hilft, 2017. World Risk Report – Analysis and prospects 2017
[549] See Annex 4 for a detailed assessment of the gender context of Timor-Leste
[550] UNDP, 2019. Briefing note for countries on the 2019 Human Development Report – Timor-Leste

Director of the Climate Change Department) has been actively engaged in the development of the Project and has formally endorsed it. Moreover, the Project is identified as a priority adaptation project in Timor-Leste's National Adaptation Plan (NAP) submitted to the UNFCCC Secretariat in March 2021.

The Secretary of State for the Environment (SSE) in Timor-Leste will serve as the lead Executing Entity (EE) for the Project and will therefore be responsible for establishing national project implementation. This modality will enhance country ownership of the Project and build in-country capacity to lead on future climate resilience actions and initiatives.

The Project will first build capacity by leveraging the technical expertise of international partners, who have been engaged at the request of the country based on their track record and expertise in Timor-Leste. In order to retain capacity in Timor-Leste beyond the Project implementation period, it should be noted that Timor-Leste is a Member State and representative of the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES). Under the membership agreement, RIMES is committed to providing technical and backup support to DNMG and all national stakeholders during and beyond any project period.

Alignment with existing national policies addressing climate change

The proposed Project will contribute to the achievement of priorities articulated by the Government of Timor-Leste in the following documents:

- **Green Climate Fund Country Programme (2019) –** The Project will provide essential information for evidence-based decision making and planning for the national priorities outlined in the Country Programme, enhancing their efficacy and preventing maladaptation. The Country Programme also explicitly prioritised this Project in its original form (with WMO as AE).
- **National Disaster Risk Management Policy (2008) –** The Project will directly address two key priorities of the Policy's objective relating to the prevention of natural disasters: i) Create early warning systems, particularly relating to rain and drought; and ii) Establish inter-sectoral coordination mechanisms to respond to natural disasters.
- **Timor-Leste National Adaptation and Program of Action (NAPA) on Climate Change (2010) –** The NAPA prioritises community awareness, increased monitoring and risk forecasting, and support for the adaptation of government policies and strategies to improve climate change resilience among vulnerable groups. The Project will contribute to Timor-Leste's achievement of these objectives either directly with communities or through mainstreaming climate services and knowledge into the work of other government agencies.
- The **Environmental Policy (2012)** directs that "land-use development and planning of inland areas shall consider the need for integrated management of water resources bearing in mind the potential impacts these may have on coastal areas".
- The **Timor-Leste Initial National Communication (INC) to the UNFCCC (2014)** identifies some key adaptation actions relevant to Early Warning Systems: i) Strengthening capacity of national and local institutions as well as communities in managing climate risks through the development of an effective climate information system, including the development of early warning system and decision support system tools for policy makers; and ii) Research and development of technologies more adaptive to climate change particularly for key sectors.

The Project will contribute directly to the achievement of the first action and will generate data and information needed for effective implementation of the second.

- **Intended Nationally Determined Contributions (INDC) Timor-Leste (2016) –** The Project will directly address the priority measures for adaptation to natural disasters identified in the INDC: i) Improve institutional and staff capacity in the disaster sector in relation to climate change induced disasters; ii) Establish early warning systems in areas identified as vulnerable to disasters such as floods and storms; and iii) Integrate climate risk information into traditional disaster risk reduction and management. The Project will also address priority measures for adaptation related to human health identified in the INDC, in particular relating to the promotion of "evidence-based decision making…taking into consideration of climate change and its adverse effects on diseases, particularly water, air and vector-borne diseases such as malaria and dengue".
- **Timor-Leste Second National Communication (SNC) to the UNFCCC (2020)** – The Project will directly address the following adaptation needs identified in the SNC: i) Increase the number of weather stations in Timor-Leste; ii) Assist, encourage and warn people who are at risk from natural disaster; iii) Promote early warning systems; and iv) Education and public awareness. In addition, it will contribute to an enabling environment for "integrating consideration of climate change to develop policies and programmes" and for "budget allocation within relevant Ministries [to] reflect the more vulnerable populations".
- **Timor-Leste's National Adaptation Plan (2021)** – As noted above, the Project is identified as a priority adaptation project in Timor-Leste's National Adaptation Plan (NAP). In addition, the Project will contribute to the achievement of the following priorities and outcomes: i) Strengthening the capacity of national, local institutions and communities in managing climate risks; ii) Reduce the vulnerability of farmers and pastoralists to increased drought and flood events; iii) Improve institutional and community capacity to prepare for and respond to climate change-induced natural disasters; iv) Integrate climate risk information into traditional disaster risk reduction and management; v) Enhance government and community strategies to respond to drought exacerbated by climate change; vi) Establish surveillance for health early warning systems and response mechanisms for climate-related health risks.
- **UN Sustainable Development Cooperation Framework Timor-Leste (2021 – 2025)**: The Project is fully aligned with Outcome 6 on "Sustainable management of natural resources and resilience to climate change", which identifies "*Strengthening early warning system and capacities*" as a specific priority.

The Government of Timor-Leste has key agencies relating to the implementation of climate and natural disaster services and these agencies have been consulted in the preparation of the proposed Project. This includes the National Directorate for Meteorology and Geophysics, the Ministry of Agriculture and Fisheries, the Ministry of Social Solidarity, the National Directorate for Climate Change, the Directorate General for Environment, the Cabinet Vice Ministry for Habitation, Ordainment and Environment, and the Ministry of Development and Institutional Reforms.

The Project is aligned with the Sustainable Development Goals (SDGs), the Paris Agreement and the Sendai Framework:

- SDG 13 advocates urgent action to combat climate change and its impacts. Target 13.1 advises countries to "*Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries*".
- SDG 3 advocates to ensure healthy lives and promote well-being for all at all ages. Target 3.D aims to *"Strengthen capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks"*.
- The Paris Agreement in Article 7, Sub-paragraph 7(c) calls for "strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making".[551]
- The Sendai Framework for Disaster Risk Reduction 2015–2030[552] in paragraph 33 b) stresses that it is important "To invest in, develop, maintain and strengthen people-centred multi-hazard, multisectoral forecasting and early warning systems, disaster risk and emergency communications mechanisms, social technologies and hazard-monitoring telecommunications systems; develop such systems through a participatory process; tailor them to the needs of users, including social and cultural requirements, in particular gender; promote the application of simple and low-cost early warning equipment and facilities; and broaden release channels for natural disaster early warning information". The Sendai Framework's Seven Global Targets calls for efforts to "substantially increase the availability and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030."

The Project will contribute directly to Timor-Leste's achievement of progress towards these objectives.

Engagement with civil society organisations

The Project will support an existing group of Government ministries and UN agencies responsible for coordinating early warning, climate change adaptation, and disaster risk reduction, expanding the group to include NGOs/CBOs and enabling the group to convene regularly. The following agencies will be invited to establish a coherent approach to and understanding of EWS in Timor-Leste—UN agencies (such as FAO and IOM), international NGOs (including Mercy Corps, CARE, Oxfam, PLAN, World Vision, Caritas, and Child Fund), and local organisations (CVTL[553], RHTO[554], ASRRD[555], Fraterna[556] and others). Existing ad-hoc early warning related work at the community level will benefit from improved coordination and integration into a broader national system.

Efficiency and effectiveness

The Government of Timor-Leste is requesting a GCF grant to enable the efficient and effective delivery of the proposed Project interventions to achieve the stated impact. The requested grant is considered the most appropriate financial instrument to enhance climate services, disaster risk reduction and MHEWS due to the public good nature of such services and limited availability of government funding as a result of prioritisation of immediate development needs. The investment will directly address financial, technical, capacity and coordination barriers to the effective delivery of climate information

[551] https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[552] https://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf
[553] Cruz Vermelha de Timor-Leste: Red Cross
[554] Ra'es Hadomi Timor Oan: the Disabled People's Organisation
[555] Asosiasaun Serbisu Redusaun Risku Dezaster: Association for Disaster Risk Reduction
[556] Fraterna: local environmental / disaster response NGO

and multi-hazard early warning services. This comprehensive approach will ensure investment in all elements of the value chain for climate services, given that each link in the value chain is essential for enhancing the effectiveness of the overall outcome. Although direct revenue will not be an outcome of the GCF investment, the Project is expected to develop information products with commercial value that will enable cost recovery options and private sector engagement beyond its term. Such opportunities will be identified under Sub-Activity 1.1.5.

The Cost-Benefit Analysis (CBA) has identified and assessed the costs and benefits of the proposed interventions and has made inherent trade-offs explicit. The feasibility of the investments was determined by calculating the economic internal rate of return (EIRR) and economic net present value (NPV). A 5% discount rate has been applied. The CBA shows that, assuming a 10-year useful life of proposed interventions at a 10% discount rate, discounted NPV is positive (US $56.01 million). The economic internal rate of return (EIRR) of 104.3% exceeds the discount rate, making the proposed investment economically viable.

Sensitivity analysis has been used to test key parameters such as a decrease in benefits by 10% or an increase in costs of 10%. Although the EIRR decreased with those simulated cost benefit changes, the EIRR remained well above the 10% threshold in both cases (90.2% and 91.5% respectively). In addition, an even more pessimistic scenario combining a decrease in benefits by 10% and an increase in costs by 10% still results in a very high NPV and EIRR (US $46.81 million and 79.4%).

There is uncertainty in the findings of the CBA, with the total net benefits ranging from USD 63.76 million and USD 40.99 million, depending on various assumptions and parameters used. Nevertheless, the sensitivity analysis provides support for the Project across all scenarios considered, as scenarios show a positive economic NPV and an EIRR greater than the discount rate, which are the criteria used to determine the efficiency of the Project. However, the net benefits are likely to be underestimated due to conservative assumptions used in calculations in addition to the omission of the qualitative benefits excluded from the quantitative analysis, such as social and environmental benefits derived from the Project interventions. Most importantly, effective early warning systems save lives, and this is arguably impossible to translate to dollar terms. As a result, the CBA (Annex 3) provides a positive quantitative justification for the Project, which is estimated to generate a benefit-cost ratio of 5.7:1. This suggests that each USD 10 invested in the Project will translate to benefits with a value of USD 57.

The benefits calculated in the CBA take the form of avoided economic damages and losses. Without the Project, economic losses incurred through increased frequency or intensity of climate-related disasters, such as flooding, drought and storm surge, will be exacerbated, particularly when considering the negative impacts of potential changes in weather patterns. Avoided economic damages include impacts on infrastructure and physical assets, particularly contents, and crops. Effective climate services and impact-based MHEWS developed by the Project have the potential to partially reduce the loss of contents and crop loss. Improved hazard information and dissemination, providing better preparedness and longer lead times to evacuate, move content and harvest crops, are key contributors to these avoided damages. Avoided economic losses represent changes in economic flows arising from the disaster, lasting up to several years. The Project aims to increase sectoral and community resilience to climate-related hazards and extreme climate events, resulting in improved productivity and avoided losses to agriculture, fisheries and other relevant sectors.

Considering the baseline low capacity to provide climate information and early warning services (CIEWS) in Timor-Leste, the Project employs a holistic capacity building approach, maximising synergies and complementarity with existing initiatives (e.g., GCF project FP109[557]) to enhance efficiency and effectiveness. The Project will build on existing networks and strengths in Timor-Leste, such that capacity for climate services is developed in an efficient, cost-effective and complementary manner. The establishment of a National Framework for Climate Services and development of a financial framework and business model will provide a robust foundation for effective and sustainable delivery of climate services and disaster risk management beyond the term of the Project. Climate services investments return benefits that are far greater than the losses they will help prevent, with an overall cost benefit ratio of one to 10. Moreover, systematic investment in the WMO global-regional-national climate information system could provide a return on investment of as much as 80 to one.[558] The implementation of an integrated value-chain approach to strengthening climate information and early warning services will deliver long-term efficiency and effectiveness benefits. Benefits from early warning systems will be maximised by developing them in parallel to disaster risk management plans and investments, such as the community-level capacity building for disaster preparedness and Forecast-based Financing (FbF) / Early Warning Early Action (EWEA). The inclusion of Result 4, which focuses on enhancing risk management and preparedness capabilities, is in line with international best practices[559] and is critical to ensure that investments are effective to the last mile.

The Project will leverage the specialised knowledge of regional and international technical partners to ensure that the most effective technologies and best practices for climate information services and disaster risk management are utilised. Technical partners will deliver targeted training in areas that are essential for transformative impact beyond the term of the Project, including: i) Innovative and cost-efficient technologies for observations, monitoring and prediction, including Internet of Things (IoT) applications to revolutionise climate services and disaster risk management; ii) Operations and Maintenance (O&M); iii) Enhancing institutional effectiveness through Quality Management Systems (QMS) and related certification; iv) Enhancing institutional efficiency through impact-based forecasting and FbF/EWEA; v) Options for ensuring long-term financial sustainability, including a funding mechanism for forecast-based early action; vi) Use of alerts, information exchange and coordination in the first instance after major sudden-onset disasters; and vii) Integration of Traditional Knowledge to enhance the effectiveness of early warning systems. The Project will also ensure that all infrastructure, systems and processes are compliant with the WMO Global Basic Observing Network (GBON) and internationally recognised standards, as relevant.

Effectiveness of the Project will be further enhanced by its direct contribution to key national priorities and strengthening of existing national mechanisms. For example, the National Disaster Risk Management Policy (NDRMP) 2008-2013 elevated Disaster Risk Management (DRM) to national priority, generated political commitment, made the policy a multi-sector responsibility, and allocated the necessary resources for implementing it. The National Disaster Management Directorate (NDMD), under the Ministry of Social Solidarity (MSS), acts as a lead organisation for DRM in the country and coordinates with all line-ministries, District Disaster Management Committees (DDMD), Sub-district Administrators, and Suco Chiefs. Participatory implementation will enhance ownership through proper engagement of all relevant stakeholders, which will lead to efficiency and sustainability. Effectiveness is expected to increase as factors influencing the decision-making become less of an obstacle – for example, access to credit, and lack of skills to interpret information received.

Further details can be found in the Economic Analysis (Annex 3).

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557 https://www.greenclimate.fund/project/fp109
558 WMO, 2019. State of Climate Services 2019
559 WMO, 2018. Multi-Hazard Early Warning Systems: A Checklist

8.2 – BUDGET DEVELOPMENT PROCESS

The Project budget has been developed through an iterative process over several months. Early estimates were made on the basis of similar work undertaken in countries with similar physical environments, geography and constraints. Once an outline was agreed in principle, detailed costings were begun by the agencies nominating the Activities with the help of the consultants.

For each Activity, the proposal required:

Timeline: Year and quarter (within the year) in which the work will be done.

Financing source: GCF funds required, the co-financing or in-kind contribution of the Timor-Leste Government and the contribution by other partner agencies or projects.

Itemised costs by type:

- Staff costs (salary for the new or current staff who will work on the Project):
    - Funding of # technical/scientific/other staff ($ per annum) for # years. When and for how long will this position be funded? In which organisation will it be located?
- Professional services (cost of services from a company):
    - Cost of company services: type of service, daily rate, number of days.
- International consultant costs:
    - Cost of the international consultant: type of consultancy or services required, daily rate, number of consultancy days.
- Local consultant costs:
    - Cost of the local consultant: type of consultancy or services required, daily rate, number of consultancy days.
- Training, workshops and conferences:
    - # of workshops in # years: for each workshop, state which year (i.e. Year 1, Year 2, ….), location and duration of the workshop, number of participants, venue hire cost per day, catering cost per day or per person, other cost such as workshop materials, WIFI.
- Equipment (includes AWSs, laptop, camera, etc.):
    - Type of equipment, number of each item, cost per item, installation cost per item where applicable, cost of operation (i.e. Internet/satellite communications) and maintenance to be included (i.e. travel costs to maintain equipment and/or cost for spares if required).
- Travel:
    - # of trips for # of people in # years: for each trip state which year (i.e. Year 1, Year 2, ….), travelling from where to where, how many people travelling, airfare per person, how many days, for the whole trip, per diem/DSA (travel allowances including accommodation and meals per day).

In many instances no precedent existed that could be used to determine costs accurately. This is particularly the case for equipment such as AWSs to be installed in locations that are remote or with difficult access, but essential to generating an adequate network of high-resolution climate data. Timor-Leste's circumstances, particularly its steep, rocky terrain and the poor condition of its roads, make many items very expensive to provide, and cost-benefit analyses were carefully evaluated with Timor-Leste's NDA and other key partners.

A very detailed budget was developed using the collated information, organised by component, output, activity and item. In many cases, agencies found it difficult to cost their proposed Activities and so the consultants checked each item and its cost, and if possible, compared it to similar costs in similar projects. An operations and maintenance budget was compiled drawing on multiple quotes from potential suppliers of equipment and services and using the experience of similar projects in Pacific island countries.

At several stages of the development of the proposal, Timor-Leste's key stakeholders reassessed the proposal and the budget, and asked for changes to Activities or for new Activities to be added, and each change required corresponding changes to the budget.

9 – PROPOSED INTERVENTIONS AND TECHNICAL FEASIBILITY

RESULT 1 – STRENGTHENED DELIVERY MODEL AND LEGISLATION FOR CLIMATE INFORMATION AND MULTI-HAZARD EARLY WARNING SERVICES

This Result will enable Timor-Leste to establish a National Framework for Climate Services (NFCS), which will structure the science–policy interface, so that sector agencies have ready access to sound scientific data and useable information. It will support Timor-Leste's meteorological service (DNMG) in creating coordination mechanisms with key climate-sensitive sectors – including health, agriculture, disaster risk reduction, water and environmental management – to facilitate the integration of climate considerations into their decision making. The responsibility for the provision of climate and weather services and roles in disaster warning will be negotiated, clarified and formalised through the development of a Meteorology Act and a National Meteorological Strategy.

A systematic User Interface Platform will be established for continuing, regular stakeholder engagement by the sector agencies through meetings and workshops with DNMG. This ongoing interaction will enhance coherence and complementarity, and inform the development of tailored, accessible products and services that serve the practical needs of end users who are building climate considerations into their policies and practices. The national Climate and Health Working Group to be established will specifically strengthen delivery of climate services for health, which are essential for increasing health resilience in a changing climate.

Long-term institutional sustainability of climate services will be achieved through active maintenance of these stakeholder partnerships. At the same time, the development of a financial framework and business model for climate services will ensure that their value is reflected in the allocation of public funding for climate data collection, analysis and long-term adaptation planning. The Project will explore options for other sources of revenue using a value-chain approach.

Furthermore, this Result will instigate a best practice approach to data governance, initially for climate data, by strengthening DNMG's climate data management system. The Project will advance the integration of climate, health, agriculture and other data for improved forecast and early warning by strengthening data sharing and coordination among DNMG and other relevant stakeholders. It will support Timor-Leste's Statistics Directorate in using climate data and information with data from other sectors in order to mainstream climate considerations into the work of those sectors. The Water Sector – a priority area of the Global Framework for Climate Services – will be strongly engaged, recognising the critical importance of continuous weather, water and climate data for the assessment of fluctuations and trends and the risks arising from exposure and vulnerability to natural hazards as well as for effective Integrated Water Resource Management.

Activity 1.1 – Establish institutional and policy frameworks, legislation and delivery models for climate services

1.1.1 – Establish a National Framework for Climate Services, National Meteorology Act and National Meteorological Strategy

Throughout the implementation of this Project, DNMG proposes to conduct a series of stakeholder consultative workshops with stakeholders to develop and refine a National Framework for Climate Services (NFCS).

In each year of the Project, DNMG will invite representatives of the government agencies responsible for key sectors including the five Global Framework for Climate Services (GFCS) sectors – health, agriculture and food security, disaster risk reduction, water, and energy – to take part in a 3-day facilitated workshop. The workshop will begin with a presentation of basic climate science, an explanation of the kinds of data the NMHS collects, and a presentation on the products and services their data can be used to create.

The workshops will be held in conjunction with the National Climate Outlook/Monsoon Forum, which provides a long-range forecast of expected rainfall, ocean conditions and tropical cyclone incidence. They will also be aligned with the preparedness planning that climate sensitive sectoral agencies undertake ahead of the wet season—this will hasten the process of integrating climate information and forecasts into the work of these key sectors. Sector representatives will be asked to present on how they use climate information and how they can best work with the NMHS to ensure their operations take account of climate change impacts. The first workshop will begin the process of agreeing with these stakeholders more specific functions, relationships and services.

The Project will use the outcomes of the first workshop to draft the NFCS, which will inform the future climate work of the DNMG. Objectives will be to agree with key sectors a suite of directly applicable information products, with a process for checking their utility regularly and revising them when needed. Services are likely to include climate-related advice for agriculture and health ministries, infrastructure planning, disaster response preparation and international advocacy—these inputs should be agreed with the relevant departments. In year five the NFCS will be re-evaluated using feedback and learnings from each sector over the previous four years.

The initial NFCS will be developed through the following steps:[560]

- Organise the national consultation workshop on climate services, bringing together the key stakeholders who link climate knowledge to adaptation on the ground, to identify the key elements and priorities of the Framework;
- Develop a strategic plan and a costed action plan with timelines, to implement the NFCS;
- Convene a follow-up meeting with stakeholders to finalise and endorse the strategic plan and the action plan; and
- Launch the agreed NFCS and initiate its implementation.

Implementation of the Framework will include scheduled monitoring and evaluation: decisions will be revisited each year in the 3-day facilitated workshops with stakeholders, immediately after the National Climate Outlook Forum/Monsoon Forum. During each workshop, the Framework will be modified in accordance with feedback and learnings by the facilitator and changes verified with the participants and an evaluation workshop with all stakeholders in Year 5 will inform the final agreed NFCS.

Once established, the NFCSs will serve the following functions:

- A platform for institutional coordination, collaboration and co-production of user-oriented climate services, among technical departments from line ministries at national and sub-national levels, DNMG and technical experts. This will give sector agencies the opportunity to articulate what information they need, and how they would like it to be provided to them—what data, what formats, what interval frequency.
- A framework for collaboration at national level to generate and share user-oriented climate services for use by social and economic sectors. This will help stakeholders to identify and

[560] WMO, 2018. Step-by-step Guidelines for Establishing a National Framework for Climate Services

agree on specific functions, relationships and services to ensure that their operations take into account climate variability and climate change impacts.

- A bridge over the gap between available climate services and user needs at national, sub-national and local levels. The Project will continuously identify user needs for climate services, communicate available climate products and services to sector users, and obtain feedback from users on the usefulness of climate products and services.
- A vehicle for coordination of scientific monitoring of the state of Timor-Leste's climate and for disseminating scientific climate knowledge to policy decision-makers through the Climate Services Information System. The twice-yearly National Climate Outlook / Monsoon Forum (NCOF: held each year in March and October, see Sub-Activity 1.1.2) and the series of professionally facilitated annual workshops will help public sector agencies (including ministerial departments for the five Global Framework for Climate Services priority sectors – agriculture, health, disaster risk reduction, water and energy) to identify and articulate how they need to use climate information. These decisions will be revisited each year during the and modified in accordance with feedback from stakeholders.
- A functional chain for linking climate knowledge with action on the ground so as to maximise the application of climate information and products, including the identification and removal of bottlenecks for improved delivery of climate information services.
- An authoritative source of climate science to inform the development of national adaptation plans, disaster risk reduction, Sustainable Development Goals and national development policies.

In order to clarify and formalise the mandate of DNMG and its relationship with other national institutions and sectors, this sub-activity will also support Timor-Leste to develop a draft Meteorology Act and a National Meteorological Strategy to guide its implementation.

In the first year, the Project will engage a legislative drafting consultant to prepare a draft Meteorology Act for approval by the Council of Ministers. The drafted Act will mandate the responsibilities of the DNMG for provision of weather and climate services (including flood forecasting) and formalise the DNMG's role in monitoring and analysing changes, advising on adaptation, contributing to warnings, and briefing delegates to international climate forums. It will also formalise its relationship with other agencies – including the National Directorate of Water Resources Management (DNGRA), which has the mandate for hydrology and hydraulics. Hence it will formalise DNMG's role in inter-agency partnerships, as well as provide budget security.

The consultant will work with the Ministry of Justice to ensure that the draft is consistent with Timor-Leste's existing legislation and looks to the future, taking into account the DNMG's role in advising the Government and people on climate change science and impacts and contributing to international advocacy. The National Directorate for Water Resource Management, National Disaster Management Directorate, disaster relief agencies and media organisations will be consulted to ensure the draft legislation supports their collaboration with the DNMG. The consultant may also consult with WMO, which has advised other SIDS on developing a Meteorology Act, and with RIMES on model legislation.

The international consultant will also work with DNMG to draft a National Meteorological Strategy, which will document the process by which DNMG will put its Meteorology Act into operation. A consultant will evaluate the implementation of the Act and the Strategy in Year 5.

1.1.2 – Establish a User Interface Platform

A User Interface Platform (UIP) will be established as a forum for interaction between DNMG – as the climate services provider – and its stakeholders and end-users of climate information services. The UIP is a key pillar of the National Framework for Climate Services (NFCS),[561] to be developed under Sub-Activity 1.1.1, and will focus on achievement of outcomes in four priority areas: Feedback, Dialogue, Outreach and Monitoring and Evaluation.

The National Climate Outlook / Monsoon Forum (NCOF) will be a critical component of the UIP and will be held twice each year, in October before the wet season and in March before the dry season. The NCOF will facilitate delivery of the intended outcomes of the UIP, as outlined below:

- **Feedback –** The NCOFs will provide a facilitated forum for DNMG to obtain feedback on how effectively its products and services are meeting the needs of user communities. The Forums will enable DNMG to respond to forecast information requests from users. This could include requests for improvements in forecast product availability, resolution, lead time and accuracy. Elicitation of decision makers' information requirements will support the development of tailored climate products for each sector.
- **Dialogue –** The NCOFs will build dialogue between climate service users – including government agencies, NGOs, private sector representatives, civil society organisations, women's groups and community representatives – and technical institutions responsible for the observation, reach and information system pillars of the NFCS – in particular, DNMG. The Forums will provide a venue for DNMG to present its forecast products and services, including a long-range forecast of expected rainfall, ocean conditions and tropical cyclone incidence. The DNMG compares the observed climate of the previous six months to the long-term average, and to the forecast for that six months, and prepares participants for the upcoming wet or dry season. The NCOFs will include sessions on preparedness planning, which will help to enhance users' capacity to interpret and integrate forecast information of various timescales into their own plans and decisions.
- **Outreach –** The NCOFs will support improved climate literacy in the user community and literacy of the climate community in user needs. They will provide platform for knowledge sharing between climate services providers and sectors, so that stakeholders can better understand the content and uncertainties in climate forecasting and the meaning and use of probability rankings about likely climate risks.
- **Evaluation –** The NCOFs will provide a mechanism to monitor and evaluate the development, delivery and effectiveness of climate services in Timor-Leste[562] to ensure that products and services meet the needs of stakeholders. This will facilitate that the NFCS promotes evidence-based decision-making and planning for climate resilience across priority sectors and in vulnerable communities.

  The strategic plan and action plan for the establishment of the National Framework for Climate Services (NFCS) to be developed under Sub-Activity 1.1.1 will include the Monitoring and Evaluation (M&E) process and reporting (the "M&E mechanism") to be undertaken, which will provide feedback on the performance progress of the NFCS. As the critical component of the User Interface Platform pillar of the NFCS, the NCOFs will maintain the M&E mechanism – bringing together DNMG (as the climate services provider) and climate services users to

[561] WMO, 2012. Guidelines on Frameworks for Climate Services at the National Level
[562] The approach to Monitoring and Evaluation (M&E) for the Project is detailed in Annex 11

provide user perspectives and feedback on the functioning of the NFCS. As per WMO guidance,[563] the NCOFs will implement the M&E mechanism outlined in the NFCS action plan using a results-based approach that is roughly based on the Logical Framework Approach. The Logical Framework Approach develops a common understanding of the expectations of a Framework (in this case, the NFCS) by delineating a hierarchy of Activities (**how**), Outputs (**what**), Purpose (**why**) and Goals (**greater why**) that collectively will lead to accomplishment of the greater Goal of the Framework.

The actual details of the M&E mechanism will be co-developed and refined during the NFCS workshops to be conducted under Sub-Activity 1.1.1. This will ensure that national stakeholders are involved throughout the entire process of development and endorsement of the NFCS, its strategic plan, and its costed action plan, so that they become partners in identifying the key priorities for investment in climate services and are engaged in ensuring the successful and sustainable implementation of the NFCS.

The Water Sector – a priority area of the Global Framework for Climate Services – will be strongly engaged through the NFCS and NCOFs, recognising the critical importance of ongoing climate data for the assessment of fluctuations and trends and the risks arising from exposure and vulnerability to natural hazards (floods and droughts) as well as for effective Integrated Water Resource Management.[564] Increased dialogue and joint action facilitated by the NCOFs will help to maximise the usefulness of climate services and foster development in new and improved applications of climate information for the water sector. Moreover, dialogue facilitated through the NCOFs will simultaneously support improved water literacy among the weather and climate service community, enabling DNMG to better understand the decision-making context of water managers.

The NCOF will also be an opportunity to establish partnerships for implementing the Early Action Protocols (EAP) developed in Activity 4.2. The sector workshops held in each year of the Project will also form part of the UIP, as will outreach work on making climate information more accessible to communities.

1.1.3 – Enhance climate data management and governance

This Sub-Activity will support Timor-Leste in managing and using climate data and information in conjunction with data from other sectors in order to mainstream climate considerations into the work of those sectors. This is particularly important for the very climate-sensitive sectors of health, agriculture, water and fisheries that are already being affected by atmospheric and ocean warming. Although some ministries have made significant progress on data collection, in most sectors, decisions are being made based on sub-optimal evidence. In addition, there is an immediate need for stronger integration of environmental science and analysis – supported by up-to-date, quality-assured, and relevant data – at both the national and international levels. The Government of Timor-Leste wants to be able to use data from various sector sources with climate data when it reports to the international community on its implementation of multilateral environmental agreements such as the Paris Agreement and the UNFCCC in general. As such, the following will be conducted:

Climate Data Strategy

Through a series of consultative workshops with key stakeholders, a Climate Data Strategy for DNMG and the Statistics Directorate will be drafted to support improved climate-related data management, governance and enhanced inter-sectoral data coordination. In Year 2, the Project will draft the Climate

[563] WMO, 2014. Annex to the Implementation Plan of the Global Framework for Climate Services – User Interface Platform Component
[564] WMO, 2014. Water Exemplar to the User Interface Platform of the Global Framework for Climate Services

Data Strategy and Action Plan and develop sector-specific training in its use by government agencies, including the Statistics Directorate, DNMG, NDMD and MAF. The training will be delivered to 30 key delegates. Throughout its term, the Project will work with partner government agencies to implement the Plan, making good quality data available for planning, reporting and evaluating activities, particularly relating to health, agriculture, disaster risk reduction, water and environmental management. Strengthened data sharing and coordination among DNMG and other key stakeholders, including DNGRA, will maximise the value of existing datasets (such as water-level monitoring observations) and advance the integration of multi-sectoral data for improved forecasting and early warning. The Strategy and Action Plan will be submitted for approval at the government level.

Upgrade and Training in Climate Database Management Systems

In this Sub-Activity, RIMES will begin the installation of its Climate Data Informatics System (CDIS), which will provide an integrated platform for climate and scientific data analytics and visualisation, with linkages to sectoral decision-making tools. CDIS is part of a technical solution for transmitting, storing, managing, processing and visualizing data from different data streams including Numerical Weather Prediction (NWP), satellites, radar, lightning and observation networks. The system is built on open-source code and is highly flexible and scalable so that any forecasting sub-system can be integrated. These sub-systems may be from RIMES such as the Forecast Customization (FOCUS) Tool for monthly and seasonal forecasting or from other sources such as BOM's ACCESS-S. As part of the installation of CDIS, RIMES will support DNMG to ensure that the current and historical meteorological data is ingested seamlessly into CDIS. The CDIS will host all hydrological data (along with weather and climate data) to provide a single integrated platform for easier access, quality control, and generation of derived products. As an intergovernmental entity, RIMES will not charge Timor-Leste any licensing and/or update/upgrade fees for CDIS. RIMES will also provide free ongoing technical support both during and after the Project lifespan. Installation of CDIS will enable the establishment and operationalisation of a forecasting centre at DNMG (see Sub-Activity 2.2.1).

1.1.4 – Mainstream climate risk knowledge into health, agriculture, disaster risk reduction and other sectors

Accurate and actionable climate information from DNMG can reduce climate risks significantly if the advice has a recognised formal role in disaster preparation, warnings and management and in long term climate change planning by infrastructure, water, health, tourism, agriculture, fisheries and other sectors. The Project will support a systematic five-year process of integrating climate considerations into the decision making and planning of government, private and community sectors, by supporting them to understand and appropriately utilise climate information services provided by DNMG.

The Project will engage an international and a local consultant to develop a National Climate Sector Action and Communication Plan (CSACP) with key stakeholders in each of the five GFCS priority sectors – health, agriculture and food security, disaster risk reduction, water and energy – and with DNMG staff. The first step will be a five-day workshop in Year 1 with senior ministry officials and technical staff and DNMG staff. Using the outcomes of the workshop, the international consultant will draft the CSACP with the support of the local consultant, to ensure the Plan is culturally appropriate and reflects Timor-Leste's situation realistically. Both consultants will ensure the Plan addresses gender issues both in the Plan itself (mainstreaming climate knowledge and information into the work of agencies) and in the application of its products within each sector.

The international consultant will develop Sector Specific Climate Training packages for the key sector agencies responsible for priority areas identified under GFCS[565] on climate basics and the logistics of integrating climate and climate change knowledge into the functions of their agencies. The training packages will include modules that ensure trainees understand the constraints imposed by gender inequality and other inequalities of access such as age and disability on receiving and using climate services.

1.1.5 – Establish a financial framework and business model for sustainable climate services

Once foundational capacity building for climate services is initiated, the Project will start to demonstrate the value, reliability and utility of climate information products and services. This is expected to generate interest from climate-sensitive sectors in utilising the strengthened climate services to address their needs for climate information (which are generally recognised and outlined in Section 6).

In order to prepare the ground for private sector engagement and mobilisation opportunities in the longer term (beyond the Project's duration), this sub-activity will further scope viable opportunities for sectors and business segments to utilise the strengthened climate services and identify opportunities to develop value-added climate products and services (e.g. targeting a particular sector such as agriculture or health, or related to a particular climate-related hazard); and potential for public-private partnerships and private investment in climate services. This will feed into the establishment of a financially sustainable business model for climate services in Timor-Leste.

Based on the NFCS established under Sub-Activity 1.1.1, the Project will develop a financial framework to ensure that DNMG has the means to sustain and ensure the ongoing operation of its mandated services, as its capacity to generate marketable climate products is developed. The financial framework will cover the following elements:

- Opportunities for greater cooperation between the public and private sectors and academia, thereby delivering win-win situations that fulfil public sector responsibility to provide weather and climate services as a public good, whilst also meeting the need of economic sectors that increasingly depend on meteorological information for safe and efficient operations. Accordingly, the Project will enhance awareness at the government and sectoral level of the economic value of climate information – for example, in reducing the costs of recovery due to tropical cyclone damage to critical infrastructure; and reducing the need for transport of drinking water and food aid to remote communities as a result of severe flooding or drought.
- Coordination and/or integration of financing for climate services and disaster risk management to establish adequate and reliable funding for disaster risk reduction and preparedness activities, which are mostly dependent on ad-hoc donor funding. This would facilitate a more efficient and streamlined approach to implementing often overlapping actions for climate change adaptation and disaster risk management. This will incorporate the financial mechanism for Forecast-based Financing (FbF) / Early Warning Early Action (EWEA) to be developed under Activity 4.2.
- Identification of the elements of a sustainable business model for DNMG based on the climate services value chain, which highlights the different roles of NMHSs in providing basic forecasts

[565] These are the agriculture and food security, disaster risk reduction, energy, health and water sectors. The Government of Timor-Leste may decide to prioritise other agencies as an outcome of the consultative workshop—for example, finance, fisheries, forestry or education.

and warnings to protect society from the adverse effects of severe weather (a public good typically supported by governments, for which predictable national budget allocations need to be ensured) but also in providing specialised value-added services to sectoral government agencies and individual businesses (which may offer opportunities for cost-recovery from governmental and non-governmental sources beyond the term of the Project). The business model will identify opportunities for DNMG to provide specialised value-added services to government agencies and individual businesses. As services are established and valued, the Project will also assist DNMG to identify potential options for cost-recovery, recognising the need to be able to first demonstrate the value, reliability and utility of climate information products.

- Potential to establish a National Climate Fund (NCF) as a mechanism to support Timor-Leste to manage its engagement with climate finance by facilitating the collection, blending, coordination of, and accounting for climate finance directed towards climate services. Functions of the NCF could include: i) Support goal setting and the development of programmatic strategies for climate resilience; ii) Fund capitalisation; iii) Management of strategic partnerships; iv) Climate services project support mechanisms; v) Support policy insurance; vi) Provision of financial control; vii) Performance management, including monitoring and reporting on activities and resource disbursement; and viii) Knowledge and information management.[566]
- Potential for continued support from the Systematic Observations Financing Facility (SOFF) as part of the Alliance for Hydromet Development, which was launched in December 2019 by 12 international organisations including UNEP. The SOFF is envisaged to ensure provision of basic systematic observations as a global public good by providing equitable, predictable, sustainable and performance-based finance as well as technical assistance to developing countries for the provision of foundational observations data as per the Global Basic Observing Network (GBON) standard adopted by the WMO Congress. GBON aims to improve the global availability of the most essential surface-based data by defining obligations for countries to implement a minimal set of surface-based observations, for which international exchange of observational data will be mandatory. Further details are provided under Activity 2.1.

In each year of the Project, an international consultant will assess the DNMG's financial situation—its income sources and costs, and options for broadening its revenue sources. A business model will be developed during years 4 and 5, based on the value chain approach to climate services delivery, including identification of opportunities for the DNMG to provide specialised value-added services to government agencies and individual businesses. As services are established and valued, the Project will assist the DNMG to identify potential options for cost-recovery, recognising the need to be able first to demonstrate the value, reliability and utility of products.

RESULT 2 – STRENGTHENED OBSERVATIONS, MONITORING, ANALYSIS AND FORECASTING OF CLIMATE AND ITS IMPACTS

This Result will strengthen the technical capacity and modernise Timor-Leste's national meteorological service (DNMG), enabling it to collect higher quality data at higher resolution and from a wider geographical range, including its oceans, and to use the extra data. This will be achieved through the installation of new and upgraded infrastructure and equipment to extend the coverage

[566] UNDP, 2015. Blending Climate Finance Through National Climate Funds

of weather, climate and ocean observations; through training and support for observations, monitoring, modelling and prediction; and through training in maintenance.

The Project will upgrade and expand the surface-based observations and monitoring network in Timor-Leste to enable compliance with the WMO Global Basic Observing Network (GBON), which represents a new approach for the international exchange of the most essential surface-based observational data and will facilitate access to 24/7 global observations as a global public good.[567] Installation and capacity building for weather radar observations will further enhance extreme weather monitoring and early warning systems, and support validation of Numerical Weather Prediction (NWP) forecasts. The establishment of a national Forecasting Centre will provide the three critical elements of telecommunications, data management and forecasting – supported by technical training and capacity building to ensure that DNMG has the ability to translate weather, water, climate and ocean observations into impact-based forecasts and value-added products and services. The Project will also build national capacity to implement innovative and cost saving technologies and practices, such as the deployment of Internet of Things (IoT) technology for climate services applications.

One of the most significant activities in the Project will be to establish climate services for health. Climate change is increasingly affecting public health and well-being[568] – for example, deaths from extreme weather events, wildfires and emerging infectious diseases. Air quality, weather and climate, and health are closely linked, with climate variability and change expected to magnify exposure to particulate matter, ozone and other pollutants.[569] As such, there is an increasing demand for relevant, timely and usable information about weather and climate variability, change, risks and impacts to enable decision-makers – from public health officials to individual citizens – to take appropriate action to keep people safe and healthy. The Project will address this critical need through several interventions, including institutional strengthening through a national Climate and Health Working Group, establishment of an air quality monitoring network and health impact advisory, and the delivery of tailored forecasting and decision-support systems for the health sector.

Activity 2.1 – Enhance infrastructure and technical support for observations and monitoring

2.1.1 – Expand and upgrade the meteorological observation network to GBON standards

The Project will enhance, modernise and automate Timor-Leste's hydrometeorological observation and monitoring network in alignment with draft WMO Global Basic Observing Network (GBON) provisions, using emerging cost-effective technologies and piloting innovative technologies where possible. The Sub-Activity will fill gaps in Timor-Leste's hydrometeorological observation network, as identified in Section 6, by increasing the number of Automatic Weather Stations (AWS) and Automated Weather Observing Systems (AWOS) and by building in-country capacity to ensure sustainable operations and maintenance.

The following interventions will contribute to Timor-Leste's achievement of WMO Category 2 (Essential) status for climate services:

- **Enhance the network of surface-based observation stations** measuring atmospheric pressure, temperature, humidity, horizontal wind and precipitation, at a horizontal resolution

[567] SOFF, 2020. The value of Surface-Based Meteorological Observation Data: Costs and benefits of the Global Basic Observing Network
[568] WHO, 2020. WHO Global Strategy on Health, Environment and Climate Change
[569] WMO, 2014. Air Quality and Human Health, a Priority for Joint Action. Available at: https://public.wmo.int/en/resources/bulletin/air-quality-and-human-health-priority-joint-action

of 200 km or better with at least hourly reporting of data **in compliance with Global Basic Observing Network (GBON)** technical requirements, which will be finalised at the WMO Congress in 2021.[570] The Project will install new climate monitoring stations: nine automatic weather stations (AWS) – including, amongst others, automatic rain gauges – and one automated weather observing system (AWOS), which will feed data into GBON for use in global Numerical Weather Prediction (NWP). Based on the Systematic Observations Financing Facility (SOFF) GBON gap analysis,[571] which used a basic method of dividing the country area by 40,000 km^2 (200 x 200 km) to obtain the number of surface-based observing stations required, Timor-Leste (area: ~15,000 km^2) requires one automatic weather station (AWS) to comply with GBON. Given that the maximum length of the country is 470 km, this could translate to the requirement for two AWSs. Therefore, the proposed equipment installations surpass the GBON requirements for resolution. All new/upgraded stations will report data on an hourly basis, thus ensuring compliance with GBON requirements for frequency.

- **Increase observation station density** based on national requirements and guided by the observation Network Development Plan developed by WMO in compliance with GBON. This will include the installation of a marine buoy, which will enable marine forecasts to be produced.
- **Introduce weather radar for severe weather and climate monitoring** through installation of a network of three dual-polarization X-band Doppler weather radar systems, supported by technical training and remote support to build in-country capacity for radar operations, maintenance and data applications for weather and climate monitoring and analyses. Establishment of a network of low-cost, high temporal resolution, short-range, small radars is an innovative and practical solution for Timor-Leste; the country's highly mountainous topography challenges the effectiveness of more advanced long-range radar systems due to issues with shielding, inhomogeneous beam filling and signal attenuation.[572] Amongst others, precipitation measurements by radar provide areal rainfall determination, and thus complement point rain gauge data with finer spatial resolution of the precipitation field – the outputs of which are advantageous for grid-based models. Radar data also provide real-time data availability and the ability to track approaching storms before they reach the boundary catchment of interest.[573] The blending of radar data with NWP in short lead time rain and flood forecast models has resulted in considerable scientific advances, enabling prediction of rain cell development and decay as well as trajectory.[574]
- **Improve observations through compliance with WMO Integrated Global Observing System (WIGOS)** regulatory and guidance material. This will include formulation of a long-term operations and maintenance schedule, procurement of spare parts and calibration equipment, and iterative training on calibration and maintenance with development partners.
- **Build capacity to use Information and Communication Technology (ICT)** for the collection and exchange of hydrometeorological observations, required for analysis, monitoring and forecasting and the delivery of comprehensive and effective weather, climate and ocean

[570] GBON draft technical requirements will be submitted to the World Meteorological Congress in 2021 for its approval. SOFF, 2020. The gaps in the Global Basic Observing Network (GBON)
[571] SOFF, 2020. Outcomes of the joint kick-off meeting 15 May 2020. Summary outcomes of Working Group 2: GBON gap analysis and implementation outcomes
[572] Gabella, M. *et al.*, 2012. A Network of Portal, Low-Cost X-Band Radars. In book: Doppler Radar Observations – Weather Radar, Wind profiler, Ionospheric Radar, and Other Advanced Applications
[573] WMO, 2011. Manual on Flood Forecasting and Warning
[574] WMO, 2013. Integrated Flood Management Tools Series. Flood Forecasting and Early Warning

information services and products. The Project will provide ICT technical support and knowledge transfer for DNMG staff to build in-house capacity to maintain operational and cost-effective systems sustainably beyond the five years.

- **Enhance data and data management – including data archival processes and systems** to ensure security, integrity, retention policy and technology migration – to be delivered under Activity 1.1. This will facilitate that historical and real-time atmospheric, surface-based and oceanic observations of the Essential Climate Variables (ECVs) prepared by the Global Climate Observing System (GCOS) and partners for climate monitoring purposes are exchanged freely for use in Regional Climate Centres (RCCs) for at least one Global Surface Network site.
- **Generate generic monitoring products** for surface-based atmospheric and marine observations, weather radar data, air pollution and fire risk monitoring.
- **Compute sector-specific climate indices** and other sector-oriented climate products – to be delivered under Activity 2.2.
- **Create value-added products** – to be delivered under Activity 2.2.
- **Establish a Quality Management System (QMS)** – to be delivered under Activity 2.1.2.
- **Enhance forecasting systems** – to be delivered under Activity 2.2.

The new and upgraded observation equipment will measure precipitation, temperature, atmospheric pressure, wind speed and direction to WMO standards for contribution to GBON. Terrestrial and ocean data will be ingested directly into the Global Telecommunications System (GTS). The improved range, volume and quality of the data will enable Timor-Leste to make a valuable contribution to the Global Climate Observing System (GCOS), which supports the sustained provision and availability of climate observations throughout the world and regularly reports on the adequacy of the current climate observing system to the UNFCCC.[575] The ocean observing equipment will also benefit Timor-Leste's fisheries sector, which is dominated by small-scale coastal fishers – with an estimated 20,000 artisanal fishers. While not contributing significantly to the country's formal economy, the sector has a vital role in food security, nutrition and household income.

2.1.2 – Implement a robust program of training and capacity building including QMS

Throughout its five-year term, the Project will manage a robust program of staff recruitment and training, capacity building and modernisation of the organisational structure of the DNMG, to adapt to new processes and functions and additional human resources. An international consultant will conduct Basic Information Package - Meteorological Training (BIP-MT) in the DNMG over two months in Year 1 and again in Year 5. The Project will arrange a week-long training program for 30 staff in Quality Management Systems (QMS) in Years 1 and 5 and testing to achieve WMO certification for the trained staff.

The DNMG is committed to providing a sound Operations and Maintenance (O&M) program for its expanded hydrometeorological networks during and after the Project (see Annex 21). DNMG has assumed responsibility for securing O&M after the Project implementation period for up to 20 years. The draft plan provided as Annex 21 will be refined during the Programme's inception and implementation. Furthermore, DNMG has formally committed to sustaining some of the critical functions to be introduced by the Project (meteorology, oceanography and Operations &

[575] WMO, IOC-UNESCO, UNEP and ISC. About GCOS. Available from: https://gcos.wmo.int/en/about

Maintenance) after its implementation period. As a Technical Partner in this Project, the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) has also formally committed to continue supporting DNMG after the end of the proposed Project. This will include back-up support, technical enhancements, and system upgrades to the Climate Data Informatics System (CDIS), as well as decision support systems for ocean services, agriculture, disaster management and health sectors. Development partners (WMO members with advanced NMHSs and regional organisations) have expertise and experience in the deployment and management of equipment in tropical environments and will contribute to DNMG's acquisition of skills in maintenance and calibration.

The training will be delivered over two weeks at a technical partner's site. Two technicians will be trained on the calibration and maintenance of automated weather stations (AWSs). They will learn to assemble and calibrate manual weather stations so they are completely familiar with their operation, and the partner agency will give them training materials such as operational competency workbooks for use in the DNMG. The maintenance training will also cover the robust and user-friendly new communications equipment to be procured by the Project.

Other training will cover more advanced meteorology and climatology. The DNMG also proposes to engage an ocean science officer in response to demand for ocean climate services: this officer will lead sector workshops introducing information users to the potential for ocean data to inform their work. The officer will engage with coastal communities to explain the contribution that ocean data can make to understanding extreme events and improving warning times. S/he will monitor threats to Timor-Leste's reefs—warming and bleaching—so that harm can be minimised.

The Project will help the ocean science officer and the DNMG to conduct ocean data stakeholder engagement workshops twice in each year of the Project, focusing on communicating the impact of hazards. This regular interaction between the ocean science officer, the DNMG, the Project team, national agencies and coastal communities will improve the understanding of stakeholders and the likelihood that they will act upon warnings. The ocean science officer will establish feedback mechanisms to make sure his/her delivery of information is effective and is modified if necessary.

2.1.3 – Initiate Internet of Things (IoT) approaches

The Project will support the DNMG in advancing towards an Internet of Things (IoT) approach to collecting data and disseminating information. IoT along with cloud computing and big data analytics has the potential to address the "big data problem" where shortly after the onset of a disaster, the volume of data dramatically increased but cannot be processed due to lack of automated and scalable ICT infrastructure. Use of IoT can enable big data streams from various digital channels to be analysed in a timely and scalable manner to establish accurate situational awareness.[576]

An annual workshop will be conducted for 30 delegates, led by a technical specialist from the International Centre for Theoretical Physics (ICTP[577]), on the use of wireless connectivity and IoT for climate services and disaster risk management.

Working closely with local partners, the Project will implement a pilot study consisting of 20 low-cost weather stations based on IoT technology. The aim of the pilot will be to develop and demonstrate the potential of diverse, low-cost sensors to provide weather data. This will be achieved through the integration of three technologies into a common data processing platform:

[576] Gaire, R. et al. 2018. Internet of Things (IoT) and Cloud Computing Enabled Disaster Management. Available at: https://arxiv.org/abs/1806.07530
[577] https://www.ictp.it/

- LoRaWAN[578]-enabled weather stations will be deployed to send data to a solar-powered, GSM[579]-compatible gateway.
- Infrastructure will be set up to enable remote data collection and will be available for future extensions (water level monitoring, air quality, landslide detection, drought monitoring, etc.).
- A local server will collect data from TTN[580] and will enable user-friendly visualisation of weather data.

Activity 2.2 – Strengthen climate modelling and impact-based forecasting

2.2.1 – Establish a National Forecasting Centre

At present, DNMG does not have sufficient facilities and capacity to run models or generate its own sub-seasonal and seasonal forecasts. This Activity will establish a Forecasting Centre with hardware, software, installation/set-up and training of DNMG staff in data management, IT and the forecasting sub-systems. This is crucial to strengthening DNMG's capacity to deliver multi-hazard early warning products and services. The Centre will provide three critical elements—telecommunications, data management and forecasting. The Regional Integrated Multi-Hazard Early Warning System for Asia and Africa (RIMES) will support technical solutions for transmitting, storing, managing, processing and visualising data from different data streams, including numerical weather prediction (NWP), satellite, radar, lightning and observation networks. The system will be built on open-source code, highly flexible and scalable so that any forecasting sub-system can be integrated with it. These sub-systems may be from RIMES such as the Forecast Customization (FOCUS) Tool for monthly and seasonal forecasting or from other sources such as BoM's ACCESS-S.

In Years 1 to 3, inputs from a senior climatologist, a synoptician, and telecommunications specialist, programmers and a database management specialist will support the setup of the centre and provide training and mentoring for DNMG staff. These specialists will continue to support the centre at a reduced rate in Years 4 and 5 as the DNMG's capacity grows. As new staff are recruited, a hydrologist and an oceanographer will be made available to support the staff and for establishing skills and functions in these fields. RIMES will deliver training at the DNMG on IT, data management and forecasting subsystems in the second and fifth years of the Project.

Furthermore, DNMG has insufficient facilities and capacity to run ocean models and produce marine forecasts. In a 2019 survey by WMO on marine and coastal services, DNMG requested access to WMO's marine/ocean forecasts as well as assistance in developing the country's marine forecasts through capacity building.[581] This Activity will provide training to DNMG staff on ocean modelling and marine forecasting. RIMES will work with DNMG to customise the Ocean State Forecasting and Advisory System (OSFAS) Decision Support System (DSS), a web-based system for generation of advisories based on location-specific ocean state forecast information. The system disseminates 3-day forecasts of wave and swell height, direction, and period, sea surface current and temperature, and wind speed, with accompanying advisories; displays real- or near real-time observation data; and receives user feedback for validating forecast information. It can also provide marine fishery advisories and coral reef mapping and health monitoring information. In addition, OSFAS has capability to track

[578] The LoRaWAN specification is a Low Power, Wide Area (LPWA) networking protocol designed to wirelessly connect battery operated 'things' to the internet in regional, national or global networks.
[579] Global System for Mobile communication
[580] The Things Network (TTN) is a global community building an open-source and decentralised LoRaWAN network
[581] See https://library.wmo.int/doc_num.php?explnum_id=9826

wave rider buoy location and has an alert messaging service in case of buoy drift. This will enable DNMG to provide forecasts to the marine sector to improve safety, efficiency and sustainability.[582]

2.2.2 – Enhance climate change risk modelling and prediction

The Government of Timor-Leste has recommended that academic institutions such as the National University of Timor-Leste (UNTL) Centre for Climate Change and Biodiversity (CCCB) in the Faculty of Agriculture have better access to and the ability to apply UNFCCC climate change scenarios to establish or improve drought and flooding predictions, in support of the DNMG. UNTL is already providing some climate change related training to relevant ministries, such as crop modelling by using DSSAT – the decision support system for agrotechnology. The University currently has no capacity to undertake deep analysis or to develop projections for drought and floods in the future, but it provides access to its climate data collection via its website.

This Sub-Activity will provide the CCCB access to climate change models such as CMIP5 (Coupled Model Intercomparison Project Phase 5) and provide related training on interpreting the outputs. The Project will arrange for a technical partner agency to provide intensive training on climate modelling to CCCB staff in the first year so that they can enhance the accuracy of their trainings to relevant ministries and stakeholders—an expert trainer on modelling will deliver a three-week course to 15 participants in the first year of the Project.

2.2.3 – Establish impact-based forecasting and decision-support systems for agriculture, disaster risk reduction and marine sectors

The Project will support Timor-Leste to establish a multi-hazard impact-based forecasting approach that translates information on weather and climate-related hazards into sector- and location-specific impacts.

Timor-Leste's Ministry of Agriculture and Fisheries (MAF) monitors drought through a manual agromet analysis and provides early warnings of seasonal-scale events through monthly and quarterly agromet bulletins. These products can be very useful, but it is challenging to detect which geographical areas will be affected, and the intensity and duration of drought from an agricultural perspective. The bulletins remain general (whole country scale) and mostly focus on meteorological drought.

MAF has a National Information and Early Warning System (NIEWS) in place, but there is insufficient capacity, data and infrastructure within MAF and NDMD to provide forecasts for drought and early warnings for agriculture sectors. Currently, drought early warning data only addresses the cropping sector, with a heavy focus on rice and maize, rather than the crops grown by subsistence farmers. No forestry or fishery-specific data is currently available. Neither is the DNMG yet able to generate the local sub-seasonal and seasonal forecasts needed for decision-making at all levels.

This sub-activity will provide technical support and capacity building for DNMG to generate sub-seasonal forecasts (2-week, 3-week and 4-week), monthly and seasonal (3-month) forecasts and to include other parameters besides rainfall in its forecasting system. Concurrently, it will support DNMG and key stakeholders to translate hydrometeorological, climate and sector information into sector-relevant impact-based forecasts. In turn, this will feed into sector-specific decision-support systems (DSS) for agriculture, disaster risk reduction (DRR) and marine sectors to enhance preparedness planning, early warning and information dissemination.

[582] For instance, warnings that the sea surface temperature is high, stressing coral reefs and fish species, allows local managers to limit human interference so that ecosystems recover faster.

Within the scope of the Project, the aim will be to establish in-country capacity to integrate hazard forecasts produced by DNMG with vulnerability curves to generate potential impacts of forecasted hazards. Simultaneously, the Project will develop overarching DSS tools containing the data, models, analytics and visualisation components that allow operational users and end users to access impact-based early warning information and advisories. In developing the sector-specific DSSs, technical partners will work intensively with DNMG and relevant sectoral agencies to i) populate the tools with the required hydrometeorological and sectoral data; ii) identify hazard thresholds and vulnerability curves (where available); and iii) develop impact assessments (based on historical disasters, agriculture impacts, etc.) as well as decision trees/sectoral advisories for different forecast/hazard scenarios. The DSSs will be developed through a participatory process to support risk-informed decision making of operational managers and users in climate-sensitive sectors. A key priority will be the integration of data from multiple sources, standardisation of data collection processes, and inter-agency cooperation in generating and sharing the derived products. Therefore, it will add value to existing projects such as GCF-funded FP109 (which has a strong focus on hydrology and hydraulics) by its integrating vulnerability assessments and flood risk maps (descriptive and predictive analytics) for use in generating the analytics required for the impact-based forecasting.

The overall aim of the DSS will be to complement and improve efficiency in the dissemination of forecasts, early warning and response advisories. It will provide a means for decision makers and disaster managers to correlate between scientific parameters and potential impacts by visualising information in a user-friendly, understandable and actionable format. The DSS aims to enhance risk knowledge through improved access to such knowledge. Whilst enhanced risk knowledge can contribute to strengthened adaptive capacity in the longer term, it should be noted that the implementation of concrete adaptation and disaster risk reduction actions is not within the scope of the Project.

The sector-specific decision support systems to be developed under this sub-activity are detailed below:

- ***Agriculture stress index system (ASIS)*****:** This global system assesses the severity (intensity, duration and spatial extent) of agricultural drought and expresses the results at administrative level, providing the possibility for comparison with the agricultural statistics of the country. ASIS is based on the Vegetation Health Index (VHI) and derived from a Normalized Difference Vegetation Index (NDVI), tested and validated in different environmental conditions around the globe, including Asia.

  This Sub-Activity will calibrate ASIS for Timor-Leste using crop masks delineated by landcover classification/ mapping. The Project will support the streaming into ASIS of high-resolution decadal satellite imagery (20 m resolution Sentinel 2 imagery) and the training of ALGIS staff on the operation of the ASIS tool. It will train MAF staff on the analysis protocol in conjunction with agromet data and the development of monitoring indicators, thresholds and triggers for early actions.

  The Sub-Activity will include both global and regional climate information and forecasts for additional real time monitoring data. It will provide trained agricultural experts to undertake crop monitoring field visits in municipalities—covering main agriculture production areas—to validate ASIS early warning products. It will include a systematic drought analysis in the maize and rice (the main staple crops) production areas of Timor-Leste, using ASIS data and 30-year time-series crop drought analysis.

Combined with the monitoring system, analysis of drought vulnerabilities and risks to agricultural dependent livelihoods, drawing on the existing village level hazard, vulnerability and livelihood assessments will enable MAF to produce impact-based forecasts and action-oriented EWs for dissemination to municipalities and villages.

ASIS simulates the analysis that an expert in remote sensing would undertake, multiplies the analytical power and simplifies the results displaying them as maps/easily communicable products. ASIS is also an analysis protocol that triangulates drought information from other sources, such as agromet data and field data. Lessons learned from the 2015/16 El Nino[583] highlighted the need to understand the creeping character of slow onset disasters, for capacity to define drought impacts and to agree on indicators that trigger more timely and adequate responses. Impact-based forecasting and improved drought early warning require not only climate outlooks but also on the ground data.

ASIS was first introduced in Timor-Leste in 2019. FAO conducted a first level user training on ASIS in 2019. The model was calibrated for national level use, albeit only partially due to the unavailability of good resolution landcover maps and satellite imagery. ASIS is essential to the agromet early warning system at MAF.

- ***Early Warning for Agriculture:*** The information will feed into the Specialized Expert System for Agrometeorological Early Warning (SESAME) Decision Support System (DSS). SESAME DSS will address some of the constraints faced by farmers by giving them access to location- and crop-specific agromet advisories, information on quality inputs and potential retailers. SESAME will be customised with high-resolution baseline information (cropland cover, soil map, etc.), hazard information (drought), and crop-specific information (sunlight and temperature requirements, pest and fertiliser information, input sources, etc.), as well as socio-economic vulnerability of agricultural livelihoods. The high-resolution baseline information will be integrated into the DSS to i) strengthen risk monitoring with agreed indicators and data sources; ii) support the development and dissemination of agrometeorological advisories to farming communities; and enhance thresholds for early warning and triggering of anticipatory early actions – to be established under Activity 4.2.

  RIMES will also work with DNMG to extend its range of forecast products to include sub-seasonal forecasts (2-week, 3-week and 4-week), monthly and seasonal forecasts (3-month), and other parameters besides rainfall. This will also feed into the Specialized Expert System for Agro-Meteorological Early Warning (SESAME) Decision Support System.[584]

  RIMES will collaborate with MAF, ALGIS and FAO to customise SESAME with high-resolution baseline information (cropland cover, soil map, etc), hazard information (e.g., drought), and crop-specific information (sunlight/temperature requirements, pest and fertilizer information, input sources, etc) that they can integrate into the system in order to enhance

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[583] https://www.rsis.edu.sg/wp-content/uploads/2017/11/CO17221.pdf and https://www.un.org/ecosoc/sites/www.un.org.ecosoc/files/files/en/2016doc/special-meeting-el-nino-background-paper.pdf

[584] SESAME is a web portal for generating and disseminating crop management advisories for specific crops at particular growth stage, based on weather and climate information at four different timescales: 3-day high resolution weather forecast to inform daily decision-making; 10-day weather forecast (separated into two pentads) for planning week-ahead activities; monthly outlook for planning activities that require longer lead time; and 3-month outlook for general planning ahead of the season. SESAME maps crop sensitivity to a particular weather condition, processes how the predicted weather shall influence crop growth, and generates crop advisories using machine-learning algorithm. The system generates: real-/ near real-time or most recent observation data and weather information for the past dekad, month, and season to aid understanding of current and recent historical weather condition; daily weather forecast, daily update of the pentads (five-day spells), monthly and 3-month outlooks; information on the normal for the pentad, dekad, monthly, and 3-month climate; and crop management advisories, accompanying the forecasts and outlooks. The system has capabilities for disseminating bulletins via email, SMS, fax, social media (e.g., Facebook), and mobile app, as well as capability for receiving user feedback.

the agro-meteorological advisories they produce for farming communities. SESAME DSS will be used to address some of the constraints faced by farmers though enhanced access to location- and crop-specific agro-met advisories, information on quality inputs as well as potential retailers—many farmers are subsistence farmers with limited access to technologies and practices for sustainable and cost-effective agricultural production.

SESAME uses all four layers of the DSS for agricultural advisory generation and assists in the farmer's decision-making process.

1. **Data Layer**

    a. **Weather Climate Forecast**

    SESAME uses climate information at four different timescales for seamless application for managing resources and climate and disaster risks: monthly to the 3-monthly outlook for strategic planning, 10-day weather forecast (separated into two pentads) for use in tactical decision-making, and 3-day high-resolution weather forecast to guide day-to-day activities and to manage risks from extreme weather events.

    b. **Ground Observation Data**

    Real-time ground observation from automatic weather stations such as the rainfall, temperature, soil moisture, humidity, and the NDVI (satellite-based products) is used to assess groundwater status and vegetation status. Long-term observation data is used to derive thresholds for different crop growth stages for different weather parameters.

    c. **Static Layers**

    Provides the decision support system additional and basic information about the local context through the soil characteristics, the topography, irrigation status and network, and the land use details.

2. **Logic Layer**

    a. **Crop Engine**

    In-situ information and customization for township-specific crops can be done through this panel. Extension workers/DOA experts are provided with access to extensive crop information such as the type of crop, verity of the crop, duration, water requirement at each stage, and crop contingency options. The DSS can automatically generate dynamic crop calendars for each crop.

    b. **Parameter Computation**

    For example, the Potential Evapotranspiration (PET) forecast was computed using the soil water balance equation.[585]

    c. **Machine Learning Algorithm**

    Markov's Decision Process (MDP), a stochastic decision algorithm, was used to build a decision tree for each scenario and choose the best decision for implementation. In a situation where the decision option is not available and was explicitly provided by the user, the algorithm learns the new user input and uses the decision in the next cycle.

    d. **Advisory (Bulletin) Generation**

[585] http://www.fao.org/3/X0490E/x0490e00.htm

Logically compares the data and information (thresholds) to automatically generate advisories for specific crops depending on the weather forecast and local conditions.

3. User Interface

a. The SESAME web interface was designed to provide access to different user categories, including meteorological, agriculture experts, and extension workers. The interface is also handling climate and crop data management.

b. The system provides spatial (sub-district level) forecast products and graphical representation of the weather forecast and agro advisories.

4. Dissemination Layer

a. The Last step of a DSS is the dissemination of the generated information through different channels. The dissemination channel can build on existing standard operating procedures of the departments. For the agriculture sector, generally, the information flow is from the National Meteorological Agencies (NHMS) to the Department of Agriculture (at the National level), and then to the district agriculture officers and finally to the farmers. The DSS can be customized to follow the same channel to automate the information flow.

b. Besides the Mobile App development, the use of Common alert protocol, SMS, and email services can be used for maximum reach.

- ***Early Warning for Disaster Risk Management:*** Stakeholder engagement[586] in Timor-Leste has identified that there are limited channels and means to disseminate and communicate early warning information. Data coverage is mostly at the national level, which limits its value for farmers in widely differing ecosystems. The information that is disseminated is mostly based on local traditional knowledge, which is becoming less useful as the climate becomes less predictable. RIMES will work with DNMG and the National Disaster Management Directorate (NDMD) to customise the System for Multi-Hazard Potential Impact Assessment and Emergency Response Tracking (SMART) DSS[587] – a dynamic, multi-hazard, impact-based forecast and advisory platform that integrates all four elements of people-centred, multi-hazard early warning systems. SMART uses baseline information on disasters, hazards, exposure, vulnerabilities and resources, and will overlay forecasts from DNMG in order to generate real-time forecasts, impact assessments and response advisories for affected communities. The DSS will integrate inputs of weather, water and climate hazards from DNMG, MAF/ALGIS and RIMES/UNDP's flood forecast model outputs.[588] Data on historical disasters will be secured from NDMD's disaster loss database. The SMART system will empower Timor-Leste with a unique operational DSS for policymakers, disaster managers and communities to manage disaster risks holistically, by transforming generic weather forecast data into actionable, impact-based early warning information and advisories, which can be

[586] See Annex 7 – Stakeholder Engagement Plan

[587] SMART is a web-based system for assessing potential impacts of a hazard using weather forecast information, and for evaluating, generating, and disseminating impact management options. SMART also acts as a data management system for managing and processing weather, disaster risk, and emergency response resources data for resource allocation, rapid deployment, and management. The system generates and disseminates weather forecasts, forecast-based risk maps, and accompanying advisories. It can visualise emergency response resource locations and quantities and can also display updates from the ground that are entered by registered users, thus allowing disaster managers to track and manage ongoing emergency response.

[588] RIMES's Flood Cautioning and Alert System (FloCASt) is a basin-based flood forecasting and warning system. It is a web-based system built on open-source code for i) generation of basin discharge and river level forecasts based on 3- and 10-day weather forecasts; ii) analysis and mapping of flood risks; and iii) generation and issuance of appropriate advisories. The system ingests real-time observation data for water level monitoring. It has modules for correction of biases in rainfall and discharge forecasts.

disseminated to communities through various channels – including SMS, mobile app and social media.

The SMART DSS will be based on RIMES' existing TNSMART,[589] a tool with eleven modules including a component on managing major hazards like tropical cyclones and floods. The system generates potential impact forecast using cyclone forecast information 3 to 10 days in advance. It uses the threshold module to compute the baseline and estimates the impact in terms of population, critical facilities (e.g., hospitals, shelters, schools, roads) potentially affected. TNSMART also generates information for risk tracking by providing development efforts contributing to associated risk reduction or risk generation dimensions on a continuous basis regardless of occurrences of extreme weather/climate events. In the case of Timor-Leste, impact-based forecasting (IBF) will be one of the components within the overall SMART DSS framework. Given forecasts of extreme weather or climate events such as floods, droughts, heatwaves, etc with different intensities, the IBF component shall estimate the potential impact based on the hazard threshold, vulnerability curve (as available) and exposure data. In addition to its risk management component, the DSS will generate information for resource management and/or risk reduction purposes.

- ***Mobile applications*** **for** ***disaster management, agriculture, water/marine sectors*****:** The Project will develop mobile applications for SMART,[590] SESAME and the Ocean State Forecasting and Advisory System (OSFAS) decision-support systems in English and Timorese (Tetum) versions. These web-based systems can disseminate advisories through SMS, social media and other channels. The development of their app versions will increase redundancies in information dissemination, and generally improve the availability, access and application of weather/forecast information in the disaster management, agriculture, water/marine sectors.

  RIMES will conduct 3-day workshops with DNMG on the use of the SMART, SESAME and OSFAS decision support systems, for 25 participants in Years 1 and 3. The first workshop will focus on the assessment of user needs in the key climate-sensitive sectors, and the second workshop will launch the DSS as a standard tool. In Years 2 and 4, RIMES will deliver training on secondment at RIMES for 12 staff from DNMG (6), NDMD (2) and MAF (4) on the use of SMART, SESAME, OSFAS DSS. The first training will focus on co-development of the DSS for Timor-Leste. The second will address any updates to the system and train new staff appointed in the interim.

  The mobile app is important, even if internet in Timor-Leste is relatively slow and expensive, because it allows users to visualise the impact assessment, unlike SMS where information is generally in text format and has input length limitations. A mobile app is also useful for key people such as emergency responders, extension workers, and port authorities. Timor-Leste has experienced rapid growth in mobile broadband penetration in the past few years, in which the rising proportion of mobile subscribers having smartphones has been the key driver. Very strong growth in the mobile broadband market is predicted to 2023.[591] The percentage of the

[589] https://tnsdma.tn.gov.in/app/webroot/img/document/publications/tnsmartReport.pdf

[590] SMART is a web-based system for assessing potential impacts of a hazard using weather forecast information, and for evaluating, generating and disseminating impact management options. SMART also acts as a data management system for managing and processing weather, disaster risk and emergency response resources data for resource allocation, rapid deployment, and management. The system generates and disseminates weather forecasts, forecast-based risk maps, and accompanying advisories. It can visualise emergency response resource locations and quantities and can also display updates from the ground that are entered by registered users, thus allowing disaster managers to track and manage ongoing emergency response.

[591] Research and Markets, 2021. Timor-Leste (East Timor) – Telecoms, Mobile and Broadband – Statistics and Analyses. Available at: https://www.researchandmarkets.com/reports/4051018/timor-leste-east-timor-telecoms-mobile-and?utm_source=BW&utm_medium=PressRelease&utm_code=r5pcfw&utm_campaign=1263225+-+Timor+Leste+(East+Timor)+Telecoms%2c+Mobile+and+Broadband+Statistics+and+Analyses+2019&utm_exec=chdo54prd

population covered by at least a 3G mobile network is high at 97 percent.[592] In January 2021, around 45 percent of the population in Timor-Leste were internet users.[593]

The development of DSS mobile applications addresses the need for multi-channel communications in climate information and early warning services to ensure that as many people as possible receive the information, to avoid failure of any one channel, and to reinforce impact-based forecast and warning messages. Whilst significant progress has been made in improving mobile broadband access in Timor-Leste, affordability remains a challenge and mobile charging capabilities (information on which is unavailable) cannot be assumed. As such, information dissemination and communication through the web based DSS and mobile applications will be complemented by other channels, such as rural radio.

Each DSS will be developed as a multi-modular web-GIS application, of which the first module will be the **Database Module**. The Database Module will integrate the vulnerability assessments (through digitization of datasets, geocoding and integration with a base map layer) and flood risk/hazard maps and related outputs (rainfall-runoff, hydraulic modelling, etc.) developed under FP109, in conjunction with the hydrological, weather and climate data stored in the Climate Data Informatics System (established under Sub-Activity 1.1.3), weather forecast data (generated by the new Forecasting Centre under Sub-Activity 2.2.1), disaster damage data (from the disaster loss database to be improved under Sub-Activity 4.1.2) – as well as all other relevant data and information sources. A **Threshold Module** will derive threshold values from historical data in the Database Module (e.g., extreme rainfall events in a day that triggered floods, saturation point of cumulative monsoon season rainfall from which flooding starts). A **Hazard Forecast Module** will provide dynamic visualization of various forecast products at different spatial scales along with base geographical maps. In turn, the **Impact-based Forecast Module** will employ big-data analytics to generate actionable early warning information with potential impacts for each Hazard Forecast, based on the identified Threshold levels, and underpinned by the data and information stored in the Database.

Realistic timescale for DSS development

With the institutional ownership of Timor-Leste, with it being a RIMES Member State, RIMES will co-develop the DSS with the participation of in-country stakeholders. Furthermore, by leveraging its readily available and customizable DSS architecture RIMES is confident that co-development of the DSS with national stakeholders and its operationalization is realistic within the proposed Project implementation period. RIMES has experience in developing and operationalizing the DSS in low-capacity countries; for example, the agriculture sector DSS – “Specialized Expert System for Agro-Meteorological Early Warning (SESAME)" for Myanmar – was operationalized in a two-year period (2015 – 2016) in a pilot phase and has been upscaled and sustained since then. Likewise, RIMES developed the DSS for Disaster Sector in Tamil Nadu state in India – System for Multi-Hazard potential impact Assessment and Emergency Response Tracking (TN-SMART) – which was developed and operationalized within 18 months (2018 – 2019).

Coherence and complementarity with the UNDP GCF-funded project FP109

This sub-activity will complement the recently approved UNDP GCF-funded project “Safeguarding rural communities and their physical assets from climate induced disasters”. The GCF UNDP project will develop dynamic multi-hazard mapping in Timor-Leste: the most recent multi-hazard (that is, tropical cyclone, flood, drought, landslide, earthquake, tsunami, coastal erosion and forest fires)

[592] UNESCAP, 2019. Asia-Pacific Information Superhighway (AP-IS) Working Paper Series. Regulatory Policies and ICT Trends: Insights from Timor-Leste
[593] Kepios, 2021. Digital 2021: Timor-Leste. Available at: https://datareportal.com/reports/digital-2021-timor-leste

assessment and mapping was conducted in 2012. It did not include exposure and vulnerability assessments and has not been updated since. The GCF UNDP Project (FP109) will generate a GIS-based socio-economic risk model that will include hazard and risk maps for floods, landslide, soil erosion and droughts, expanding and updating the multi-hazard assessment and mapping exercise undertaken in 2012. It will also produce vulnerability maps based on infrastructure, land use, property and socio-economic data and these will form a baseline model to be used in climate risk informed infrastructure planning.

Through the DSS, the proposed Project will link the UNDP-led vulnerability assessments and flood hazard maps with newly established near real-time rainfall forecasts to generate sector-specific IBF (for agriculture, health, etc.), thus extending the application of the FP109 outputs beyond the initial small-scale rural infrastructure focus.

In a mutually reinforcing manner, the enhanced data availability facilitated by this proposed Project – both through the provision of *in-situ* observation data and the Climate Data Informatics System (which will host all weather, climate, and water data in a single platform for easier multi-sectoral access and quality control) – will provide valuable data inputs for several activities implemented under FP109. Amongst others, this will include the generation of sub-daily rainfall data required for the calibration of rainfall-runoff modelling and for the development of design rainfall parameters; improved access to satellite imagery required for the calibration and verification of hydraulic modelling; and high-resolution rainfall amount and intensity data as the fundamental meteorological criteria required to identify flash-flood prone areas. The accuracy of the hydrological and hydraulic models developed under FP109 is dependent on the quality of the input data, and particularly the availability of high-quality rainfall data for model calibration and verification. By building the infrastructural and technical capacity of DNMG to provide high-quality data in line with WMO specifications, the Project will contribute to enhanced accuracy of FP109 outputs, which in turn will improve the inputs (namely the flood hazard maps) available for integration into the Project-developed DSS.

Sustainability of the DSS beyond the Project

The following mechanisms will allow RIMES to sustain all tools beyond the Project implementation period.

- **Member State Mandate –** Timor-Leste is one of the RIMES Member States and a representative of the RIMES Council. Under the membership agreement, RIMES is committed to providing technical and backup support to the National Hydro Met Agency (DNMG) and all stakeholders during and beyond any project period.
- **Co-development process –** Tools developed at RIMES are done through a participatory approach involving scientists and experts from the relevant departments and stakeholder agencies as on-the-job training. This brings the complete blend of domain knowledge, practical experience, and technical expertise to make a relevant system for the country's requirements and sustainable in the longer term.

  RIMES' experience in co-development of DSS reveals that even in data-sparse regions, the process catalyses DSS development with available data and incrementally enriches it through augmentation within 2 – 3 years. This process also provides incentives to augment data availability and a culture of sharing among stakeholder departments, considering the tangible benefits of getting operationally usable information for efficient disaster management and climate-resilient development.

- **Technology Transfer and Backup Support –** Upon completing the tool development, RIMES conducts the DSS audit adhering to the country's ICT standards before transferring the tool to the country. Besides, RIMES maintains a mirror of the tools in a private cloud environment and provides continuous backup support to ensure 99.9% uptime in the event of a system failure at the national level.
- **Open Source and Agile Development Environment –** RIMES utilises all open-source software packages to develop the DSS to avoid any recurrent costs for using the tool in an operational environment and refining and enhancing DSS using the latest and emerging technologies.
- **Capacity building –** RIMES conducts capacity-building activities for different levels of users on various aspects of the DSS operation and maintenance. RIMES also provides training on specific aspects of the tools based on demand. The capacity building and co-development process strengthen the departments to sustain the tools beyond the project period with minimal intervention of RIMES.

Activity 2.3 – Establish climate services for health

2.3.1 – Establish a national Climate and Health Working Group

This Sub-Activity aims to enhance coordination and collaboration between the climate and health communities in Timor-Leste. It will convene experts in climatology, public health and epidemiology through the establishment of a national Climate and Health Working Group. The main focus areas for the Working Group will be to determine the key climate-related health risks for Timor-Leste; identify climate and weather information and service needs of the health sector, including gaps in current data, information and service delivery; and enhance the capacity of DNMG to meet the specific needs of the health sector. Multi-stakeholder training workshops will be organised to improve knowledge and understanding of climate data and information, linkages between health and climate, and methods to access, analyse and interpret both epidemiological and climate data. Representatives from health-relevant partners, disaster risk management actors, and agencies delivering health services at the community level will also be invited to participate. The Working Group will also support development of the National Climate Sector Action and Communication Plan for Health (Sub-Activity 1.1.4).

2.3.2 – Establish an air quality monitoring framework

This sub-activity will build in-country capacity to better understand, manage and reduce the impacts of poor air quality on human and environmental health in Timor-Leste through monitoring, forecasting, early warning and impact advisory. Air quality is strongly dependent on weather and is therefore sensitive to climate change.[594] In particular, increasing temperatures and extreme heat can increase the concentration of fine particulate matter (PM2.5) and ground-level ozone (O_3).[595] PM2.5 is a significant contributor to ill health (including cardio- and cerebrovascular disease, adult chronic and child acute respiratory illnesses, and lung cancer[596]) and is identified as the highest priority pollutant for air quality monitoring.[597] Nitrogen dioxide (NO_2) is a precursor for PM2.5 and O_3, of which

[594] Jacob, D.J. and Winner, D.A., 2009. Atmospheric Environment. Effect of climate change on air quality
[595] Exhaustion.eu., 2020. The feedbacks between climate change and air pollution. Available at: https://www.exhaustion.eu/resources/the-link-and-feedbacks-between-climate-change-and-air-pollution
[596] IPCC, 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability. Chapter 11 – Human health: impacts, adaptation, and co-benefits
[597] WMO, 2014. Air Quality and Human Health, a Priority for Joint Action. Available at: https://public.wmo.int/en/resources/bulletin/air-quality-and-human-health-priority-joint-action

exposure to high concentrations is associated with increased mortality due to respiratory and cardiovascular diseases.[598]

The Project will establish a hybrid ambient air quality monitoring system consisting of low-cost sensors for fine particulate matter (PM2.5 / PM10), NO_2 diffusion tubes and reference grade particle counters overlaid with MAIAC/Aerosol Optical Depth (AOD) PM2.5 satellite data. High-resolution remote sensing data can be derived from NASA[599] and Copernicus global products.[600] The combined use of surface-based and satellite observations will facilitate the collection of high-resolution spatiotemporal air pollution data. This will provide a robust baseline of gaseous and particulate pollutants for the capital Dili that can be incrementally scaled across the nation. Establishment of the monitoring system will be facilitated by development of an air quality monitoring framework – including co-location and monitoring protocols with local authorities. To enhance understanding, internalisation and application of the new information and datasets, the Project will deliver in-country technical training and capacity building, including on data management, quality assurance and reporting.

The data outputs will feed into a customised mobile application that can disseminate hyperlocal air pollution forecasts, warning alerts and health impact advisories and advocacy. Local stakeholder engagement workshops will be conducted to enhance awareness of air pollution, its sources (including anthropogenic contributors such as vehicle emissions and burning of household waste), related health risks and appropriate actions to reduce impacts on health and well-being – including impacts on biodiversity and ecosystems health.

2.3.3 – Co-develop tailored forecasting and decision support for health

This sub-activity will support the co-development of tailored information products that will provide decision-makers with timely and relevant information to proactively manage weather and climate-related health risks. The Project will work with DNMG and the Ministry of Health to integrate weather, climate, epidemiological and other relevant data (e.g., disease prevalence/incidence, models, indices, and analytics) to generate health risk forecasts that anticipate when and where changes in key parameters – such as humidity, temperature, particulate matter (PM) readings – may increase the likelihood for health impacts to occur. The forecasts will be visualised through a web-based decision-support system (DSS), which will be co-developed in collaboration with the national Climate and Health Working Group (Sub-Activity 2.3.1) to ensure that the DSS is responsive and tailored to the most pertinent needs of Timor-Leste. Workshops will be conducted to build capacity of the Ministry of Health and related authorities to identify the required data to assist with analysis, modelling and decision-making.

The DSS will address the critical need for increased access, understanding and use of weather and climate information for risk-informed decision making in the health sector.[601] This could include the following tailored information products and services:

i) Heat/cold spells and indices indicating potential impacts to health;

ii) UV radiation for UV exposure forecasts;

iii) Atmospheric chemical observations to generate haze and air pollution information advisory;

[598] Zhang, J., *et al.*, 2019. Frontiers in Immunology. Ozone Pollution: A Major Health Hazard Worldwide

[599] Keller, C.A. *et al.,* 2021. Journal of Advances in Modeling Earth Systems. Description of the NASA GEOS Composition Forecast Modeling System GEOS-CF v1.0

[600] https://apps.ecmwf.int/datasets/data/cams-nrealtime/levtype=sfc/

[601] WMO, 2014. Health Exemplar to the User Interface Platform of the Global Framework for Climate Services

iv) Potential disease outbreaks/hotspots, especially during the rainy season where incidence of dengue, malaria and water-borne diseases (e.g. diarrhoea) could increase; and

v) Monitoring for other critical communicable diseases in Timor-Leste, such as tuberculosis (TB).

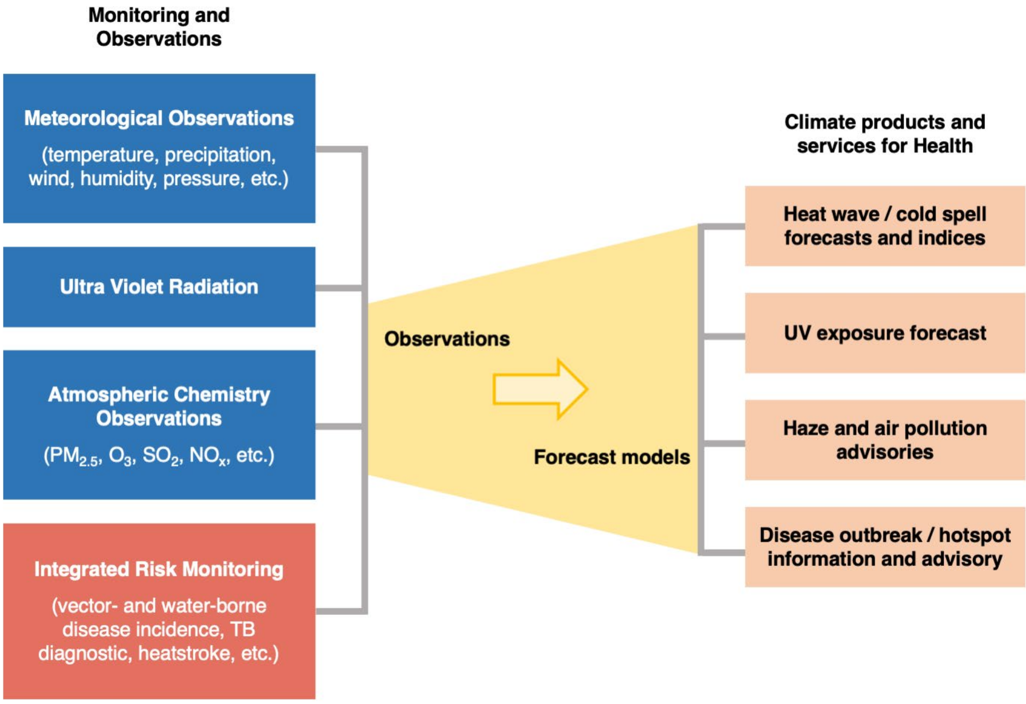

Figure 256: Example framework for the translation of monitoring and observations information into climate products and services for health. (Source: Adapted from Liisa Jalkare, WMO)

2.3.4 – Develop a mobile app for health-related forecasts and advisories

This sub-activity will develop a mobile application to enhance access to health-related forecasts and advisories for the general public. The app will expand the reach of the tailored forecasts and information products in the health DSS (Sub-Activity 2.3.3) by delivering actionable information services and health advisories that are relevant to individual-level decision making. Where data exist, the forecasts will be combined with thresholds to develop targeted early warnings that can alert the population to rapid-onset emergencies such as extreme weather or disease outbreaks, thus increasing the lead time to prepare and respond to the potential disaster event. The content of the forecasts and advisories will be guided by the localised communication strategies (Sub-Activity 3.1.2) so that the information can better reach vulnerable populations and provide an evidence base for proactive risk-informed decision making and planning.

RESULT 3 – IMPROVED DISSEMINATION AND COMMUNICATION OF RISK INFORMATION AND EARLY WARNING

This Result focuses on the targeted dissemination and communication of climate risk information and early warnings as a key element of a people-centred impact-based Multi-hazard Early Warning System (MHEWS). The Project will build capacity for the delivery of clear messages containing straightforward, practical and actionable information, which are critical to enable appropriate preparedness and response actions that can safeguard lives and livelihoods.[602] Trust is an essential part of effective risk

[602] WMO, 2018. Multi-hazard Early Warning Systems: A Checklist

communication, facilitating those at risk to respond proactively to information received. Engagement with "last-mile" communities to integrate Traditional Knowledge into NMHS products and services will be a key intervention in this regard. Furthermore, the Project will convene a regular working group with government agencies involved in disaster management, national and international NGOs and CBOs, and community representatives to maximise the coordination of their work, generate consistency in messages, improve technical capability and extend awareness of risks and effective mitigation measures at all levels of society.

Activity 3.1 – Establish targeted multi-hazard early warning information systems

3.1.1 – Convene a technical working group for EWS

This sub-activity will ensure the effective and coordinated delivery of early warning systems, and by extension the impact-based forecasting that feeds into the EWS, through strengthened organisational and decision-making processes of DNMG, NDMD, civil society organisations and other key actors. The Project will convene a regular working group to leverage the large network of organisations – local and international NGOs and CBOs – with the capacity to further disseminate messaging, reach community-level actors, and build a robust network of community (suco) level early warning communication systems to support the national system.

There is an existing group of Government ministries and UN agencies responsible for coordinating early warning, climate change adaptation, and disaster risk reduction, but it does not meet regularly and will benefit from a small input of secretariat functions, such as arranging regular meetings and agendas, and providing a venue. The Project will invite existing and new members to participate, expanding the group to include NGOs/CBOs.

The following agencies will be invited to establish a coherent approach to and understanding of EWS in Timor-Leste—UN agencies (such as FAO and IOM), international NGOs (including Mercy Corps, CARE, Oxfam, PLAN, World Vision, Caritas, and Child Fund), and local organisations (CVTL,[603] RHTO,[604] ASRRD,[605] Fraterna[606] and others). Existing ad-hoc early warning related work at the community level will benefit from improved coordination and integration into a broader national framework.

As well as fostering coordination and avoiding duplication, the Working Group will allow for the Project to leverage the variety of other community-based DRM programs in Timor-Leste to further raise awareness in their target communities about the Early Warning System and obtain feedback from communities to inform the updating of the system. This sub-activity will facilitate regular coordination, planning and review meetings between warning issuers, the media and other stakeholders. Meetings can include collaboration around:

- Political/policy support required for operationalising EWS;
- Resource allocations to operationalise and sustain EWS;
- Accuracy of risk assessments;
- Functionality and accuracy of the hazard monitoring system;
- Timely dissemination of early warning alerts during disaster events;
- Integration of EWS in contingency planning; and

[603] Cruz Vermelha de Timor-Leste: Red Cross
[604] Ra'es Hadomi Timor Oan: the Disabled People's Organisation
[605] Asosiasaun Serbisu Redusaun Risku Dezaster: Association for Disaster Risk Reduction
[606] Fraterna: local environmental / disaster response NGO

- Feedback mechanisms to verify that warnings have been received and to protect potential failures in dissemination and communication.

In conjunction with the establishment of the National Framework for Climate Services (Sub-Activity 1.1.1), the technical working group will define the functions, roles and responsibilities of key EWS actors and include them in standard operating procedures (SOPs), such as the Early Action Protocols to be developed under Activity 4.2. The UNDP and JICA project teams managing complementary GCF-funded projects in Timor-Leste will be invited to participate in the technical working group. This will facilitate regular communication between EWS actors to improve coordination and avoid duplication of efforts. Participation of the UNDP project team in the EWS Working Group will therefore provide an opportunity to realise complementarity of FP109 outputs in impact-based forecasting / EWS.

The Project will engage a full-time Gender Expert who will be responsible for ensuring that gender needs are integrated into EWS and disaster risk management activities; tracking gender-specific indicators; and assessing progress towards achieving gender equality. Traditional knowledge holders (such as indigenous elders) will also be engaged to ensure that the EWS builds on and incorporates local and traditional methods of forecasting and responding to climate extremes and natural hazards. International research has made clear that the integration of traditional knowledge into NMHS products and services greatly increases community acceptance of their materials and concurrently improves communication and understanding.[607]

Warning communication strategies will be developed to ensure coordination between DNMG – as warning issuers – and downstream dissemination channels, such as community volunteer networks and women's groups. The strategies will include the development of community feedback mechanisms to verify that warnings have been received and to alert DNMG to potential gaps in communication networks. The feedback mechanisms will relay experience directly from the communities in which partner agencies are working and their local Disaster Management Committees regarding the outreach and effectiveness of the EWS as it evolves. Knowledge gained and outputs from the annual workshops will be leveraged in development of the Forecast-based Financing mechanism (Activity 4.2).

In addition, this Sub-Activity will work with the Cruz Vermelha de Timor-Leste (CVTL – Timor-Leste Red Cross Society) to build national capacity for EWS through in-country training on planning, monitoring, evaluation, and reporting (PMER) and EWS. It will also support attachment training for five persons at Palang Merah Indonesia (PMI – Indonesian Red Cross Society) for peer learning and sharing of best practices and lessons learned.

3.1.2 – Co-develop socially inclusive and gender-responsive localised communication strategies

The Project will engage in multi-stakeholder dialogue to analyse the effectiveness of existing warning communication and dissemination systems and identify the ways in which gender and other intersectional vulnerabilities impact on the accessibility, reach and understanding of early warnings. This will be facilitated through a series of consultations with community leaders (e.g., the Suco Chief, traditional leaders and *suco* council representatives) and community members – with a proactive focus on meaningful engagement with marginalised and/or vulnerable groups, such as women, youth, elderly people and people with disabilities.

[607] Bremer, S. *et al.* Climate Services, 2019. Towards a multi-faceted conception of co-production of climate services

Based on the initial consultations, the Project will coordinate with the EWS working group (Sub-activity 3.1.1) and community stakeholders to co-develop localised socially inclusive and gender-responsive communication strategies based on understanding of last-mile connectivity (which population groups can be reached by different communication channels) and tailored to the differential vulnerabilities and needs of specific population groups. This will include the integration of local and traditional knowledge systems as a critical means to enhance the understanding and reach of scientific knowledge-based communications.

An important focus of the strategies will be on ensuring the effective communication of climate-related risks to health and well-being of populations in Timor-Leste. The Climate and Health Working Group (Sub-Activity 2.3.1) will be engaged in this regard to provide inputs and ensure coherence and complementarity with local public health messaging. The Project will employ an inclusive and intersectional approach – acknowledging the interaction of gender with other socially excluding factors – to build trust between stakeholders and ensure that warning communication and dissemination systems work effectively for all members of the community.

3.1.3 – Enhance community-based early warning systems

This sub-activity will work with the Timor-Leste Red Cross Society (CVTL) to establish community-based early warning systems (EWS). With trained volunteers at the municipal level and well-established community volunteer teams within *sucos*, CVTL is well positioned to extend the reach of the national EWS to the community level and ensure that early warning messages are understood and translated into action. To this end, CVTL will train municipal and community-based volunteers to understand, monitor and communicate available forecasts, which will facilitate that in the event of an impending disaster early warning messages reach the last mile.

In addition, the Project will install flood/sea level markers, megaphone systems, information signboards, and solar panels to detect landslides – a key hazard for which EWS are needed. Localised EWS frameworks will be developed, taking into account the different risks and needs of subpopulations in the target communities, including differential vulnerabilities (women and men, elderly people and youth, people living with a disability, etc.). Regular field monitoring will be conducted to evaluate and maintain the EWS and ensure that it remains operational and effective. These interventions will be further complemented by capacity building to enhance disaster preparedness under Sub-Activity 4.1.1.

3.1.4 – Disseminate sector-specific early warning information for agriculture

MAF has a network of 305 agriculture extension officers and 65 extension coordinators covering 423 rural *sucos* in the country. This sub-activity will provide training on disaster risk management to all agriculture extension officers, their supervisors and 105 MAF staff members, enabling them to understand forecasts and early warnings and to integrate agriculture disaster risk management (DRM) in their services to farmers.

Local government and farmers' access to agrometeorological and climate hazard information is very limited in the absence of infrastructures in rural areas. Only a few copies of food security bulletins are distributed to the municipalities. Agriculture extensionists physically come to each municipality every three months and meet their coordinators once a month.

Existing FAO projects include climate resilient agriculture in their training and capacity for extensionists, and the extension officers in turn transfer the technologies and practices to farmers through farmer field schools—this has proven effective, but discussion of early warning systems is not yet included. Consequently, agriculture extensionists have very limited knowledge of climate and disaster risks and ways to mitigate and manage them. This knowledge is an essential component of Timor-Leste's transition to climate resilient agriculture technologies and practices such as Conservation Agriculture.

Provision of basic tablets will partly address the extension officers' need for climate and EWS information and will make possible the sharing of knowledge among extension officers. Access to modern technology will link them to social networks, allowing them to disseminate early warnings and other information about climate resilient agriculture. The dissemination of agriculture-related early warnings through agriculture extension services will reinforce communities' awareness of risks and options to mitigate risks in the agriculture sector.

This Sub-Activity will disseminate agricultural sub-sector-specific forecast and early warning products (developed under Sub-Activity 2.2.3), such as agrometeorological advisories, food security bulletins and action-oriented early warnings to local agriculture offices and extension workers. Existing MAF information sharing systems such as the Ministry's website as well as social media will be used. Agriculture extension workers will be trained to establish social media networks among farmers in their responsible areas and disseminate localised advisories and early warnings.

Furthermore, a compendium of agriculture early actions and climate resilient agriculture practices adapted to Timor-Leste will also be developed, which could be applied by farmers with support from the extension officers, as part of the Forecast-based Financing / Early Warning Early Action implementation under Activity 4.2.

RESULT 4 – ENHANCED CLIMATE RISK MANAGEMENT CAPACITY

The value of climate information and early warning services in supporting disaster risk reduction (DRR) is clearly acknowledged in the resilience agenda of post-2015 international agreements and frameworks[608] – in particular, the Sendai Framework for Disaster Risk Reduction (2015 – 2030), which explicitly highlights climate services under Priority 4: *Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction*. This Result is therefore designed to increase coherence and mutual reinforcement between disaster risk management – defined as the application of DRR policies and strategies[609] – and climate information and early warning services, which will be strengthened under Results 1 – 3.

Result 4 focuses on capacity building to prepare for climate risks and hazards and the introduction of Forecast-based Financing (FbF) – also known as Early Warning Early Action (EWEA)[610] – an innovative mechanism whereby early actions at community and government level are pre-planned based on credible forecasts and are implemented before a climate shock, enabling risks to be reduced and responses to be timely and effective. FbF/EWEA been shown to minimise losses and damages caused by climate-related hazards and reduce the need for humanitarian assistance in their aftermath.[611] The development and operationalisation of disaster preparedness measures, including community-based disaster risk reduction plans, and targeted public awareness and education campaigns will enable the institutions and people of Timor-Leste to act early when warnings are received, facilitated by enhanced risk education. Particularly in agriculture, FbF/EWEA will be critical for the sector to

[608] Frontiers, 2020. Research Topic – Climate Services Supporting Disaster Risk Reduction. Available at: https://www.frontiersin.org/research-topics/15248/climate-services-supporting-disaster-risk-reduction#overview
[609] PreventionWeb, 2017. Terminology – Disaster risk management. Available at: https://www.preventionweb.net/terminology/view/476
[610] Forecast-based Financing (FbF) and Early Warning Early Action (EWEA) are synonymous. Both terms have become popular in recent years on account of the various agencies who frequently use them. While there has been a shift towards streamlining this language, an agreement is yet to be reached. As such, the Funding Proposal will refer to both terms according to that used by the relevant technical partner.
[611] WFP, 2018. Forecast-based Financing Factsheet. Available from: https://www.wfp.org/publications/forecast-based-financing-factsheet

accelerate the urgently required actions to manage climate hazard risks and increase resilience to long term climate change, resulting in enhanced food security, improved nutrition and protection of vulnerable farmers from poverty.

The outcomes of this Result will complement focused training on disaster risk management to be undertaken by DNMG staff through the GCF UNDP Project, *Safeguarding Rural Communities*. It will also put in practice the *Disaster Risk Management Training Manual* prepared by NDMD, a complete plan to reduce the impacts of natural disasters in the country, particularly from landslides, floods and strong winds.

Activity 4.1 – Build capacity to prepare for and respond to climate risks and hazards

4.1.1 – Enhance disaster preparedness capabilities from national to community level

The Project will work with Cruz Vermelha de Timor-Leste (CVTL – Timor-Leste Red Cross Society) and the National Directorate for Climate Change (NDCC) to enhance disaster preparedness capabilities from national to municipal to community level for effective action in response to climate variability and climate change.

At the national level, this sub-activity will support the Government of Timor-Leste to hold two National Climate Change Conferences over the term of the Project, which will aim at enhancing country ownership and abilities to better prepare for and manage climate-related risks. In addition, the Project will support regular Community-Based Disaster Risk Management (CBDRM) Working Group and stakeholder coordination meetings to facilitate a coherent strategy for disaster preparedness, including plans and standard operating procedures. It will also build capacity among national institutions and stakeholders to better understand community perceptions on existing early warning processes and optimise their effectiveness in relation to preparedness capabilities, which in turn is more likely to result in early action at the local level. This will be complemented by targeted capacity building for CBDRM and disaster preparedness municipal/district-level actors.

At the community level, the Project will use participatory approaches such as risk mapping and focus group discussions to support vulnerable population groups to assess their own exposure to and capacity to deal with climate-related hazards. Understanding differential vulnerabilities and capacities is an integral part of disaster preparedness and contributes to the development of community-based initiatives that are mutually supportive and responsive to the needs of the people most closely concerned. Accordingly, this sub-activity will support the co-development of Community Action Plans (CAPs) to improve preparedness for early action in response to early warning messaging. Indicative activities may include developing community-level contingency plans, identifying suitable evacuation sites and routes, identifying strategies for protecting household assets and conducting simulation exercises. Co-development of the CAPs will complement the enhancement of community-based early warning systems under Sub-Activity 3.1.3.

In addition, this sub-activity will conduct community-based workshops across Timor-Leste in each year of the Project. The workshops will train community members on the use of climate forecasts to support contingency planning and preparedness measures based on improved understanding of disaster risk. Basic climate and climate change concepts and information will also be introduced. The overall aim of the workshops will be to sensitise communities to the value of climate information and early warnings towards reducing the impact of climate-related hazards and providing an entry point to build trust in scientific knowledge systems and demonstrate their complementarity with local knowledge.

4.1.2 – Build capacity of the National Disaster Management Directorate (NDMD) for EWS

The National Disaster Management Directorate (NDMD) is responsible for providing disaster risk management coordination and technical support to the Government and community in Timor-Leste, including responsibility for disaster preparedness and early warnings.

This sub-activity will employ an integrated and holistic approach to build the technological, technical and institutional capacity of NDMD to utilise EWS information for performing its mandated functions in disaster preparedness.

The Project will work with NDMD to co-develop Standard Operating Procedures (SOPs) for disaster preparedness, taking into account the differential vulnerabilities and needs of population groups. Targeted training for NDMD staff will be delivered to enhance risk knowledge on weather, water and climate-related hazards that could impact the population, and build capacity to deliver effective, people-centred early warning systems that facilitate a constant state of preparedness and, in the longer term, reduce disaster risks.

The Project will ensure that staff in all 13 Municipal Disaster Management Committees (MDMCs) of Timor-Leste have the capacity to use the existing disaster loss database – the Baze de Dadus Dezastre Timor-Leste (BDDTL)[612] – and that the MDMCs have the requisite knowledge to oversee appropriate data collection by the Suco (village) Disaster Management Committees, for which they are responsible. Improving disaster loss data collection will provide essential data to better quantify the impacts of climate hazards and climate change in Timor-Leste and will provide valuable inputs to the impact-based forecasting and decision-support systems developed under sub-activities 2.2.3 and 2.3.3.

In addition, the Project will facilitate equipment maintenance and upgrade to ensure resilience of communication channels and early warning system hardware, supported by technical training and IT expertise for long-term sustainability. It will also establish capacity in NDMD to deploy broadband wireless links to complement the existing network infrastructure.

4.1.3 – Increase public awareness and education on climate hazards, related health risks and early warning

Despite the prevalence of disasters in communities around Timor-Leste, there is relatively little awareness of risk, and in the absence of an operational end-to-end Early Warning System, vulnerable communities lack understanding or knowledge on how to use early warnings or weather information. As a fully functional end-to-end MHEWS is constructed in Timor-Leste, the Project will work with CVTL to implement a broader awareness campaign to ensure that communities across Timor-Leste better understand climate hazards, risks, the early warning services available, and appropriate actions to take to reduce disaster risk and increase their resilience. The campaign will support communities to understand the differential vulnerabilities, exposure and impacts of hazards and how to act upon warning messages to minimise loss and damage during disasters. The International Day for Disaster Risk Reduction on 13th October will be celebrated in a national event, as well as through awareness campaigns across several municipalities.

Moreover, health risks are increasing due to climate change. Accordingly, CVTL will conduct targeted awareness-raising from national to municipality to community level to improve understanding of the current and future climate-related health risks, communicate local evidence of climate and weather impacts on community health, and provide education on community-based health and first aid. The

[612] http://tldd.mss.gov.tl/DesInventar/main.jsp?countrycode=tl&lang=EN

outcomes of the multi-stakeholder dialogue on localised communication strategies (Sub-Activity 3.1.2) will inform utilisation of the most effective media (e.g., established broadcasting media, social networks, informal communication channels, etc.) to ensure that awareness-raising reaches vulnerable communities at the last-mile.

Timor-Leste's Secretary of State for Environment will complement the work of CVTL through information dissemination and environmental educational outreach throughout the Project.

4.1.4 – Conduct a targeted disaster risk awareness and education campaign for women

This Sub-Activity will focus on empowering women through enhanced awareness and understanding of disaster risks to support increased participation in disaster risk management and decision making for climate resilience. The Project will establish localised women's networks – through linkages with women's groups and local NGOs/CBOs – to disseminate IECs tailored to the specific needs of women and other vulnerable groups (e.g., youth, elderly people and people with disabilities) and participate in disaster risk education workshops. The networks will enhance women's roles in disaster risk awareness-raising and support increased engagement in peer-to-peer learning. Given the disproportionate effects of climate change on women's health,[613] the campaign will seek to educate women on how to use risk information to take actions at the household and individual levels to protect health. Training of trainers (ToT) workshops will support women's group facilitators to expand the disaster risk awareness and education campaigns to other communities, thereby developing local educators and enhancing sustainability beyond the Project implementation period. These interventions will support implementation of the gender-responsive localised communication strategies developed under Sub-Activity 3.1.2.

Activity 4.2 – Establish Forecast-based Financing (FbF)

The Project will introduce Forecast-based Financing (FbF) – also known as Early Warning Early Action (EWEA) – in Timor-Leste. FbF is an innovative mechanism whereby early preparedness actions at community and government level are pre-planned based on in-depth forecast and risk analysis, and resources are automatically allocated when a specific threshold is reached. FbF/EWEA has been shown to enhance preparedness, and reduce loss and damage caused by climate-related disasters and the need for humanitarian assistance in their aftermath.[614] Most importantly, FbF/EWEA saves lives.[615]

[613] Carbon Brief, 2020. Mapped: How climate change disproportionately affects women's health. Available at: https://www.carbonbrief.org/mapped-how-climate-change-disproportionately-affects-womens-health
[614] World Food Programme, 2019. Forecast-based Financing (FbF) – Anticipatory actions for food security. Available at: https://docs.wfp.org/api/documents/WFP-0000104963/download/
[615] IFRC, 2017. Forecast-based Financing: Effective early actions to reduce flood impacts. Available at: https://www.preventionweb.net/files/62642_casestudy5bangladeshfbffinal.pdf

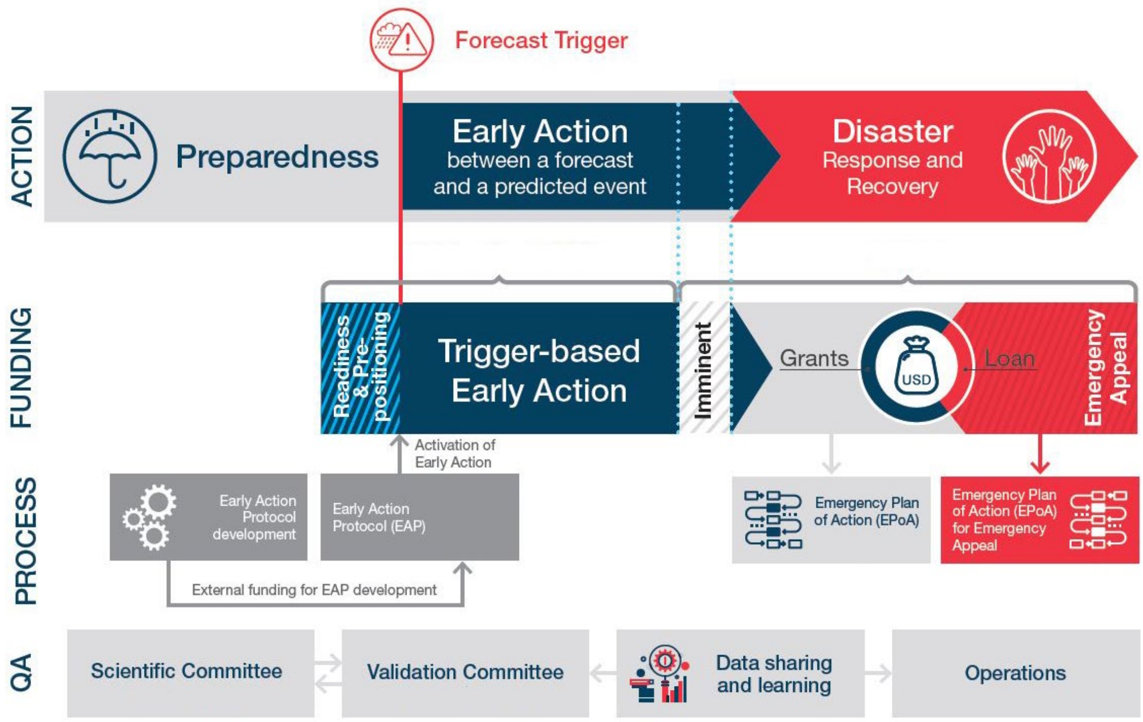

Figure 257: Forecast-based Financing conceptual framework (Source: Adapted from IFRC, 2020)[616]

The approach taken in the Project follows the precedent set by the approved GCF project "Enhancing Climate Information and Knowledge Services for resilience in 5 island countries of the Pacific Ocean" (FP147),[617] for which the combination of impact-based forecasting and FbF was commended as an innovative mechanism that would improve disaster preparedness and enable more efficient management of government budgets. The International Federation of Red Cross and Red Crescent Societies (IFRC) – as the lead international agency spearheading FbF – has designed this activity based on their experience in developing FbF in low-capacity countries and will lead its implementation together with Timor-Leste's National Red Cross Society (CVTL).

4.2.1 – Establish a Roadmap for FbF

This sub-activity will establish a Roadmap for Forecast-based Financing in Timor-Leste, which will identify the early warning information – based on forecast attributes (magnitude, probability and lead time) – and decision criteria that can trigger worthwhile action.[618] The Roadmap will include the following components:[619, 620]

- **Stakeholder Identification** – The Roadmap will identify the key stakeholders to be involved in the development and implementation of FbF, including international, national, regional and local actors and lead agency/s.
- **Risk Assessment** – The Assessment will utilise a participatory approach to analyse risk factors, key hazards, past impact, exposure and vulnerability. Based on the analysis, the priority impacts to be addressed will be identified. The assessment will provide an overview of the

[616] IFRC, 2020. Forecast-based Action (FbA) by the DREF. Available from: https://media.ifrc.org/ifrc/fba
[617] https://www.greenclimate.fund/project/fp147
[618] Lopez, Coughlan de Perez, Bazo, Suarez,Van den Hurk, Van Aalst, 2018: Bridging forecast verification and humanitarian decisions: A valuation approach for setting up action-oriented early warnings
[619] IFRC, 2018. Forecast-based Financing Early Action Protocol template
[620] IFRC, 2021. FbF Practitioners Manual. Available at: https://manual.forecast-based-financing.org/en/

different types of early actions that could be taken to mitigate risk by the identified stakeholders, in different sectors (including agriculture, water, health, etc.).

- **Impact-based Forecasting (Triggers)** – The Trigger is the specific threshold value, based on weather and climate forecasts, that dictates when an early action is initiated. In line with an impact-based forecasting approach, the trigger model will be developed based on detailed risk analysis, and analysis of exposure and vulnerabilities.
- **Financial Mechanism** – The Roadmap will identify a country-driven, scalable financial mechanism for FbF that will provide a sustainable source of funding for early action suitable for the context of Timor-Leste.

The first phase in development of the Roadmap will comprise a scoping study that will cover feasible hazards to target with FbF, forecasting capability, and the institutional landscape in Timor-Leste. For FbF to be a sustainable and effective mechanism, it must be embedded in national institutions, who have roles and responsibilities for taking early action. The scoping phase will identify national and/or sub-national actors (government and civil society) and enter into a dialogue with them about the potential for FbF, its effectiveness, and added value to existing disaster risk management efforts.

Following the scoping phase, the second phase of Roadmap development will consist of collaborative consultations with institutional stakeholders and local communities to delineate three key elements that would enable country-led design of a FbF mechanism:

- Defined triggers, based on improved forecasts, for preparedness actions aiming at avoiding losses and damage if an extreme event materialises;
- A "menu" of the available early warning information derived from forecasts that can trigger the early actions;
- A potential framework of country-level technical working groups and institutional ownership for FbF, including funding mechanisms when necessary. A lead national agency/s in which to embed EAPs will be identified.

Forecast-based Financing is only as strong as the National Society supporting it.[621] Accordingly, the Project will undertake extensive capacity development to ensure that CVTL has the requisite knowledge and skills to develop and implement EAPs, and foster ownership to establish FbF. This will include technical support to connect with existing national and sub-national strategies, mechanisms and/or priorities to improve coordination and enhance countrywide understanding and buy-in for FbF. In addition, specific links between FbF/EWEA approaches and the principles and activities embedded in other areas of the Project will be identified – for example, collaboration with the national Climate and Health Working Group (Sub-Activity 2.3.1) to identify opportunities to implement forecast-based early action in the health sector.

Building on the scoping study, the Project will identify a financial mechanism to ensure that key stakeholders have access to immediate, reliable and sustainable funding in the event of Early Action Protocol (EAP) activation. The Project will initially explore existing financial mechanisms currently operational in Timor-Leste, and hence assess a variety of potential financing tools for early action – including dedicated funds, specific windows in existing emergency response funds (e.g. IFRC's Disaster Relief Emergency Fund[622]), and direct links to regular resource allocation processes, including ring-

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[621] IFRC, 2021. FbF Practitioners Manual. – Make your National Society FbF Ready. Available at: https://manual.forecast-based-financing.org/en/chapter/make-your-national-society-fbf-ready/
[622] IFRC, 2020. Disaster Relief Emergency Fund (DREF)

fenced budgets. This scoping and assessment will identify whether efforts would be best place adapting an existing fund or creating a new one; and inform the design of a sustainable source of funding for FbF. Given the existing baseline, the financial mechanism is expected to utilise public sector resources in the first instance. Private sector financing for FbF is not envisaged within the five-year implementation period; however, the Project aims to build a foundation for mobilising and integrating private sector resources in the longer term.

Finally, this sub-activity will initiate the process of Early Action Protocol (EAP) development. The EAP is a tool to guide the timely and effective implementation of early actions based on impact-based early warning information. It contains information on triggers, early actions and funding allocation, and describes the step-by-step process for the implementation of early actions once a trigger is hit. To identify what should be in the EAP, the Project will convene a technical working group, engaging stakeholders at all levels – including community representatives, disaster risk management actors, women's groups, civil society organisations, local and national government departments, NGOs and private sector actors. The technical working group will build on the consultations in the second phase of Roadmap development to complete the Risk Assessment and set the Trigger, and accordingly identify and select the most appropriate forecast-based early actions. The draft EAP will be presented to the identified key Stakeholders for validation and refinement. It should be noted that actual implementation of the EAP is beyond the scope of the Project.

4.2.2 – Develop capacity for Early Warning Early Action (EWEA) in agriculture

Early Warning Early Action (EWEA), also known as Forecast based Financing (FbF) has been piloted by FAO, the World Food Programme (WFP) and the Red Cross and Red Crescent Society in several countries in Asia and the Pacific. The principle of EWEA/FbF is that allocation of financial resources is agreed in advance, together with specific forecast thresholds that will trigger the release of those resources for the implementation of Early Actions, pre-defined in the Early Action Plan (or FbF Protocol). FAO evaluation of the pilots shows positive results, especially for drought.[623]

This sub-activity will build capacity of national, sub-national and community-based partners to utilise impact-based forecasts and early warning information for FbF/EWEA in agriculture – given the importance of this sector for the population of Timor-Leste – with a focus on institutionalising the forecast-based early action approach.

The Project will work with DNMG, NDMD and the Ministry of Agriculture and Fisheries (MAF) to enhance mutual understanding of the value of forecast-based early action for the agriculture sector and facilitate collaboration to co-develop EAPs focused on addressing sector-specific risks. It will engage Suco Disaster Management Committees (SDMCs), MAF local staff, agriculture extensionists and local NGOs will be engaged to enhance the local relevance of EAPs; and deliver targeted training – including Training of Trainers (ToT) – to develop capacity of local stakeholders to use the improved forecasts, EWS and on-the-ground data and information (supported under Results 1 – 3) to identify early actions with the highest potential to reduce the identified impacts.

[623] In Mongolia the cost benefit ratio is estimated to be as high as seven dollars for every one dollar invested: https://www.preventionweb.net/publications/view/62643

SELECTION CRITERIA FOR STAKEHOLDERS AND BENEFICIARIES

Specific communities / beneficiaries[624] will be identified based on the following general eligibility criteria:

- **Exposure and vulnerability to hydrometeorological hazards:** Measured based on historical trends in the National Disaster Management Directorate (NDMD)'s disaster loss database and secondary data analysis (e.g., existing hazard, vulnerability and exposure maps). Geographical targeting is the first level of beneficiary selection and will coordinate with development of the Monitoring and Evaluation (M&E) framework for the Project and will be validated by national stakeholders in the Project Steering Committee (PSC).
- **Dependency of livelihoods in climate-sensitive sectors:** Measured based on the proportion[625] of households in a community for which the main source of income generation is one of the five priority sectors of the WMO Global Framework for Climate Services (GFCS) – i.e. agriculture and food security, disaster risk reduction, energy, health and water. This analysis will be conducted through consultation with government agencies, sector representatives and local government.
- **Potential to support increased livelihood opportunities:** The Project will prioritise inclusion of beneficiaries that satisfy at least one of the following criteria –
    - Women / Single parent / Elderly / Widows / Youth / People with Disabilities
    - Not receiving external assistance (i.e., from international organisations, NGOs, community groups, etc.)
    - High levels of debt / no access to credit / no formal savings that could be used to (re)start livelihood
    - Previous loss of assets or labour opportunities due to a natural disaster
- **Willingness to participate in Project activities**.

At the inception phase, the Project Management Unit (PMU) will further elaborate and refine transparent and just selection criteria in consultation with the Project Steering Committee (PSC), the Gender Expert and the Monitoring and Evaluation (M&E) Advisor. Selection criteria will be made available to all and will be disseminated to affected populations and shared with local government authorities and community-based organisations, including those representing women's interests, for endorsement. A beneficiary feedback mechanism will be established through the PSC to monitor that the selection criteria continue to be appropriate throughout implementation of the Project and that the most vulnerable people are being reached.

[624] In accordance with the analysis of international development banks, including the World Bank, and other approved GCF projects (e.g. SAP 021), for purposes of development projects, essentially everyone in Timor-Leste is considered indigenous, and thus no specific selection criteria related to indigenous peoples is required.
[625] Exact percentile thresholds will be established in the Project inception phase

Activity / Sub-activity	Target Beneficiaries and Selection Criteria
Activity 1.1 – Establish institutional and policy frameworks, legislation and delivery models for climate services	
1.1.1 – Establish a National Framework for Climate Services	**National Framework for Climate Services (NFCS) stakeholders:** NFCS stakeholders (also referred to in this Sub-Activity as “key stakeholders” and “national stakeholders”) include the following:[626] • In-country data providers – i.e., the National Directorate of Meteorology and Geophysics (DNMG); • Sector experts and co-producers – e.g., ministerial departments for agriculture, health, disaster risk reduction, water and energy; • Boundary organisations – e.g., media, rural radio, agriculture extension officers, NGOs and CBOs; • National-level users – e.g., disaster managers, public health and the private sector; • Community-level users – including representatives of communities, women’s groups and *suco* councils. Selection of “NFCS stakeholders” for participation in development of the NFCS will be made on the basis of: i) Maximising representation of the stakeholder groups outlined above – focusing on in-country data providers and sector experts/co-producers (Year 1), national-level users (Year 2), boundary organisations (Year 3), community-level users (Year 4) and all groups (Year 5); ii) Maximising geographical coverage of the Project; iii) Aiming for 50:50 gender disaggregation in participants.
1.1.2 – Establish a User Interface Platform	**Stakeholders and end users of climate information services** comprise the “NFCS stakeholders” outlined above. **Decision makers** refers to the sector experts and co-producers – e.g. ministerial departments for agriculture, health, disaster risk reduction, water and energy – outlined above. Selection of “stakeholders and end users of climate information services” and “decision makers” will be made on the basis of: i) Maximising representation of the stakeholder groups outlined above; ii) Maximising geographical coverage of the Project; iii) Aiming for 50:50 gender disaggregation in participants.
1.1.3 – Enhance climate data management and governance	**Key stakeholders for climate data:** Climate data key stakeholders include the National Directorate for Meteorology and Geophysics (DNMG), the Statistics Directorate, and the ministerial departments for agriculture, health, disaster risk reduction, water and energy. Selection of these stakeholders will be made on the basis of maximising representation of these stakeholder groups; whilst also aiming for 50:50 gender disaggregation in participants.

[626] WMO, 2018. Step-by-step Guidelines for Establishing a National Framework for Climate Services

1.1.4 – Mainstream climate risk knowledge into health, agriculture, disaster risk reduction and other sectors	**Key stakeholders in the Global Framework for Climate Services (GFCS) priority sectors:** Key stakeholders in the GFCS priority sectors include the ministerial departments for agriculture, health, disaster risk reduction, water and energy. Selection of these stakeholders will be made on the basis of maximising representation of these stakeholder groups; whilst also aiming for 50:50 gender disaggregation in participants.
1.1.5 – Establish a financial framework and business model for sustainable climate services	The Project will design the financial framework and business model with a socially inclusive and gender-responsive lens to ensure equitable access for beneficiaries from marginalised and/or vulnerable groups, such as **women**, **youth**, **elderly people**, **widows** and **persons with disabilities**.
Activity 2.1 – Enhance infrastructure and technical support for observations and monitoring	
2.1.1 – Expand and upgrade the meteorological observation network to GBON standards	**National Directorate for Meteorology and Geophysics (DNMG) staff:** DNMG will be invited to nominate staff members to participate based on relevance of the training to the respective individual's responsibilities and expertise. The Project will review the list of nominated participants and select participants based on assessment of the relevance of the participants' responsibilities and expertise, whilst also aiming for 50:50 gender representation in participants.
2.1.2 – Implement a robust program of training and capacity building including QMS	**DNMG staff** will be selected as per the criteria outlined under Sub-Activity 2.1.1. **Coastal communities:** For the purposes of the Project, "coastal communities" will be defined as persons residing in coastal and lowland areas at an elevation of up to 500 metres. Selection of "coastal communities" for participation in engagement with the Project-hired ocean science officer and ocean data stakeholder workshops will be made on the basis of: i) Maximising meaningful engagement with marginalised and/or vulnerable groups, such as **women**, **youth**, **elderly people**, **widows** and **people with disabilities**; ii) Aiming for 50:50 gender disaggregation in participants. **Women:** Defined on the basis of self-identification as female. The Project will also prioritise the selection of women from women-headed households. **Youth:** Defined as persons under 18 years of age. **Elderly people:** Defined as persons over 60 years of age. **Widow:** Defined as a woman who has lost her spouse by death and has not married again. **Persons with disabilities:** Defined on the basis of eligibility to receive the Timor-Leste disability pension.
2.1.3 – Initiate Internet of Things (IoT) approaches	**Internet of Things (IoT) delegates:** The National Directorate for Meteorology and Geophysics (DNMG) will be invited to nominate staff members to participate in IoT workshops based on relevance of the training to the respective individual's responsibilities and expertise. The Project will also invite applications from scientists and degree-level students to participate. The Project will review the list of nominated participants/applicants and select participants based on assessment of the relevance of the participants'

	responsibilities and expertise, whilst also aiming for 50:50 gender representation in participants.
Activity 2.2 – Strengthen climate modelling and impact-based forecasting	
2.2.1 – Establish a National Forecasting Centre	**DNMG staff** will be selected as per the criteria outlined under Sub-Activity 2.1.1.
2.2.2 – Enhance climate change risk modelling and prediction	**Centre for Climate Change and Biodiversity (CCCB) staff:** The CCCB will be invited to nominate staff members to participate based on relevance of the training to the respective individual's responsibilities and expertise. The Project will review the list of nominated participants and select participants based on assessment of the relevance of the participants' responsibilities and expertise, whilst also aiming for 50:50 gender representation in participants.
2.2.3 – Establish impact-based forecasting and decision-support systems for agriculture, disaster risk reduction and marine sectors	**DNMG staff** will be selected as per the criteria outlined under Sub-Activity 2.1.1. **Ministry of Agriculture and Fisheries (MAF) staff:** MAF staff from Directorates with a mandate for agriculture data/information gathering and use – such as the National Directorate (ND) of Agriculture and Horticulture, ND of Irrigation and Water Management, ND of Animal Husbandry, and the ND of Agriculture Community Development – as well as from District Agriculture Services will be selected for training on the analysis protocol; whilst also aiming for 50:50 gender representation in participants.
Activity 2.3 – Establish climate services for health	
2.3.1 – Establish a national Climate and Health Working Group	**National Climate and Health Working Group:** The Working Group will include representatives from the National Directorate for Meteorology and Geophysics (DNMG), the Ministry of Health and the Statistics Directorate. Selection of the Working Group representatives will be made on the basis of maximising representation of the government agencies, whilst also aiming for 50:50 gender disaggregation in participants. **Climate-health stakeholders:** Climate-health stakeholders include staff in the agencies represented in the Working Group, as well as health-relevant partners (e.g., NGOs, research institutions and universities), disaster risk management actors (including the National Disaster Management Directorate – NDMD) and agencies delivering health services at the community level. Selection of the Working Group representatives will be made on the basis of maximising representation of the stakeholder groups; whilst also aiming for 50:50 gender disaggregation in participants.
2.3.2 – Establish an air quality monitoring framework	**Air quality monitoring actors:** Air quality monitoring actors include representatives from the National Directorate for Meteorology and Geophysics (DNMG) and the National Directorate of Pollution Control and Environmental Impact (NDPCEI). The DNMG and NDPCEI will be invited to nominate staff members to participate in technical training and capacity building based on relevance of the training to the respective individual's responsibilities and expertise. The Project will review the list of nominated participants and select

	participants based on assessment of the relevance of the participants' responsibilities and expertise, whilst also aiming for 50:50 gender representation in participants. **Local stakeholders:** Selection of "local stakeholders" for participation in local stakeholder engagement workshops to enhance awareness on air pollution, its sources, related health risks and appropriate actions to reduce impacts on health and well-being will be made on the basis of the general eligibility criteria outlined above. Additional criterion includes aiming for 50:50 gender representation in participants.
2.3.3 – Co-develop tailored forecasting and decision support for health	**DNMG staff** will be selected as per the criteria outlined under Sub-Activity 2.1.1. **Ministry of Health staff:** The Ministry of Health will be invited to nominate staff members to participate based on relevance of the training to the respective individual's responsibilities and expertise. The Project will review the list of nominated participants and select participants based on assessment of the relevance of the participants' responsibilities and expertise, whilst also aiming for 50:50 gender representation in participants.
2.3.4 – Develop a mobile app for health-related forecasts and advisories	The Project will develop the mobile application with a socially inclusive and gender-responsive lens to ensure equitable access for beneficiaries from marginalised and/or vulnerable groups, such as **women**, **youth**, **elderly people**, **widows** and **persons with disabilities**.
Activity 3.1 – Establish targeted multi-hazard early warning information systems	
3.1.1 – Convene a technical working group for EWS	**Early Warning System (EWS) actors:** "EWS actors" include the National Disaster Management Directorate (NDMD) and Disaster Management Committees at the district, sub-district and *suco* (village) level, agencies responsible for issuing hazard warnings and advisories (e.g., National Directorate of Meteorology and Geophysics – DNMG, Ministry of Social Solidarity), humanitarian and relief organisations (e.g. Timor-Leste Red Cross Society – CVTL) and public and private communication entities. Other actors include ministries and agencies responsible for potentially affected sectors, such as agriculture, health, water, energy, fisheries, transport, telecommunications and education. [627] Local actors include representatives of communities, women's groups and *suco* councils. Selection of "EWS actors" for participation in Project activities will be made on the basis of: i) Maximising representation of the stakeholders outlined above; ii) Maximising geographical coverage of the Project; iii) Aiming for 50:50 gender disaggregation in participants. **Women** beneficiaries will be selected as per the criteria outlined under Sub-Activity 2.1.2.
3.1.2 – Co-develop socially inclusive and	**Community members:**

[627] WMO, 2018. Multi-hazard Early Warning Systems: A Checklist

<table>
<tr><td>gender-responsive localised communication strategies</td><td>Specific communities will be identified based on the general eligibility criteria outlined above. Selection of “community members” for participation in co-development of the localised communication strategies will be made on the basis of:
i) Maximising meaningful engagement with marginalised and/or vulnerable groups, such as women, youth, elderly people, widows and persons with disabilities;
ii) Aiming for 50:50 gender disaggregation in participants.

Women, youth, elderly people, widows and persons with disabilities will be selected as per the criteria outlined under Sub-Activity 2.1.2.</td></tr>
<tr><td>3.1.3 – Enhance community-based early warning systems</td><td>Specific communities will be identified based on the general eligibility criteria outlined under Sub-Activity 3.1.2. Additional criterion includes maximising the geographical coverage of this sub-activity.</td></tr>
<tr><td>3.1.4 – Disseminate sector-specific early warning information for agriculture</td><td>Agriculture extension officers and extension coordinators:
This sub-activity will cover all 305 agriculture extension officers and 65 extension coordinators in Timor-Leste’s Ministry of Agriculture and Fisheries (MAF) network.

MAF staff will be selected for the training on disaster risk management as per the criteria outlined under Sub-Activity 2.2.3.</td></tr>
<tr><td colspan="2">Activity 4.1 – Build capacity to prepare for and respond to climate risks and hazards</td></tr>
<tr><td>4.1.1 – Enhance disaster preparedness capabilities from national to community level</td><td>Specific communities will be identified based on the general eligibility criteria outlined above. Additional criterion includes maximising the geographical coverage of this sub-activity.

Selection criteria for beneficiaries to participate in capacity building workshops and trainings by Timor-Leste Red Cross Society (Cruz Vermelha de Timor-Leste – CVTL) will be outlined in the livelihood analysis, which will be undertaken as part of the Project.

Selection of “community members” for participation in workshops on the use of climate forecasts for improved water management conducted by the National Directorate for Climate Change (NDCC) will be made on the basis of the general eligibility criteria outlined above. Additional criterion includes aiming for 50:50 gender representation in participants.

Women beneficiaries will be selected as per the criteria outlined under Sub-Activity 2.1.2.</td></tr>
<tr><td>4.1.2 – Build capacity of the National Disaster Management Directorate (NDMD) for EWS</td><td>National Disaster Management Directorate (NDMD) staff:
NDMD will be invited to nominate staff members to participate in training based on relevance of training outcomes to the respective individual’s responsibilities and expertise. The Project will review the list of nominated participants and select participants based on assessment of the relevance of the participants’ responsibilities and expertise, whilst also aiming for 50:50 gender representation in participants.</td></tr>
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<table>
<tr><td>4.1.3 – Increase public awareness and education on climate hazards, related health risks and early warning</td><td>Last-mile communities:
Communities at “the last mile” will be selected on the basis of:
i) Geographic isolation;
ii) Lack of critical infrastructure (e.g., water supply, public health, transportation, communications);
iii) Lack of access to climate hazard and disaster risk information.</td></tr>
<tr><td>4.1.4 – Conduct a targeted disaster risk awareness and education campaign for women</td><td>Community-based organisations:
Partnerships with women’s groups, NGOs and community-based organisations to establish women’s networks will be prioritised on the basis of:
i) Potential for synergies and complementarities with existing projects and initiatives and avoidance of overlaps and doubling of efforts;
ii) Level of organisation and ability based on the expectation that ownership of and investment of time and resources in activities is key to ensure sustainability.

Women, youth, elderly people, widows and persons with disabilities will be selected as per the criteria outlined under Sub-Activity 2.1.2.</td></tr>
<tr><td colspan="2">Activity 4.2 – Establish Forecast-based Financing (FbF)</td></tr>
<tr><td>4.2.1 – Establish a Roadmap for FbF</td><td>Forecast-based Financing (FbF) actors (including institutional stakeholders and local communities) will be selected as per the criteria for “EWS actors” outlined above.

Community-based organisations will be selected as per the criteria outlined above.

Timor-Leste Red Cross Society (CVTL) staff:
CVTL will be invited to nominate staff members to participate in training based on relevance of training outcomes to the respective individual’s responsibilities and expertise. The Project will review the list of nominated participants and select participants based on assessment of the relevance of the participants’ responsibilities and expertise, whilst also aiming for 50:50 gender representation in participants.

Other Professional staff:
Professional staff who will benefit from training and capacity building under the Project include suco councillors, NGO staff and government employees. These beneficiaries will be selected according to the following process:
i) Organisations have and/or will be identified based on alignment between the proposed activities and the organisation’s mandate, expertise and/or services delivered;
ii) Identified organisations will be invited to nominate staff to participate in the activities based on alignment between the propose outcomes of the intervention (e.g. technical focus of the training) and the respective individual’s responsibilities and expertise within the organisation;
The Project will review the list of nominated participants and select participants based on assessment of alignment between the intervention and the participants’</td></tr>
</table>

	responsibilities and expertise; whilst also aiming for 50:50 gender disaggregation in participants. **Financial mechanism:** The Project will design the financial mechanism for forecast-based early action with a socially inclusive and gender-responsive lens to ensure equitable access for beneficiaries from marginalised and/or vulnerable groups, such as **women**, **youth**, **elderly people**, **widows** and **persons with disabilities**.
4.2.2 – Develop capacity for Early Warning Early Action (EWEA) in agriculture	**FbF/EWEA stakeholders** will be selected as per the criteria for "EWS actors" outlined above. **Professional staff and community-based organisations** will be selected as per the criteria outlined above.

Table 12: Preliminary selection criteria for stakeholders and beneficiaries

COHERENCE WITH GCF UNDP PROJECT FP109

The Project is designed to complement the existing GCF-funded UNDP project "Safeguarding rural communities and their physical assets from climate induced disasters in Timor-Leste" (FP109), rather than duplicate it. A multi-level institutional arrangement has been developed to facilitate establishment of synergy and effective collaboration. The arrangement is outlined below:

- ***Activity-level:*** A key priority in developing the DSS will be the integration of data from multiple sources, standardisation of data collection processes, and inter-agency cooperation in generating and sharing the derived products. The NFCS and NCOFs will play a key institutional role in this regard, providing an enabling environment to enhance cooperation and maximise synergies between the multiple actors in weather, water and climate services in Timor-Leste – including the UNDP project team and the national stakeholders involved in FP109.

  Moreover, the UNDP and JICA project teams will be invited to participate in the technical working group for EWS (Sub-activity 3.1.1), which aims at establishing a more coherent approach to Early Warning Systems in Timor-Leste – and by extension, the impact-based forecasting that feeds into the EWS. The Working Group will facilitate regular communication between EWS actors to improve coordination and avoid duplication of efforts. Participation of the UNDP project team in the EWS Working Group will therefore provide an opportunity to realise complementarity of FP109 outputs in impact-based forecasting / EWS.

- ***Project-level:*** The Project Steering Committee (PSC) will provide high-level oversight and guidance towards achieving the Project's objectives, which will include ensuring full cooperation of various stakeholders, including those involved in hydrology and hydraulics. Co-chaired by the NDA, the PSC will pay particular attention to ensuring that complementarity with FP109 is effectively operationalised as envisaged. In addition, an in-country Project Management Unit (PMU) will establish the necessary operational linkages with the UNDP team managing FP109 in Timor-Leste.

- ***Country-level:*** The United Nations Country Team (UNCT) works to ensure inter-agency coordination and decision-making at the country level, building on the comparative advantages of the UN family and in line with "Delivering as One" model endorsed by the UN General Assembly. The UNCT provides an overarching framework for coordination and cooperation among UN entities operating in Timor-Leste, including UNDP and UNEP. UNEP's

Asia Pacific Regional Office is already participating in the UNCT for Timor-Leste, and the in-country PMU will further strengthen this engagement.

UNEP's participation in the UNCT and related processes will amongst others facilitate coordination, cooperation and complementarity with the UNDP GCF-funded project FP109. To this end, UNEP and UNDP have a Memorandum of Understanding (MoU) to increase collaboration and joint activities in support of internationally agreed environment and sustainable development goals established by member countries. The MoU builds on existing collaborative arrangements and lessons learned seeking to further enhance effectiveness and avoid duplication. The MoU between UNEP and UNDP is provided as Annex 22.

Enhancing the UNEP/UNDP strategic partnership is a priority of both organisations to deliver synergies, demonstrate clear added-value and show that multi-lateral action is more than the sum of its respective parts. The UNEP/UNDP collaboration requires no extra cost from the Project and both organisations are committed to continuing collaboration long beyond the Project's five-year duration.

10 – PROJECT GOVERNANCE

10.1 – ACCREDITED ENTITY

UNEP will be the Accredited Entity for the Project and will be responsible for managing the implementation, financial management, evaluation, reporting and closure of the activities under the Project. UNEP will monitor and supervise the execution of the Project and ensure the proper management and application of GCF Grant Proceeds by the Executing Entities. UNEP will ensure that the Grant Proceeds are utilised in accordance with the terms of the Funded Activity Agreement to be entered into between GCF and UNEP and the Accreditation Master Agreement. UNEP will also assume a limited role as Executing Entity, as described in the relevant section below.

UNEP brings more than 25 years' experience working on climate change issues and is an established GCF Accredited Entity. It brings a comprehensive approach to climate change mitigation and adaptation that is grounded in both natural science and economics and is tied to the environmental and development concerns of countries. Based on its core science-based mandate, one of UNEP's seven sub-programmes is entirely dedicated to keeping the world environment under review.

Through its Science Division, UNEP has longstanding expertise in environmental and climate change information management and early warning systems. For example, with GEF and EC funding it is currently supporting over 50 countries in establishing or strengthening their environmental information management systems and using them for reporting progress on SDGs and MEAs. Its Science Division manages the CLIMWARN and Country Level Impacts of Climate Change (CLICC) projects, the Global Environment Monitoring System for Air (GEMS Air), and UNEP also convenes and facilitates regional environmental information networks and the world adaptation science program (former PROVIA). Through its work on climate information, early warning and foresight, UNEP enables stakeholders to respond to the latest emerging issues related to environment and climate change. A concrete example is the approved UNEP GCF FP147 on "Enhancing Climate Information and Knowledge Services for resilience in 5 island countries of the Pacific Ocean".[628]

UNEP is also a key player in the "One Health" approach – a cross-cutting and systematic approach to health that recognises the interdependence of human, animal and environmental health as critical for

[628] https://www.greenclimate.fund/project/fp147

addressing the three planetary crises: the climate crisis, the nature and biodiversity crisis, and the pollution and waste crisis. As a member of the One Health High-Level Expert Council, UNEP is supporting the collection, distribution and publicizing of reliable scientific information on the links between human, animal and environmental health, which in turn aims to assist public officials to make appropriate decisions to address future crises and to inform citizens.

In addition, the United Nations Country Team (UNCT) works to ensure inter-agency coordination and decision-making at the country level, building on the comparative advantages of the UN family and in line with "Delivering as One" model endorsed by the UN General Assembly. The UNCT provides an overarching framework for coordination and cooperation among UN entities operating in Timor-Leste. UNEP's Asia Pacific Regional Office is already participating in the UNCT for Timor-Leste. The work of the United Nations in Timor-Leste is guided by the UN Sustainable Development Cooperation Framework (UNSDCF) 2021 – 2025, which outlines the actions needed for more strategic, transformative and integrated UN support to accelerate Timor-Leste's progress towards achieving the Sustainable Development Goals and its national development priorities. The UNSDCF was developed through a consultative and participatory process involving the Government of Timor-Leste, civil society and development partners. This Project will specifically support national efforts in the UNSDCF Strategic Priority 6, which aims at achieving enhanced resilience to climate change impacts and natural hazards.

UNEP's participation in the UNCT and related processes will amongst others facilitate coordination, cooperation and complementarity with the UNDP GCF-funded project FP109. UNEP's participation in the UNCT and related processes will amongst others facilitate coordination, cooperation and complementarity with the UNDP GCF-funded project FP109. To this end, UNEP and UNDP have a Memorandum of Understanding (MoU) to increase collaboration and joint activities in support of internationally agreed environment and sustainable development goals established by member countries. The MoU builds on existing collaborative arrangements and lessons learned seeking to further enhance effectiveness and avoid duplication.

10.2 – PROJECT MANAGEMENT UNIT (PMU)

At the request of the NDA, UNEP will set up and manage a Project Management Unit (PMU) drawing on its Global Support Services Agreement with the UN Office for Project Services (UNOPS), where necessary. The PMU will provide management and support to the national implementation of the Project through coordination by the national Executing Entity (SSE) and Technical Partners involved in Project implementation, in line with their obligations under the respective legal instruments and will coordinate to ensure that reports are received. The PMU will consolidate all half yearly progress reports and quarterly financial reports, including co-financing reports and annual audit reports, from the EE and Technical Partners and submit these to the AE. The PMU will provide guidance and source expertise as needed on project management, financial management, procurement and technical issues. It will establish contact with other development partners working with Timor-Leste to ensure that activities in related fields are complementary, and to seek opportunities for collaboration. The PMU will also provide secretariat services to the Project Steering Committee (PSC).

The PMU will be staffed by three full-time staff reporting to UNEP in its EE capacity: a Project Manager (PM), a Fund Management, Monitoring and Procurement Officer (FMMPO) and a Finance and Admin Assistant (FAA). The FMMPO and FAA will report directly to the PM. All staff will be recruited in line with UN regulations, rules and policies. The PMU will be overall responsible for the day-to-day management of the Project. This role will include an overall responsibility for:

i. Coordinating the Project Steering Committee (PSC);
ii. Managing the Project in line with the budget and workplans, and in accordance with GCF and UNEP guidelines;
iii. Being responsible for financial management and disbursements;
iv. Coordinating the national EE and Technical Partners to manage the Project effectively;
v. Consolidating national EE and Technical Partner reports and report to the AE; and
vi. Ensuring exchange of information and knowledge across the EE and Technical Partners.

To achieve the targets of the proposed Project the PM will, inter alia:

i. Acquire on-the-ground information to inform UNEP progress reports;
ii. Engage with Project stakeholders;
iii. Arrange PSC, PMU and other meetings;
iv. Provide technical support, including measures to address challenges to Project implementation;
v. Participate in training activities;
vi. Write technical reports;
vii. Facilitate relevant expert activities; and
viii. Establish the necessary operational linkages with the UNDP team managing FP109 in Timor-Leste as part of the overall UNDP-UNEP Strategic Partnership.

Additionally, the PM will liaise with members of the PSC, technical experts, government staff and stakeholders involved to coordinate the implementation of the proposed Project's activities.

A range of equipment (i.e. AWS, AWOS, weather radars, etc.) and communication infrastructure upgrades will be procured to strengthen observations in Timor-Leste, based on the priorities identified in Section 6. In addition to undertaking direct procurement as part of UNEP's EE function (with the support of UNOPS where necessary), the PMU will provide guidance and support to the national EE and technical partners on procurement in line with the provisions of the respective Project Cooperation Agreements (PCAs). The PMU will ensure compliance with the UN rules and regulations related to procurement.

10.3 – EXECUTING ENTITIES (EES)

The Secretary of State for the Environment (SSE) in Timor-Leste will serve as the national Executing Entity (EE). The SSE will be accountable to UNEP as AE for Project execution at the national level and for the effective and efficient use of resources.

UNEP will enter into an appropriate agreement (Project Cooperation Agreement) with the SSE for the execution of the Project. The Project Cooperation Agreement (PCA) will establish clear roles and responsibilities for the delivery of the proposed activities, and the schedule and conditions for instalments, the determination of the prevailing fiduciary standards and the terms and conditions for arbitrations and termination of contract. The PCA will include specific obligations for the national EE on Project execution, financial management, personnel administration and reporting, as well as arbitration and liability terms.

The national EE will be responsible for establishing national project implementation in a relevant part of the government administration to provide implementation guidance and support to national service providers and Technical Partners (see below section). The national EE will thus provide technical and implementation guidance and will facilitate cooperation and coordination among the national service providers. It will be accountable to and submit regular progress reports to the PMU.

At the request of the NDA, UNEP will undertake limited Executing Entity functions. Through its Global Support Services Agreement with UNOPs, UNEP is able to operate at the country level without necessarily having a national office. The Agreement covers the provision of HR and procurement services. UNEP will execute the Project in line with its programme manual and standard business procedures and will contract international consultants and Technical Partners to undertake relevant activities as appropriate.

Amongst others, UNEP will undertake EE functions to establish climate services for health in Timor-Leste (Activity 2.3), through provision of technical advisory to the Climate and Health Working Group and operationalisation of the Health Decision Support System (DSS). Moreover, UNEP's Global Environment Monitoring System for Air (GEMS Air) will lead on establishment of an air quality monitoring framework. GEMS Air supports countries to provide quality assured data to keep the state of the world's air quality under continuous review; develops capacity of member states; provides information and services across the science-policy-public interface; and fosters transformation by leveraging the collective knowledge of a global network of partners.

Implementation arrangements for the EEs are outlined in the table below.

Executing Entity	**Details of EE and track record**	**Role in project sub-activities**
Secretary of State for the Environment (SSE)	The SSE assists the Coordinating Minister for Economic Affairs to support the implementation of policies for economic governance areas, including ensuring national development in an environmentally sustainable manner. The Acting Executive Secretary and Principal Adviser for Climate Finance and Resource Mobilisation Director of the SSE is the NDA and the Focal Point for interaction with the Green Climate Fund. A HACT assessment was carried out of SSEs capacity on behalf of UNDP in 2019. In addition, SSE has provided details of its track record in implementing projects over the past 5 years: • GCF/UNDP: Safeguarding Rural Communities and their Physical Assets from Climate Induced Disasters in Timor-Leste (\$59,443,867; GCF – \$22,356,805, Government of Timor-Leste – \$36,687,062)	SSE will deliver parts of and engage relevant service providers to implement **sub-activity 1.1.1:** Development of the National Framework for Climate Services (NFCS) and coordination of inputs and review of draft legislation; **sub-activity 1.1.2:** Establishment of a User Interface Platform; **sub-activity 1.1.3:** Coordination to enhance climate data management and governance; **sub-activity 1.1.4:** Mainstream climate services and disaster risk knowledge into sectors; **sub-activity 1.1.5:** Advisory for development of the financial framework and business model for climate services; **sub-activity 2.1.1:** Ensure that meteorological observation equipment is suited to the national context through coordination with DNMG and technical partners in alignment with GBON obligations and WMO standards; **sub-activity 2.1.2:** Engagement of an ocean science officer and coordination of training and capacity building for DNMG; **sub-activity 2.1.3:** Coordination of Internet of Things (IoT) workshops; **sub-activity 2.2.1, 2.2.2 and 2.2.3:** Coordination of national service providers and technical partners to strengthen climate modelling and impact-based forecasting; **sub-activity 2.3.1:** Coordination to establish a national Climate and Health Working Group; **sub-activity 3.1.1,**

	• GEF – Access Benefit Sharing (ABS) ($1,300,000) • GEF Dugong and habitat (sea grass) Conservation ($830,000) • EU- GIZ Adapting to Climate Change and Sustainable Energy (ACSE) ($1,000,000) • Intra-ACP GCCA+ PACRES - USP Component, climate change advocacy ($188,266) • Intra-ACP GCCA+ Pacific Adaptation to Climate Change and Resilience Building (PACRES) ($354,000) • GCF Readiness project stage 2 ($695.038) • GCF Readiness stage 1 ($300,000) • Climate Technology Centre & Network (CTCN), GCF ($30,449)	**3.1.2, 3.1.3 and 3.1.4:** Coordination of national service providers, technical partners and local consultants to establish targeted multi-hazard early warning information systems; **sub-activity 4.1.1, 4.1.2, 4.1.3 and 4.1.4:** Coordination of national service providers, technical partners and consultants to build climate risk preparedness capacities; and **sub-activity 4.2.2:** Coordination of national service providers and technical partners to develop capacity for Early Warning Early Action in agriculture.
UN Environment Programme (UNEP)	UNEP has significant experience in working on climate change and is an established GCF Accredited Entity. Through its Science Division, UNEP has longstanding experience in environmental and climate change information management and early warning systems, with recent examples including: • GEF-funded “Inform” project ($4.3 million); • Climate Change Early Warning (CLIM-WARN) project in Kenya, Ghana and Burkina Faso; • Country-Level Impacts of Climate Change (CLICC) project. UNEP also convenes and facilitates regional environmental information networks, the World Adaptation Science Programme (formerly PROVIA) and the Global Environment Monitoring System for Air (GEMS Air).	UNEP, including through its Global Environment Monitoring System for Air (GEMS Air), will deliver **sub-activity 2.3.1:** Technical advisory to the Climate and Health Working Group; and **2.3.2:** Establishment of an air quality monitoring framework; **sub-activity 3.1.1:** Technical advisory to the EWS Working Group. UNEP will contract international consultants to deliver parts of **sub-activity 1.1.1, 1.1.3, 1.1.4 and 1.1.5:** Development of institutional and policy frameworks, legislation, data strategy, sector-specific plans and training, and a financial framework and business model for climate services, and mainstreaming gender throughout the project; and **sub-activity 4.1.4:** Deliver targeted disaster risk awareness and education workshops for women. UNEP will conclude Project Cooperation Agreements with technical partners to deliver parts of **sub-activity 1.1.3; sub-activity 2.1.1, 2.1.2 and 2.1.3; sub-activity 2.2.1 and 2.2.3; sub-activity 2.3.3 and 2.3.4; sub-activity 3.1.3 and 3.1.4; sub-activity 4.1.1 and 4.1.2; sub-activity 4.2.1 and 4.2.2.**

Table 13: Details of Executing Entities (EEs) and role in project sub-activities

The PMU will convene regular meetings with the EEs and the service providers to monitor the progress, facilitate cooperation among the implementing organisations and seek collaborative solutions to any issues that arise. As part of Project management, the EEs will undertake regular monitoring exercises. The EEs will contribute to the continuous monitoring of project implementation, a formative Mid-Term Evaluation and a summative Terminal Evaluation of the overall Project.

10.4 – TECHNICAL PARTNERS

The Project will benefit from the expertise of a broad coalition of Technical Partners, thereby ensuring coherence and complementarity. Technical Partners will include FAO, RIMES, IFRC (including its Climate Centre and national society – CVTL), BMKG and ICTP. These are highly qualified, internationally recognised professional agencies with many years' experience of partnership in the Asia-Pacific region. Based on the priorities of Timor-Leste, the Technical Partners will lead or provide support for the implementation of specific interventions that require highly technical or scientific expertise and are in line with their mandates and comparative advantages. These agencies will be sub-contracted by UNEP in its capacity as Executing Entity, in line with UNEP's procedures and policies – i.e. to deliver their agreed body of work in Timor-Leste through consultation and coordination with the national EE. Technical Partners will report to the PMU and Project Steering Committee.

Agency supporting national execution	**Details of technical partner and track record**	**Role in project sub-activities**
Food and Agriculture Organization (FAO)	FAO is a specialised agency of the United Nations that leads international efforts to achieve food security for all. Climate change is a top-line priority for FAO, which is implementing a series of global programmes and projects to create an enabling environment for agricultural development under climate change. FAO is an established GCF Accredited Entity and has a track record in managing similar projects and initiatives, including: • GCF-funded Transforming the Indus Basin with Climate Resilient Agriculture and Water Management in Pakistan (USD 47.7 million); • GCF-funded Upscaling climate resilience measures in the dry corridor agroecosystems of El Salvador (RECLIMA) (USD 127.7 million); • Modelling System for Agricultural Impacts of Climate Change (MOSAICC); • Analysis and Mapping of Impacts under Climate Change for Adaptation and Food Security (AMICAF); • Agriculture Stress Index System (ASIS).	FAO will support delivery of **sub-activity 2.2.3:** Enhancement of the Agriculture Stress Index System (ASIS) for Timor-Leste; **sub-activity 3.1.4:** Technical support to disseminate sector-specific early warning information; and **sub-activity 4.2.2:** Technical support to develop capacity for Early Warning Early Action (EWEA) in agriculture.

Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES)	RIMES is an international and intergovernmental institution for the generation and application of early warning information covering Africa and Asia. Timor-Leste is a Member State of RIMES. RIMES has an extensive track record of implementing similar projects, including: • Development of flood forecast technology in Bangladesh (USD 1.46 million); • End-to-end Early Warning of Tsunamis and other Natural Hazards in the Indian Ocean and Southeast Asia: Phase 2 (USD 1.21 million); • Enhanced Climate Risk Management Technical Assistance Support Project (USD 1.05 million).	RIMES will support delivery of **sub-activity 1.1.1:** Technical support to help draft the NFCS and support the National Climate Outlook Forum (NCOF); **sub-activity 1.1.3:** Technical support to install the Climate Data Informatics System (CDIS); **sub-activity 2.1.1:** Technical support for the installation of the Buoy; **sub-activity 2.2.1:** Establishment of a National Forecasting Centre; **sub-activity 2.2.3:** Establishment of sector-specific impact-based forecasting and SMART, SESAME and OSFAS decision-support systems; **sub-activity 2.3.3:** Establishment of tailored forecasting and decision support for health; and **sub-activity 2.3.4:** Development of a mobile app for health-related forecasts and advisories.
International Federation of Red Cross and Red Crescent Societies (IFRC) – including its Climate Centre and national society (Cruz Vermelha de Timor-Leste – CVTL)	IFRC assists the Red Cross and Red Crescent Movement and its partners to reduce the impacts of climate change and extreme weather events on vulnerable people. Together with CVTL and the National Disaster Management Directorate, IFRC will support the Project with expertise on last-mile delivery and Forecast-based Financing (FbF).	CVTL will support delivery of **sub-activity 3.1.1:** National capacity building on Early Warning Systems (EWS); **sub-activity 3.1.3:** Enhance community-based EWS; **sub-activity 4.1.1:** Enhance disaster preparedness capabilities from national to community level; and **sub-activity 4.1.3:** Awareness and education on climate hazards, related health risks and early warning. IFRC will support delivery of **sub-activity 4.2.1:** Technical support to establish a Roadmap for FbF.
Indonesian Meteorological, Climatological and Geophysical Agency (Badan Meteorologi, Klimatologi dan Geofisika – BMKG)	BMKG is an Indonesian government agency with a ministry status. It is headed by a Director General who reports directly to the President of the Republic of Indonesia. BMKG is responsible for monitoring and providing information services on weather, climate, air quality, earthquake, tsunami and related environmental information. In addition to its role in disaster risk reduction and management, BMKG provides weather services to the agriculture, fisheries, forestry and aviation sectors amongst others.	BMKG will support delivery of **sub-activity 2.1.1:** Technical support for the assembly, installation, calibration, operation and maintenance of observations equipment in compliance with the Global Basic Observing Network (GBON) requirements; **sub-activity 2.1.2:** Technical support, training and capacity building for DNMG staff.

	BMKG has a Memorandum of Understanding (MoU) with Timor-Leste's Ministry of Public Work, Transport and Communication (under which the national meteorological service operates) to provide technical support for the calibration of meteorological equipment, human resource development, and to exchange data and information about meteorology, climatology and geophysics. In addition, as an established WMO Regional Training Centre, BMKG delivers training and capacity building in meteorology, climatology, hydrology and related sciences to fulfill the needs of the RA II (Asia) and RA V (South-West Pacific) regions.	
Abdus Salam International Centre for Theoretical Physics (ICTP)	Founded by Abdus Salam (Nobel Laureate in Physics), ICTP operates under a tripartite agreement among two UN agencies – UNESCO and IAEA – and the Italian Government. ICTP is a Category 1 UNESCO institute. The mission of ICTP is to foster advanced studies and research in developing countries. Its activities encompass most areas of theoretical and applied sciences, including Earth System Physics and ICT. Since its establishment, the Centre has received around 120,000 scientists, half of whom have come from the developing world. Since 2019, ICTP hosts the only European ITU Centre of Excellence in Internet of Things (IoT), Big Data and Statistics.	ICTP will support delivery of **sub-activity 2.1.3:** Technical support and training to initiate Internet of Things (IoT) approaches; and **sub-activity 4.1.2:** Technical support and capacity building for NDMD to plan, deploy and maintain wireless infrastructure.

Table 14: Details of Technical Partner agencies, mandates and role in project sub-activities

10.5 – PROJECT STEERING COMMITTEE

The Project Steering Committee (PSC) will be established comprising the NDA (also serving as national EE) and UNEP. It will meet at least once per year and will be co-chaired by the NDA and the AE (UNEP). The PSC will provide high-level oversight and guidance towards achieving Project objectives. The PSC is a consensus-based decision-making body within the Project governance structure and will provide, review and monitor strategic direction and policy guidance to the Project team. Among other functions, the PSC will review and approve the annual workplan and budget and approve the Project's annual report as prepared by the PMU and national EE. The committee will also provide recommendations on Project approaches and participate in discussing general strategies and opportunities for project planning and implementation.

The functions of the Steering Committee are:

- Providing overall guidance for Project execution to the PMU, especially on cross-cutting issues which require consensus from the various stakeholders involved in the Project;
- Ensuring that recommended policy and institutional strengthening undertaken under the Project is consistent with the Project's overall agenda;
- Ensuring full cooperation of various regional and national stakeholders under their jurisdictions to provide access and support to the Project team in carrying out their tasks;
- Representing the interests of civil society and communities in their countries derived from a regular formal dialogue between NDAs and national peak bodies;
- Reviewing and monitoring progress in Project execution; and
- Ensuring that complementarity with other GCF-funded projects (in particular, the UNDP-led FP109) is effectively operationalised.

The members of the Steering Committee will be the NDA, the UNEP AE Representative and national EE representatives. Observers will include:

- the Project Manager;
- Representatives from the Technical Partner agencies involved in Project implementation – FAO, RIMES, IFRC, Mercy Corps, BoM, ICTP and others as appropriate;
- Representatives from additional entities involved in Project implementation, in particular DNMG, NDMD, DNGRA, MAF and community-based organisations with experience in disaster risk management;
- Representatives of civil society and women's organisations; and
- Representatives of the private sector.

Secretariat services will be provided by the Project Management Unit (PMU). The minutes of the meetings will be provided to the AE by the Project Manager.

10.6 – NATIONAL SERVICE PROVIDERS

National service providers will be engaged through relevant agreement modalities by the national EE. These include the National Directorate for Meteorology and Geophysics (DNMG), National Disaster Management Directorate (NDMD), National Directorate for Water Resource Management (DNGRA), Ministry of Agriculture and Fisheries (MAF), the National University of Timor-Leste's Center for Climate Change and Biodiversity (CCCB), and the National Directorate for Climate Change (NDCC), amongst others.

APPENDIX 1 – LIST OF ACRONYMS

AEs	Accredited Entities
ARGs	Automated Rain Gauges
AWS	Automatic Weather Stations
BMKG	Indonesian Agency for Meteorology, Climatology and Geophysics
CBEWS	Community-Based Early Warning System
CSO	Civil Society Organisations
CCDA	Climate Change Development Authority
CDCCC	Community Disaster and Climate Change Committees
CDPRP	Community Disaster Preparedness and Response Plans
CliDE	Climate Data for Environment
CORDEX	Coordinated Regional Climate Downscaling Experiment
COSPPac	Climate and Oceans Support Program in the Pacific
CRISP	Community Resilience to Climate and Disaster Risk Project
CREWS	Climate Risk and Early Warning Systems
DFAT	Department of Foreign Affairs and Trade (Australia)
DNMG	National Directorate for Meteorology and Geophysics
DNPM	Department of National Planning and Monitoring
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DWR	Department of Water Resources
E&S	Environmental and Social Impact Assessment
ECMWF	European Centre for Medium-Range Forecasts
ENSO	El-Nino Southern Oscillation
EWS	Early Warning System
FBO	Faith Based Organisations
FFGS	Flash Flood Guidance System
FINPAC	The Finland & Pacific project
FMS	Fiji Meteorological Service
FRDP	Framework for Resilient Development in the Pacific
GCF	Green Climate Fund
GCOS	Global Climate Observing System
GHG	Greenhouse Gas

GIS	Geographic Information System
GTS	Global Telecommunications System
ICAO	International Civil Aviation Organization
ILO	International Labour Organization
IMO	International Maritime Organization
ITCZ	Inter Tropical Convergence Zone
M&E	Monitoring and Evaluation
MAL	Ministry of Agriculture and Land
MDPAC	Ministry of Development Planning and Aid Coordination
MECDM	Ministry of Environment, Climate Change, Disaster Management and Meteorology
MEMRE	Ministry of Energy, Mines and Rural Electrification
MFAT	Ministry of Foreign Affairs and Trade (New Zealand)
MID	Ministry of Infrastructure and Development
MOF	Ministry of Forestry
NDA	National Designated Authority
NDC	Nationally Determined Contribution
NDC	National Disaster Centre
NDMO	National Disaster Management Office
NEOC	National Emergency Operations Centre
NGO	Non-Government Organisation
NMHSs	National Meteorological and Hydrological Services
NWP	Numerical Weather Prediction
O&M	Operation and Maintenance
OGCIO	Office of the Government of the Chief Information Officer
OMMP	Operation, Maintenance and Monitoring Plan
PCCSP	Pacific Climate Change Science Program
PCRAFI	Pacific Catastrophic Risk and Financing Initiative
PDC	Provincial Disaster Centre
PEOC	Provincial Emergency Operations Centre
PICTs	Pacific Island Countries and Territories
PIMS	Pacific Islands Meteorological Strategy
PIU	Project Implementing Unit
PMU	Project Management Unit

PNG	Papua New Guinea
PRSCS	Pacific Roadmap for Strengthened Climate Services
P-SIDS	Pacific Small Island Developing States
RIMES	Regional Integrated Multi-Hazard and Early Warning System
RSMC	Regional Specialized Meteorological Centre
SCOPIC	Statistical Model Climate Predictions with Drought Monitoring Tool
SDG	Sustainable Development Goals
SOP	Standard Operating Procedures
SPC	The Pacific Community
SPCZ	South Pacific Convergence Zone
UNDP-RESPAC	United Nations Development Programme Regional Disaster Resilience in the Pacific Small Island Developing States Project
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNISDR	United Nations Office for Disaster Reduction
WB	World Bank
WDQMS	WIGOS Data Quality Monitoring System
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting model

APPENDIX 2 – BIBLIOGRAPHY

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APPENDIX 3 – CLIMPACT 2.0 PLOTS FOR PRECIPITATION IN TIMOR-LESTE

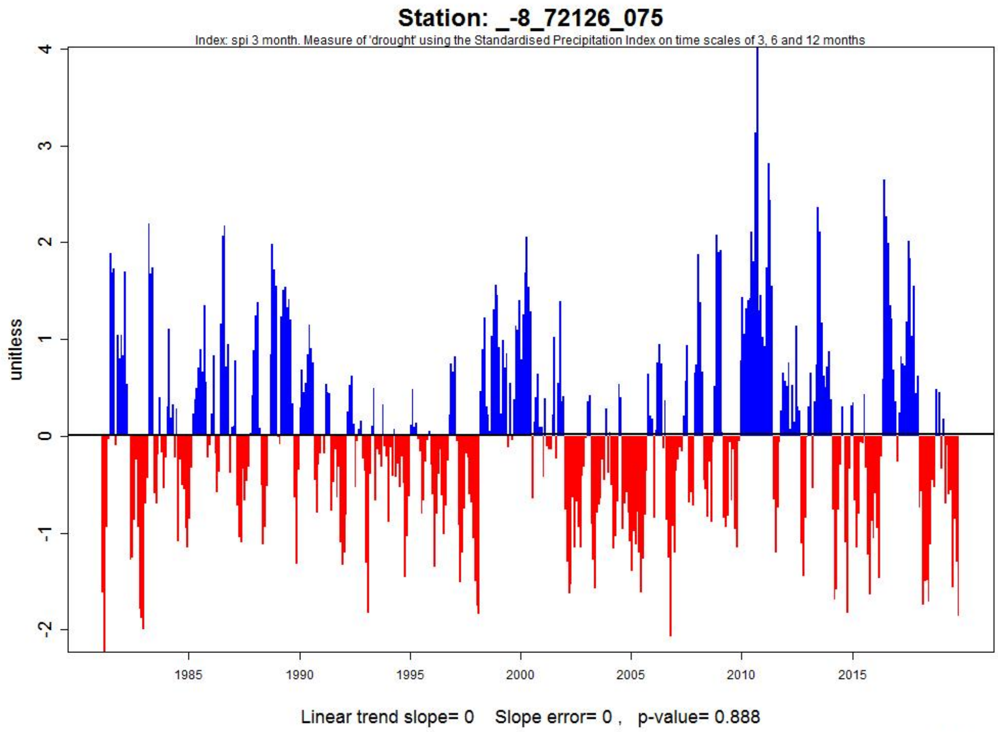

Figure A3.1: 3-month Standardised Precipitation Index. Measure of "drought". Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

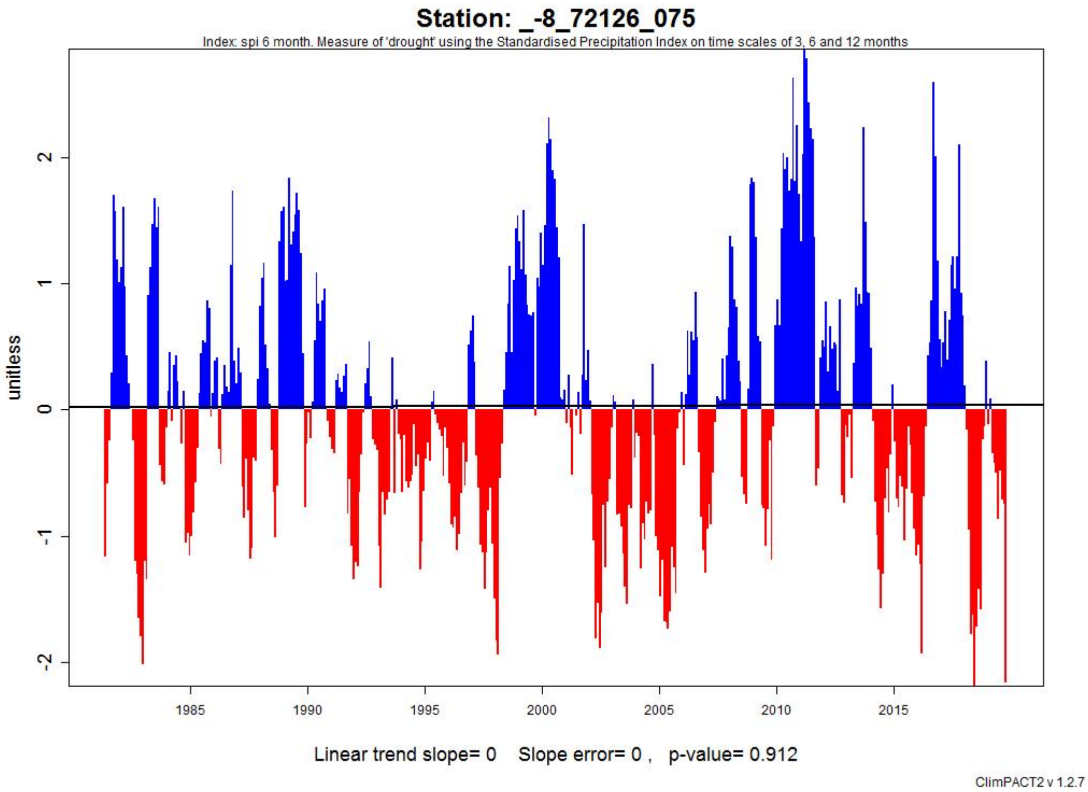

Figure A3.2: 6-month Standardised Precipitation Index. Measure of “drought”. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

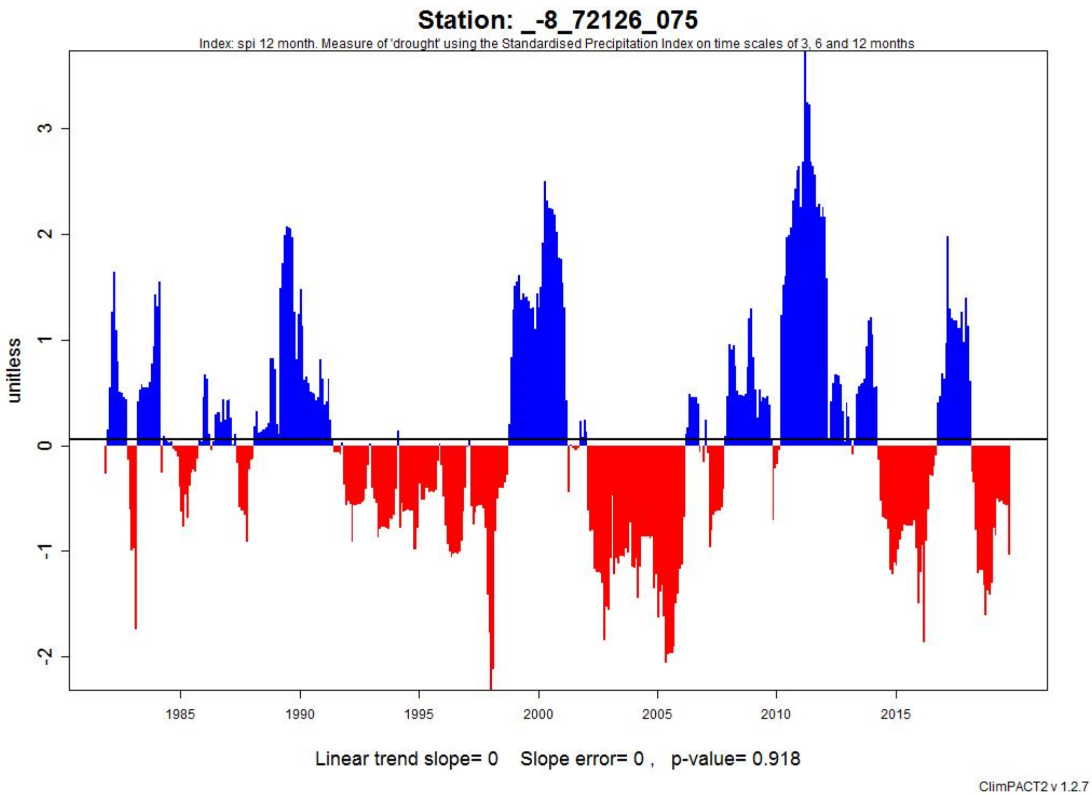

Figure A3.3: 12-month Standardised Precipitation Index. Measure of “drought”. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

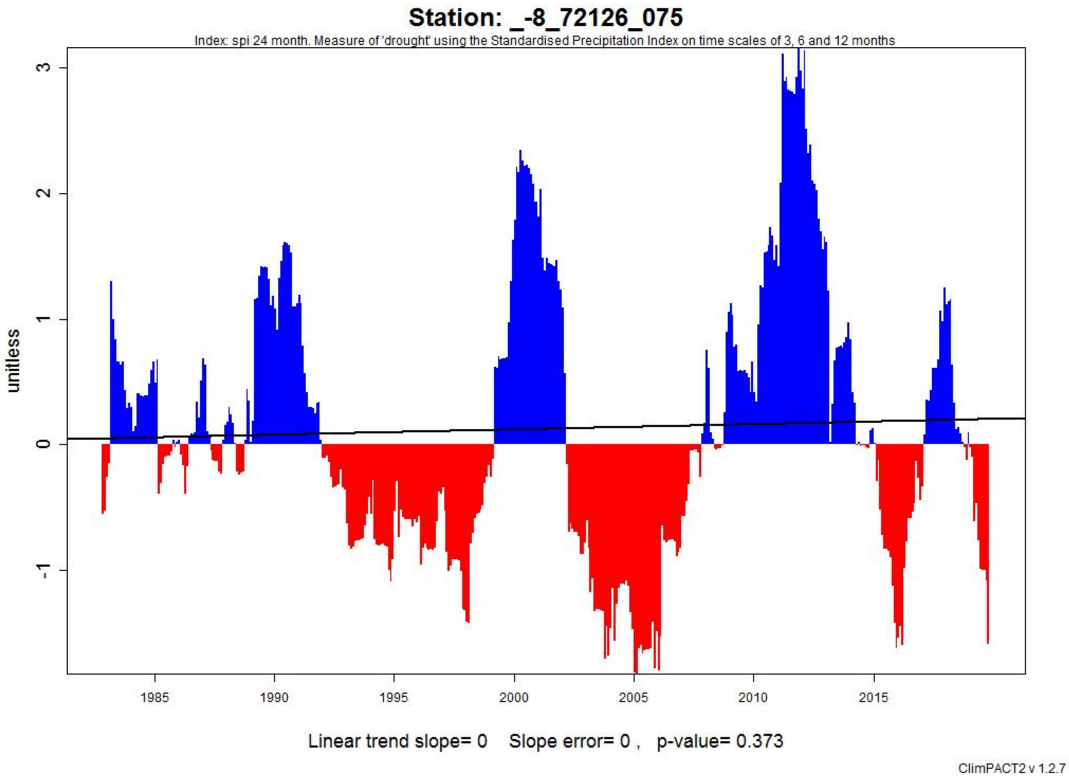

Figure A3.4: 24-month Standardised Precipitation Index. Measure of “drought”. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

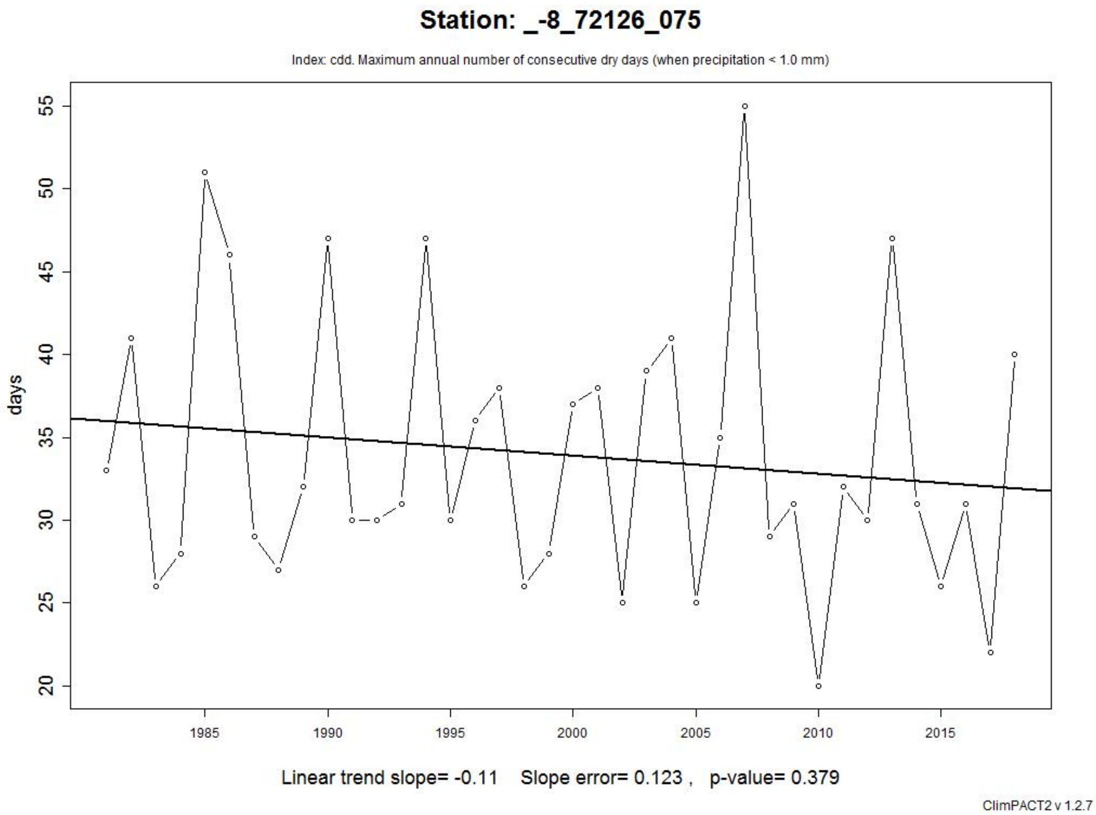

Figure A3.5: Consecutive Dry Days. Maximum annual number of consecutive dry days (when precipitation < 1.0 mm). Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

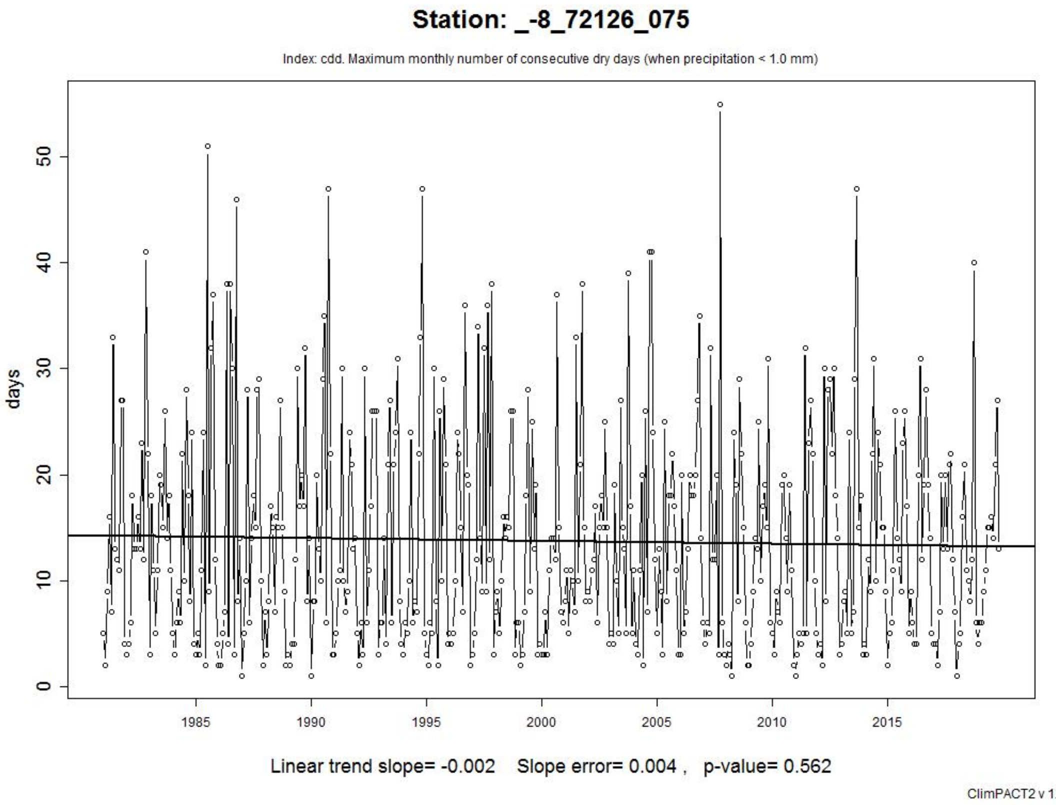

Figure A3.6: Consecutive Dry Days. Maximum monthly number of consecutive dry days (when precipitation < 1.0 mm). Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

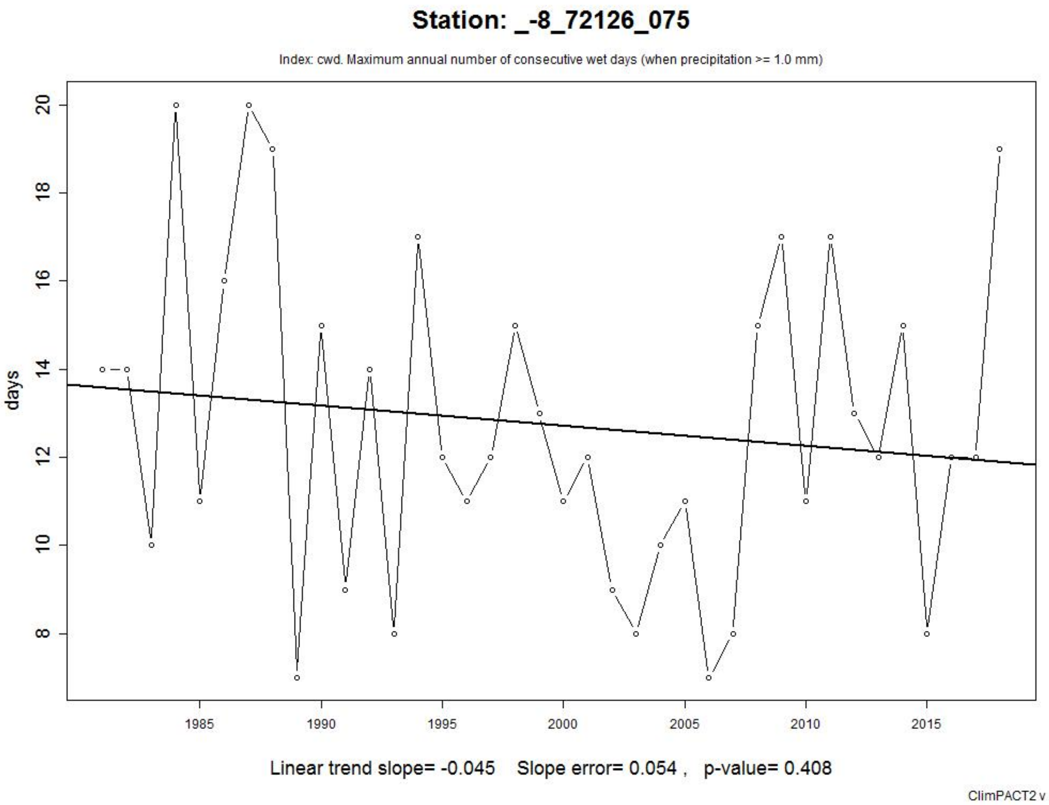

Figure A3.7: Consecutive Wet Days. Maximum annual number of consecutive wet days (when precipitation >= 1.0 mm). Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

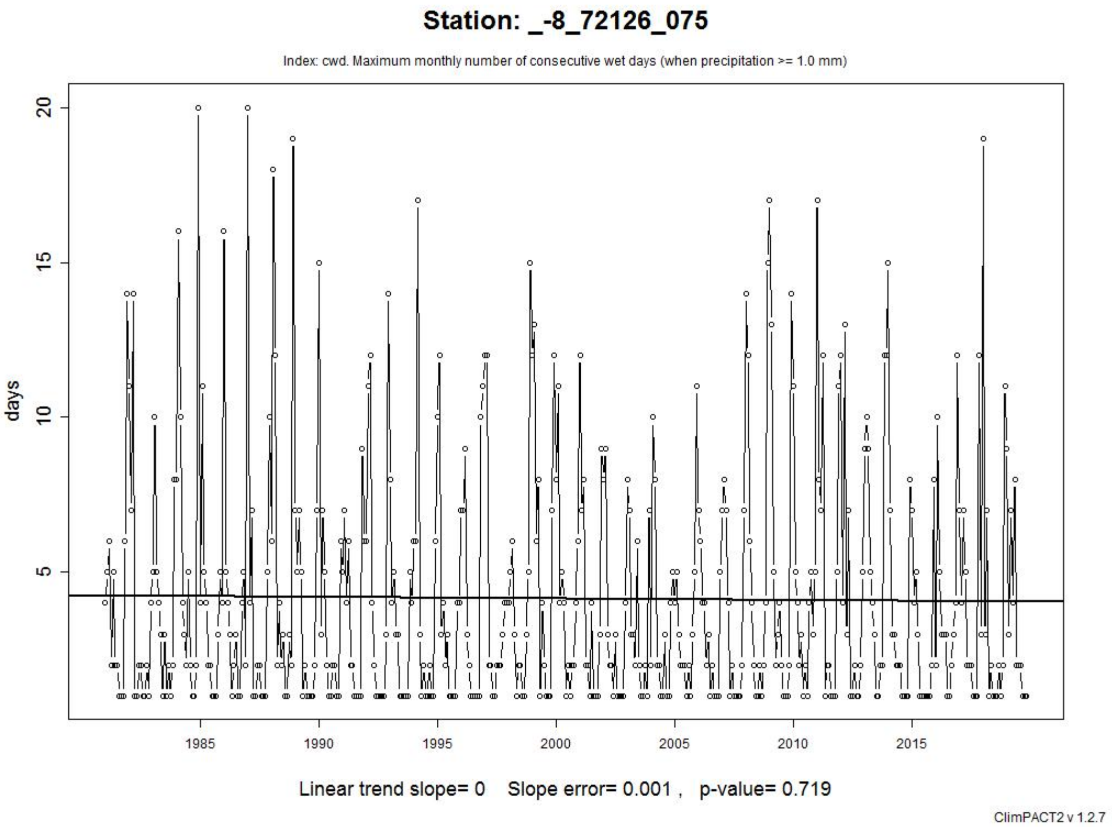

Figure A3.8: Consecutive Wet Days. Maximum monthly number of consecutive wet days (when precipitation >= 1.0 mm). Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

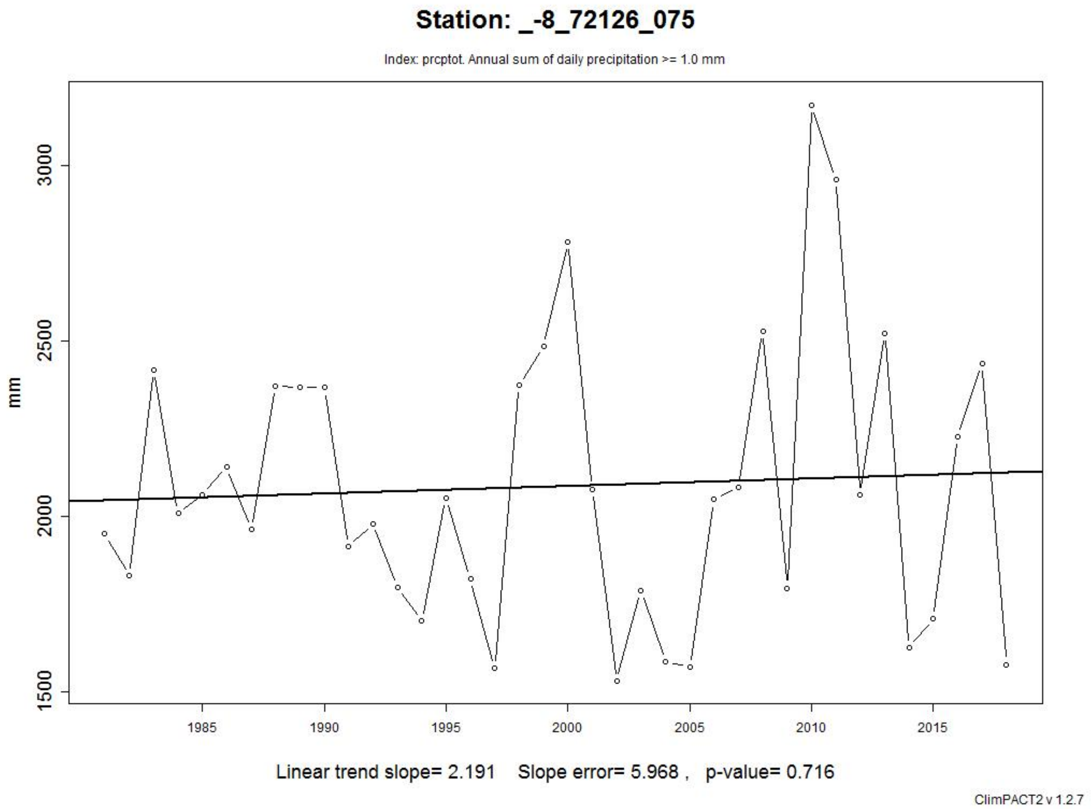

Figure A3.9: Total wet-day precipitation. Annual sum of daily precipitation >= 1.0 mm. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

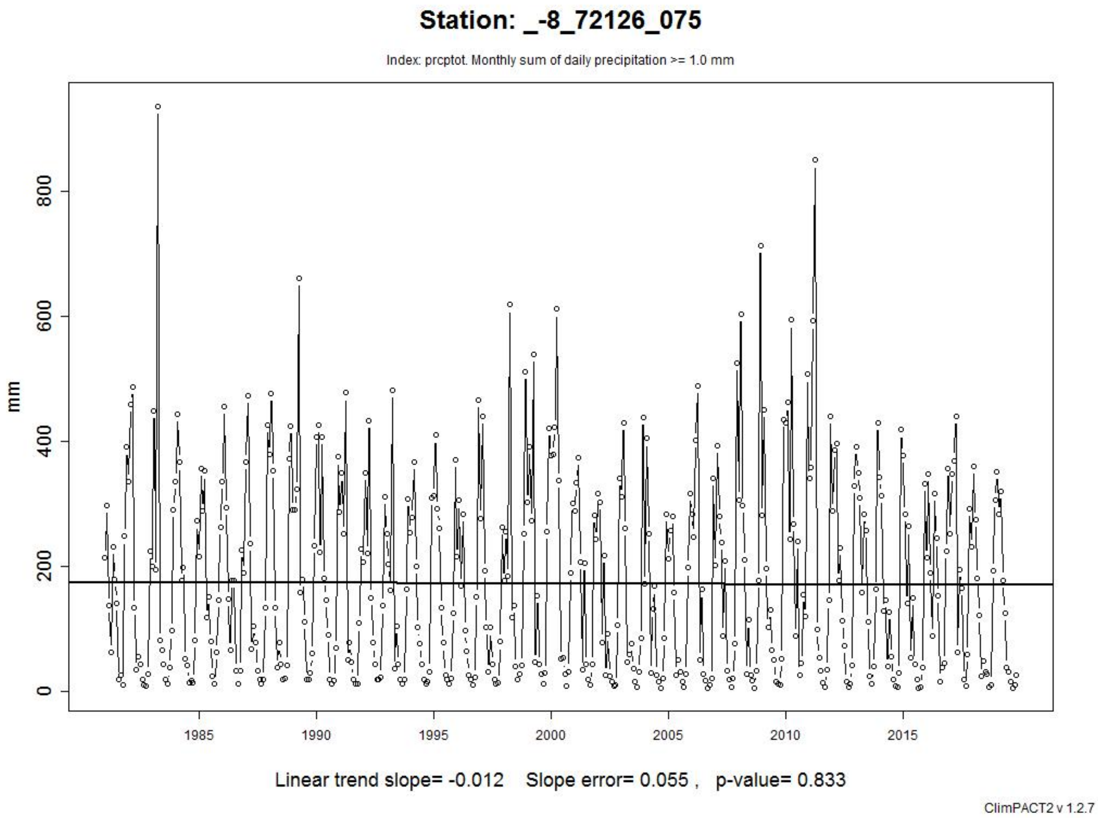

Figure A3.10: Total wet-day precipitation. Monthly sum of daily precipitation >= 1.0 mm. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

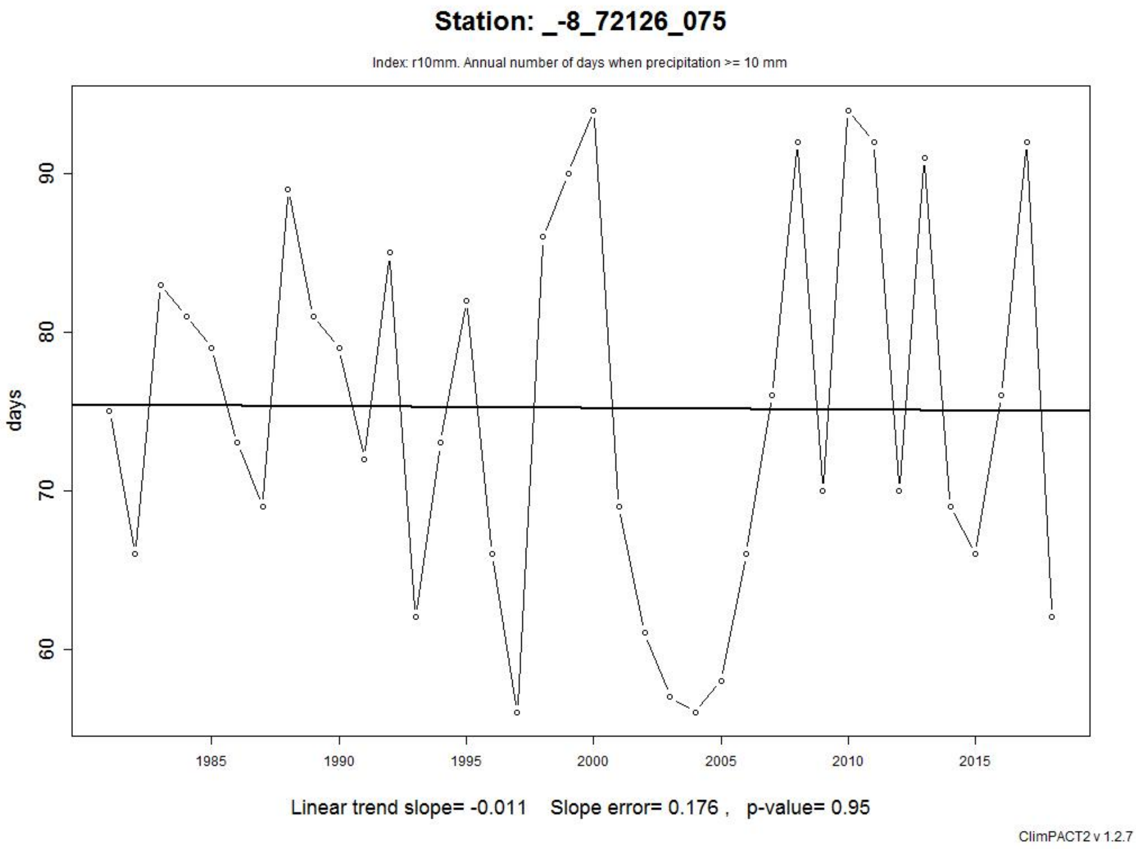

Figure A3.11: Number of heavy rain days. Annual number of days when precipitation >= 10 mm. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

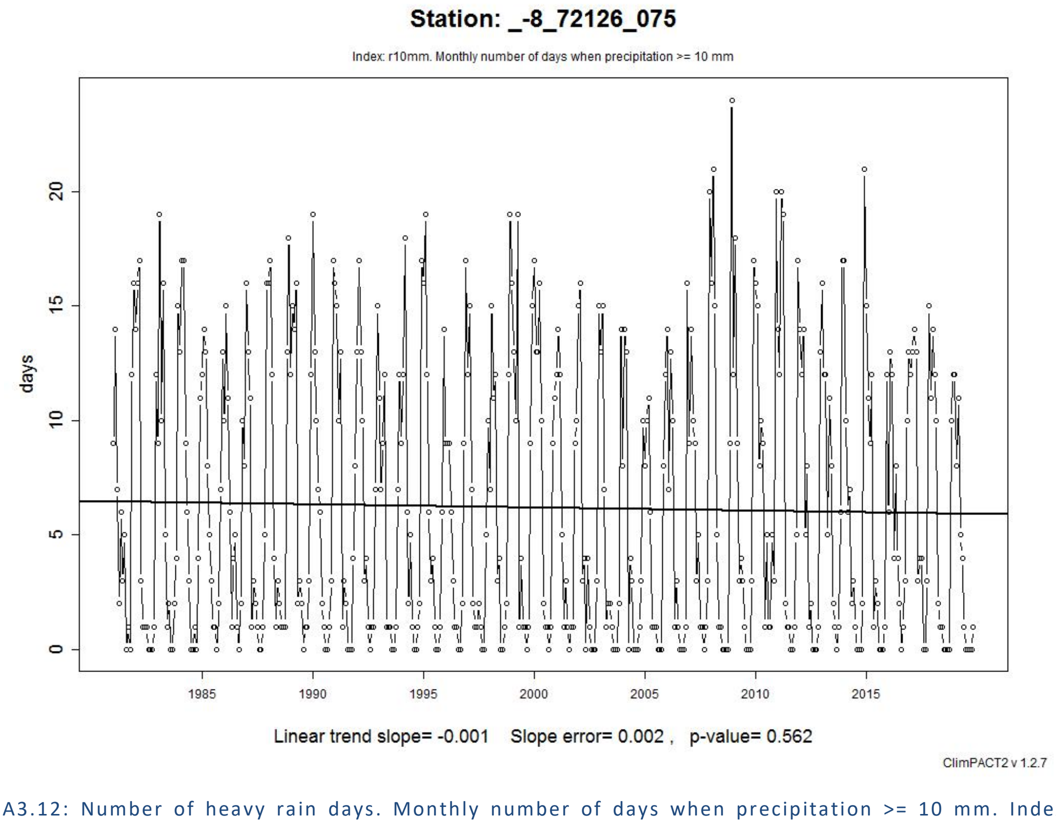

Figure A3.12: Number of heavy rain days. Monthly number of days when precipitation >= 10 mm. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

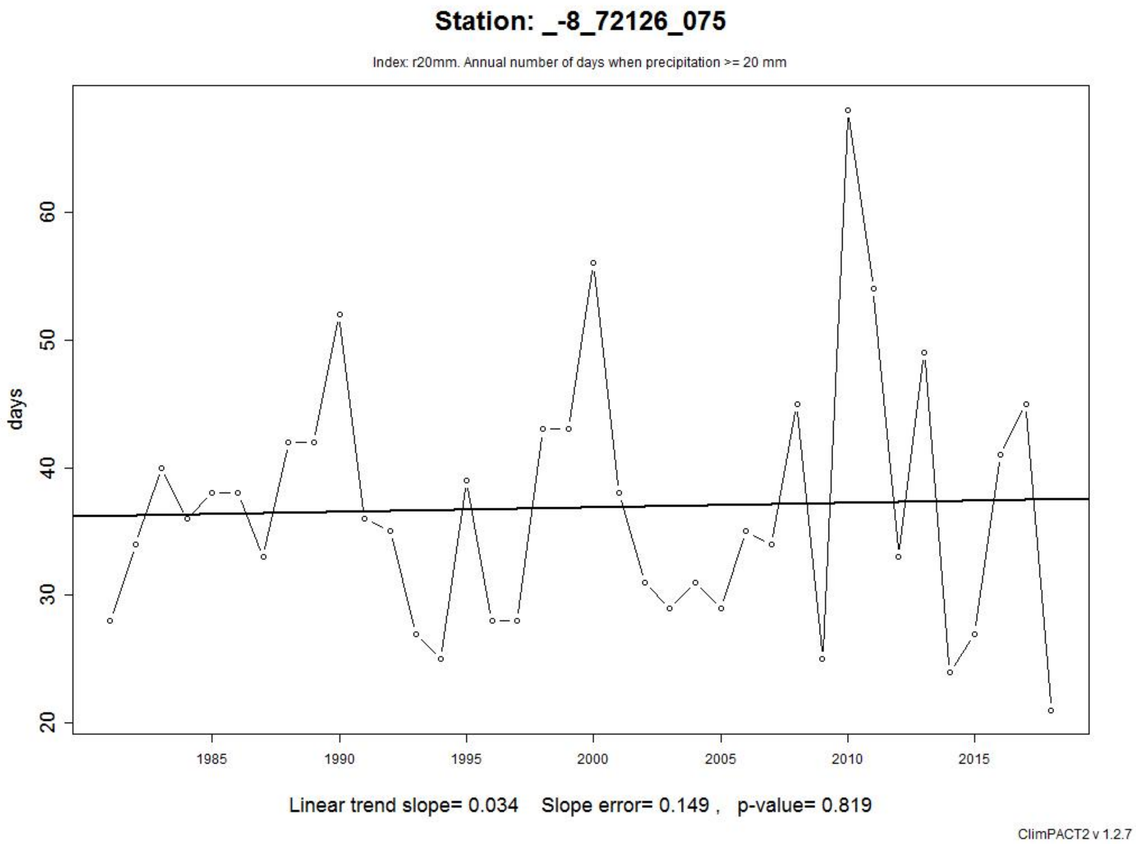

Figure A3.13: Number of very heavy rain days. Annual number of days when precipitation >= 20 mm. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

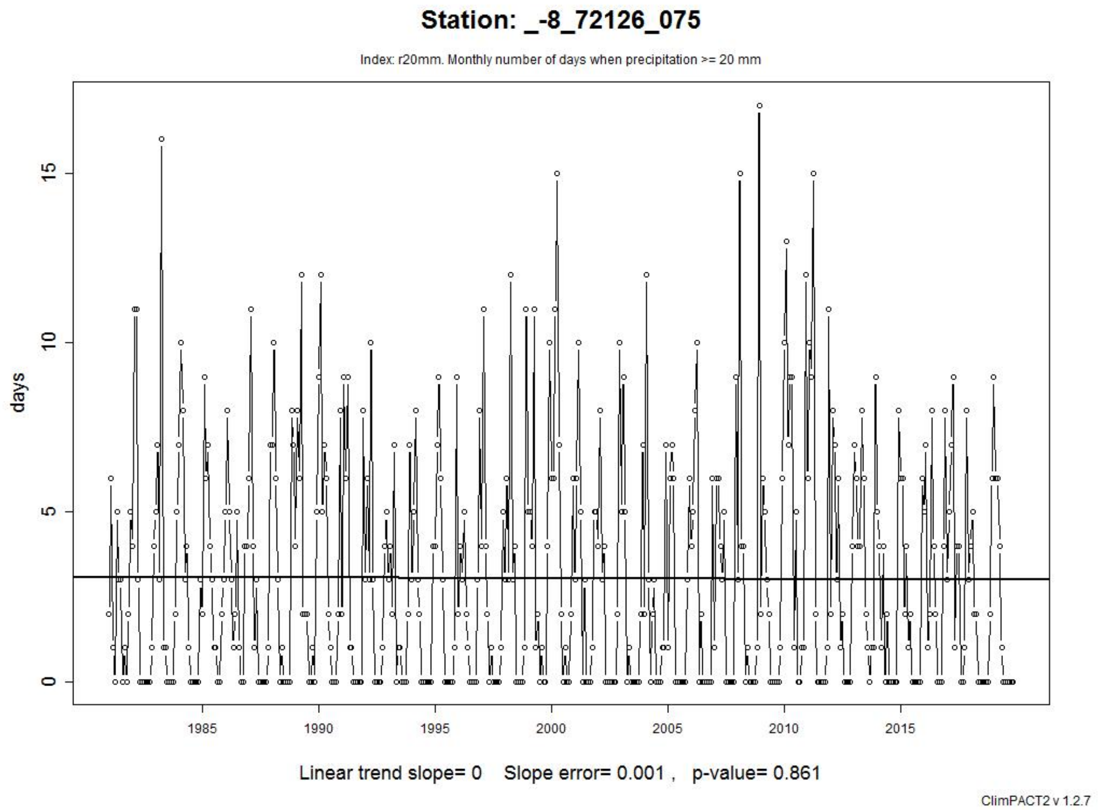

Figure A3.13: Number of very heavy rain days. Monthly number of days when precipitation >= 20 mm. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

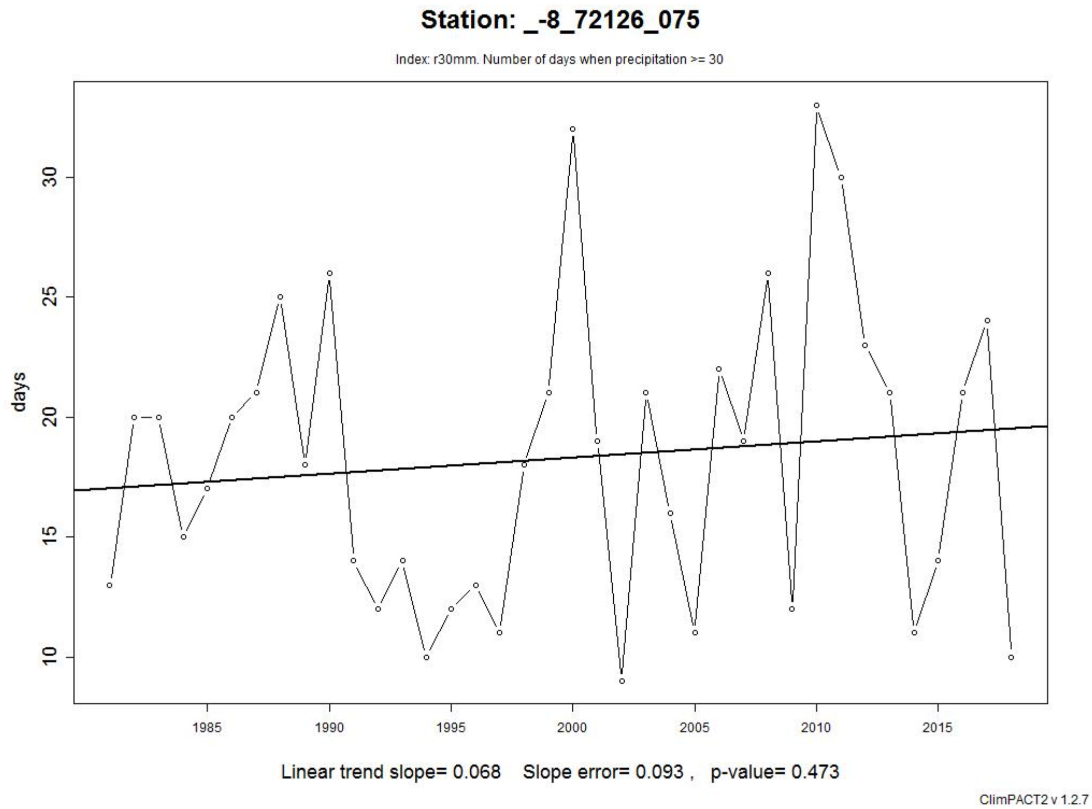

Figure A3.14: Number of customised rain days. Annual number of days when precipitation >= nn. In this case nn is defined as default as 30. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

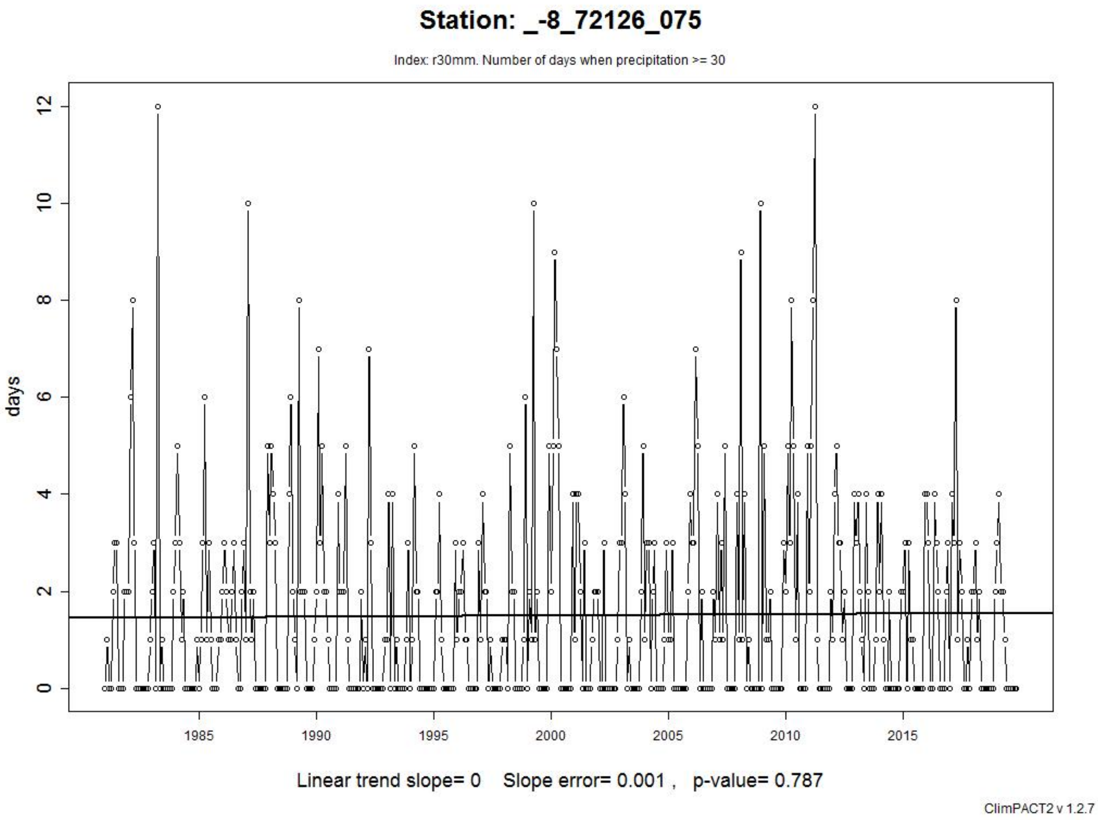

Figure A3.15: Number of customised rain days. Monthly number of days when precipitation >= nn. In this case nn is defined as default as 30. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

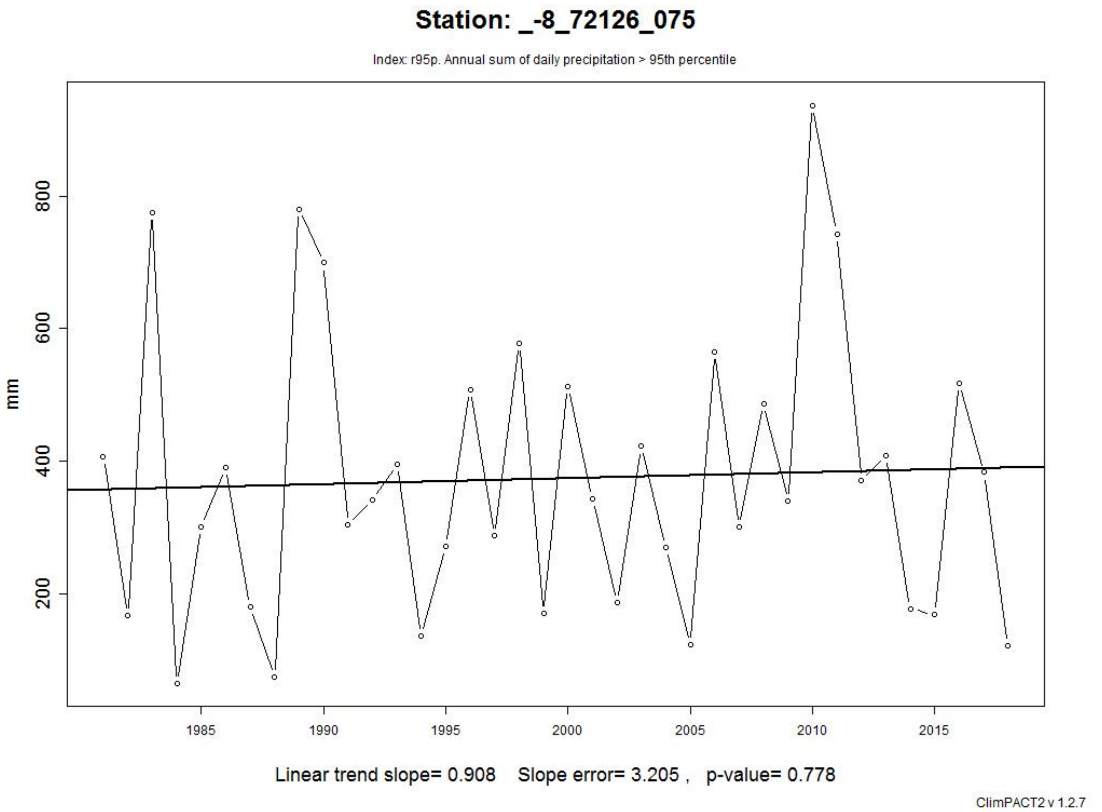

Figure A3.16: Total annual PR from heavy rain days. Annual sum of daily precipitation > 95th percentile. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

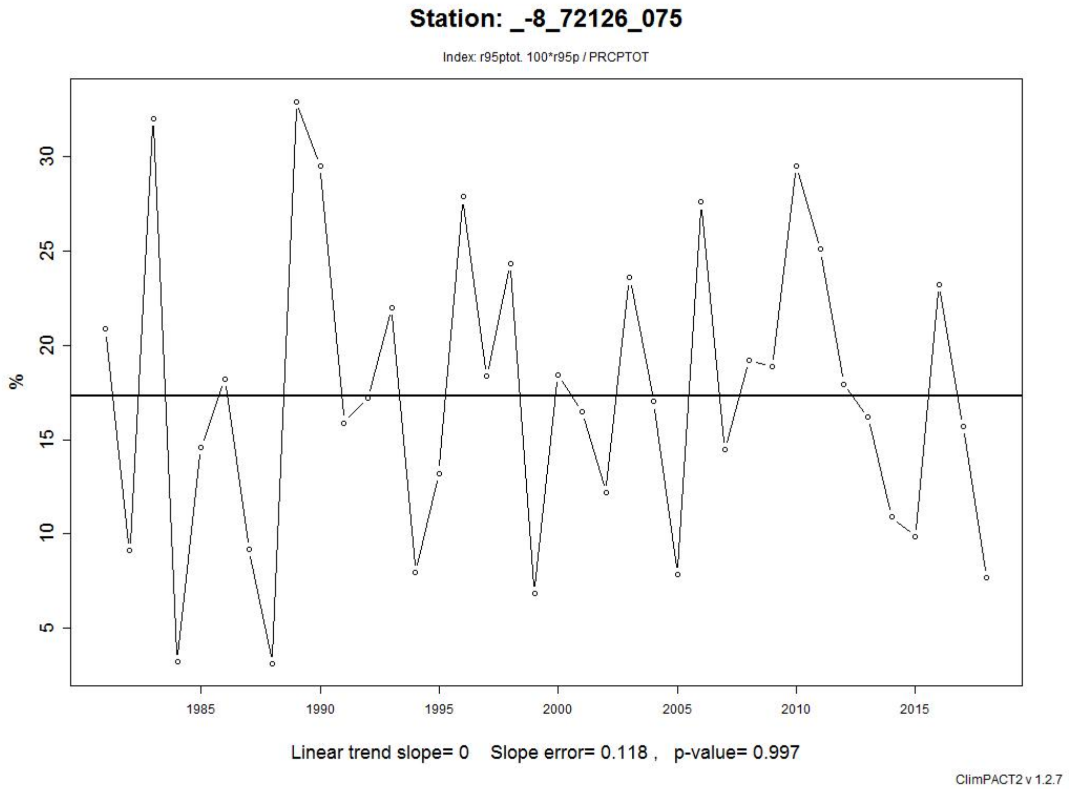

Figure A3.17: Contribution from very wet days. (100*r95p)/PRCPTOT. Fraction of total wet-day rainfall that comes from very wet days. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

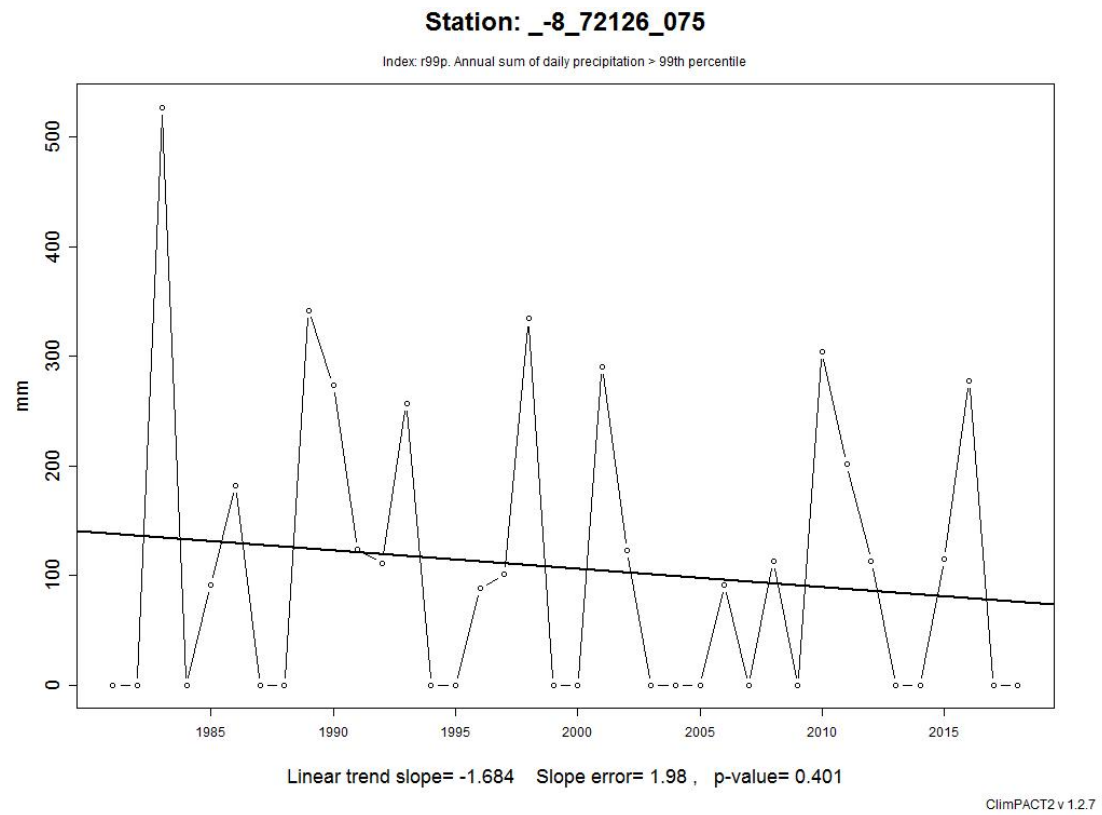

Figure A3.18: Total annual precipitation from very heavy rain days. Annual sum of daily PR > 99th percentile. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

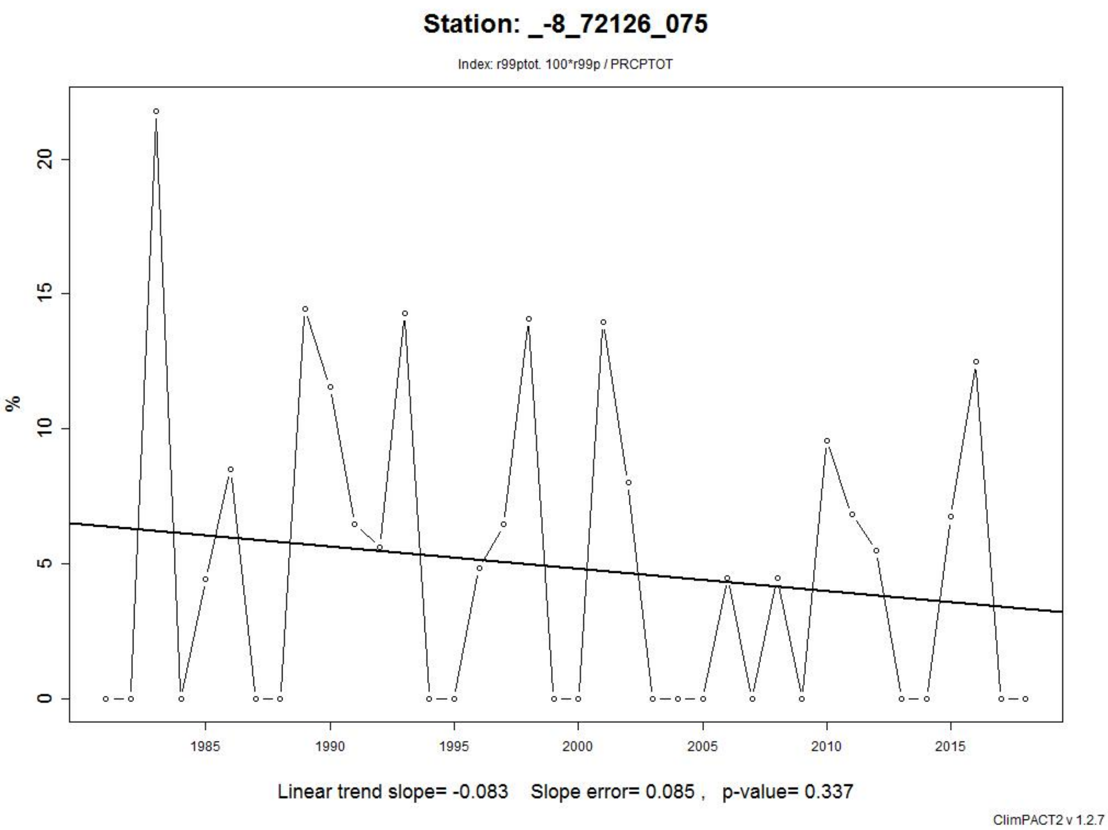

Figure A3.19: Contribution from extremely wet days. (100*r99p)/PRCPTOT. Fraction of total wet-day rainfall that comes from extremely wet days. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

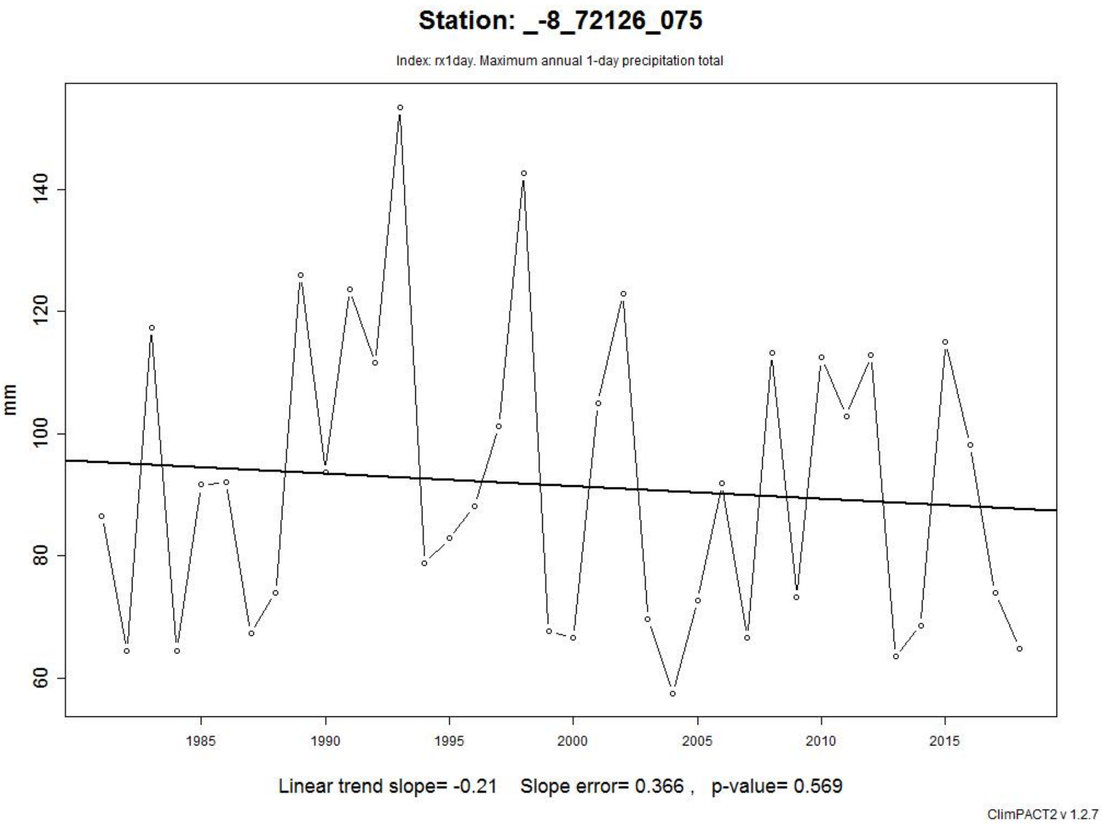

Figure A3.20: Max 1-day precipitation. Maximum annual 1-day precipitation total. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

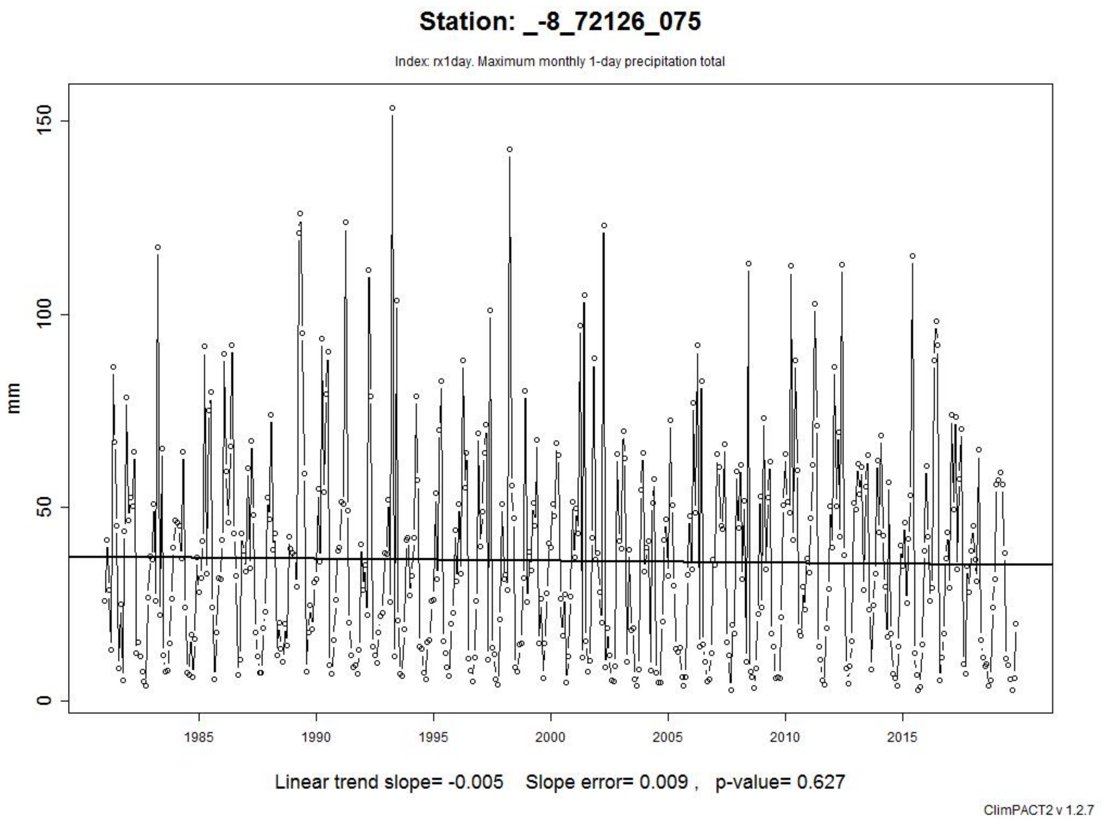

Figure A3.21: Max 1-day precipitation. Maximum monthly 1-day precipitation total. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

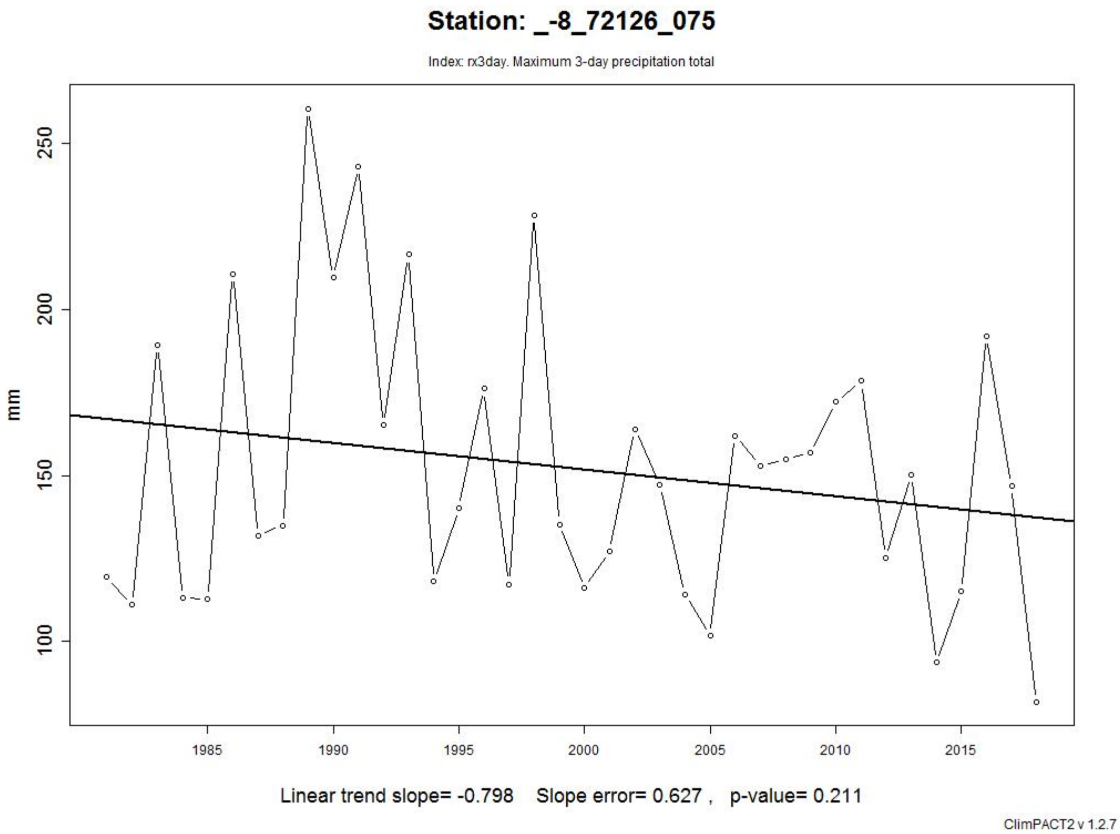

Figure A3.22: Max 3-day precipitation. Maximum annual 3-day precipitation total. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

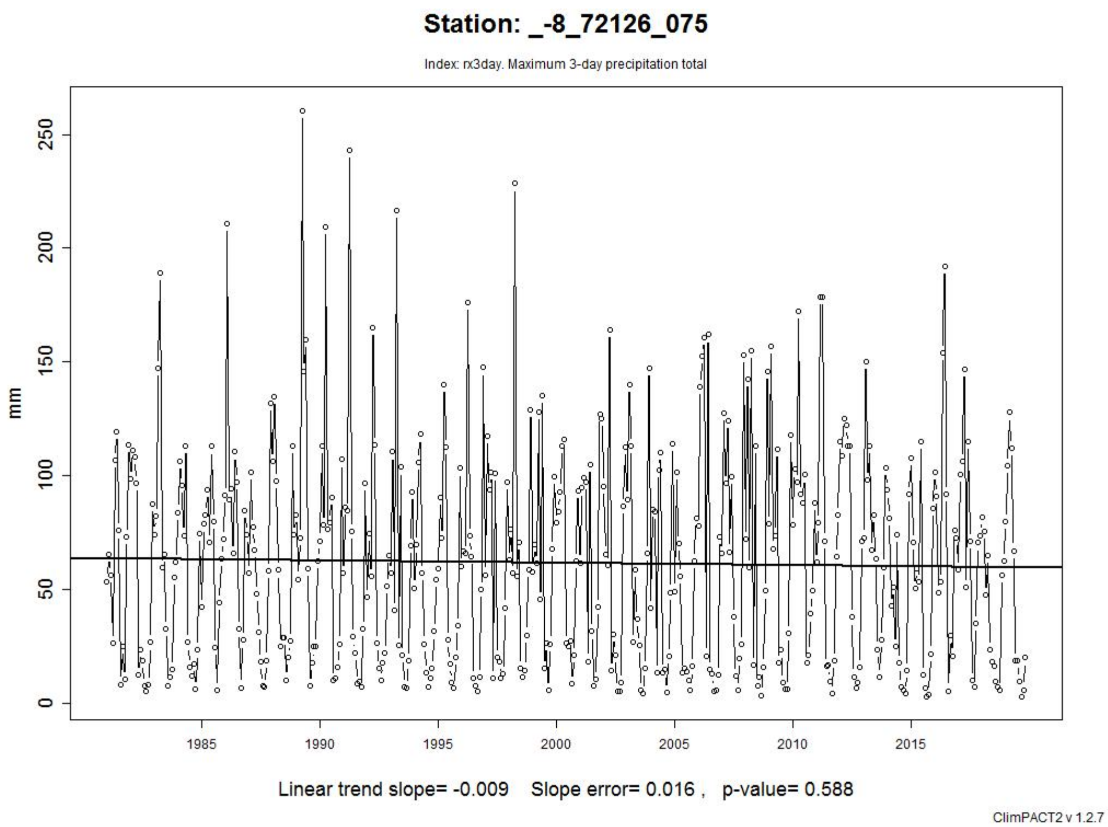

Figure A3.23: Max 3-day precipitation. Maximum monthly 3-day precipitation total. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

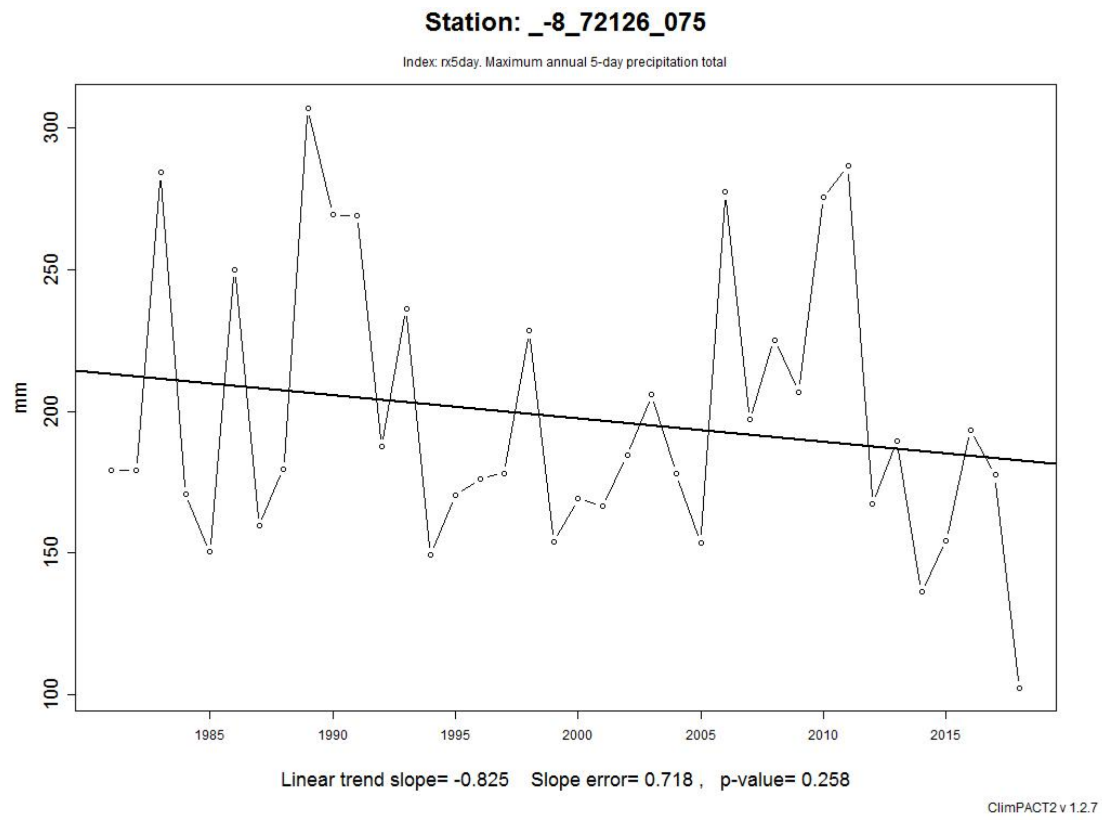

Figure A3.24: Max 5-day precipitation. Maximum annual 5-day precipitation total. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

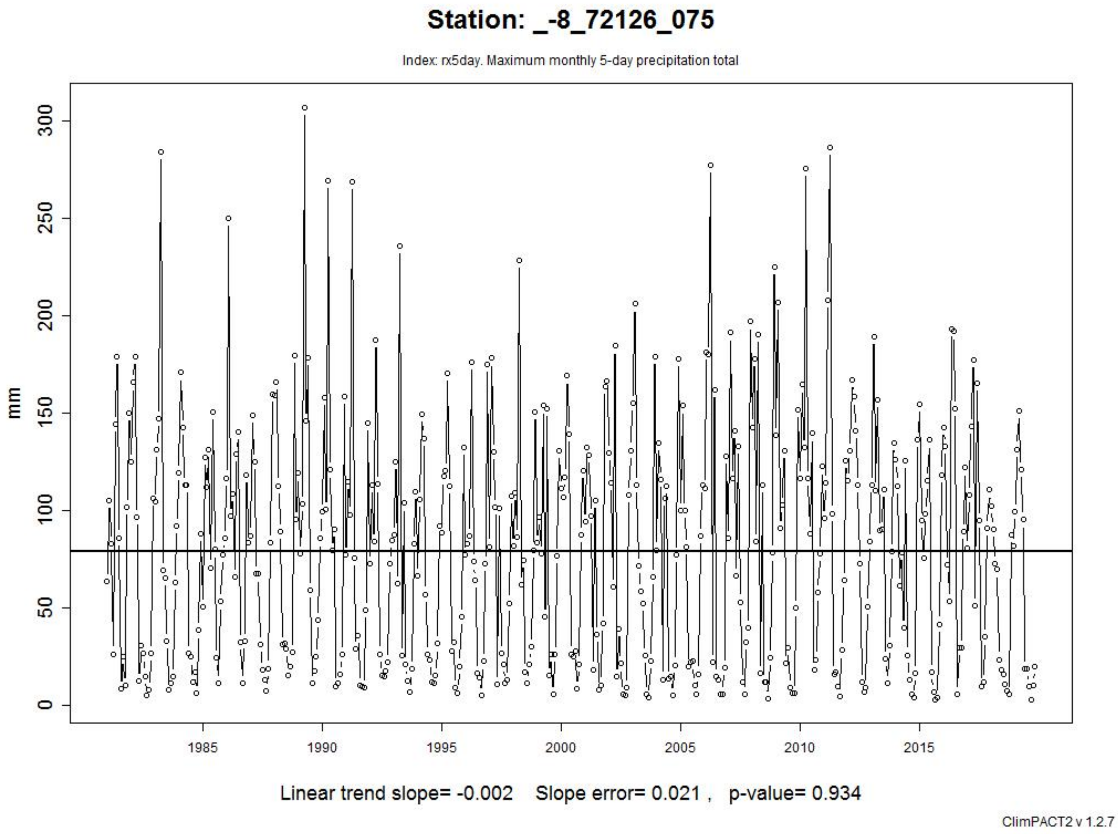

Figure A3.24: Max 5-day precipitation. Maximum monthly 5-day precipitation total. Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

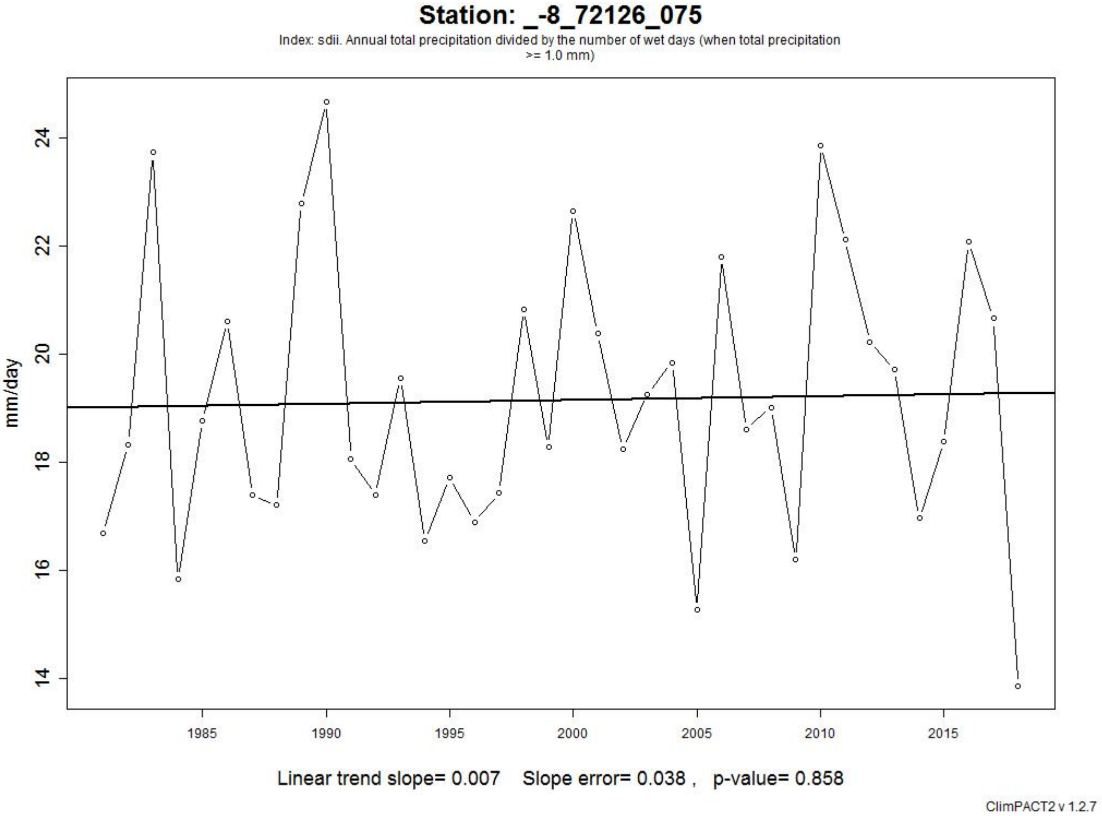

Figure A3.25: Daily precipitation intensity. Annual total precipitation divided by the number of wet days (when total precipitation >= 1.0 mm). Index for a gridpoint located at the center of Timor-Leste (longitude 126.075, latitude -8.72) [CHIRPS data].

APPENDIX 4 – CLIMPACT 2.0 PLOTS FOR TEMPERATURE IN TIMOR-LESTE

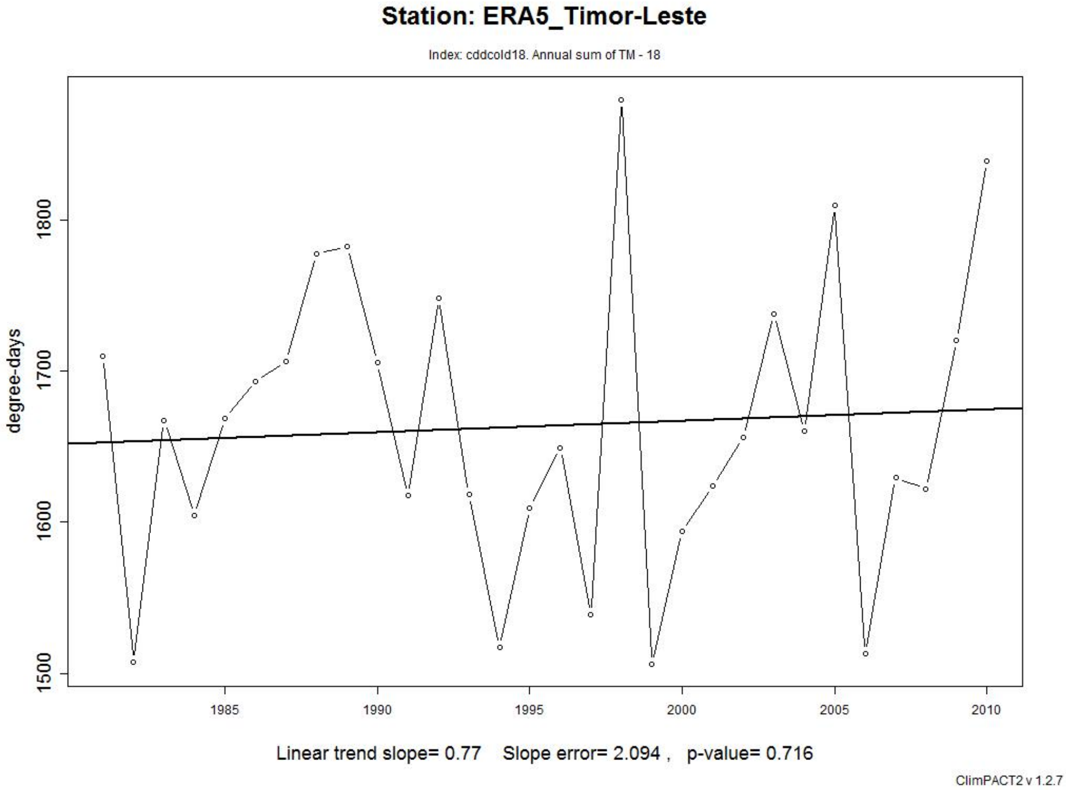

Figure A4.1: Cooling Degree Days. Annual sum of mean temperature - n (where n is a user-defined location-specific base temperature and mean temperature > n). In this case n is defined as default as 18. Index for a gridpoint located at the center of Timor-Leste (longitude 126, latitude -8.75) [ERA5 data].

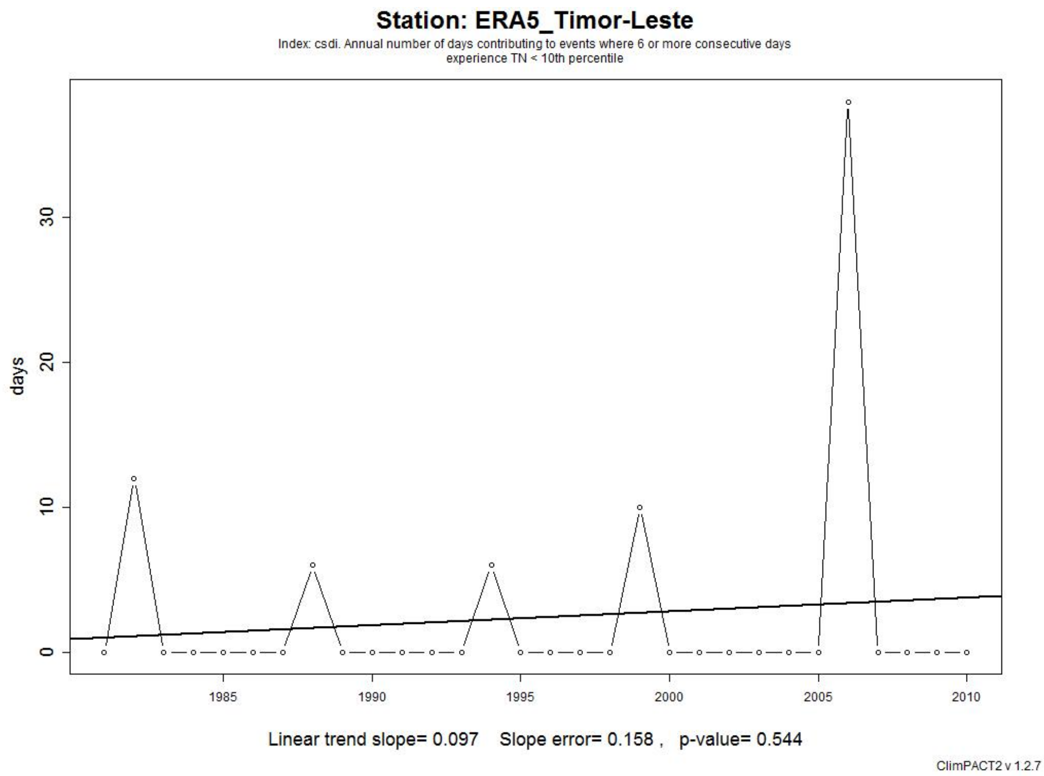

Figure A4.2: Cold Spell Duration Indicator. Annual number of days contributing to events where 6 or more consecutive days experience minimum temperature < 10th percentile. [ERA5 data].

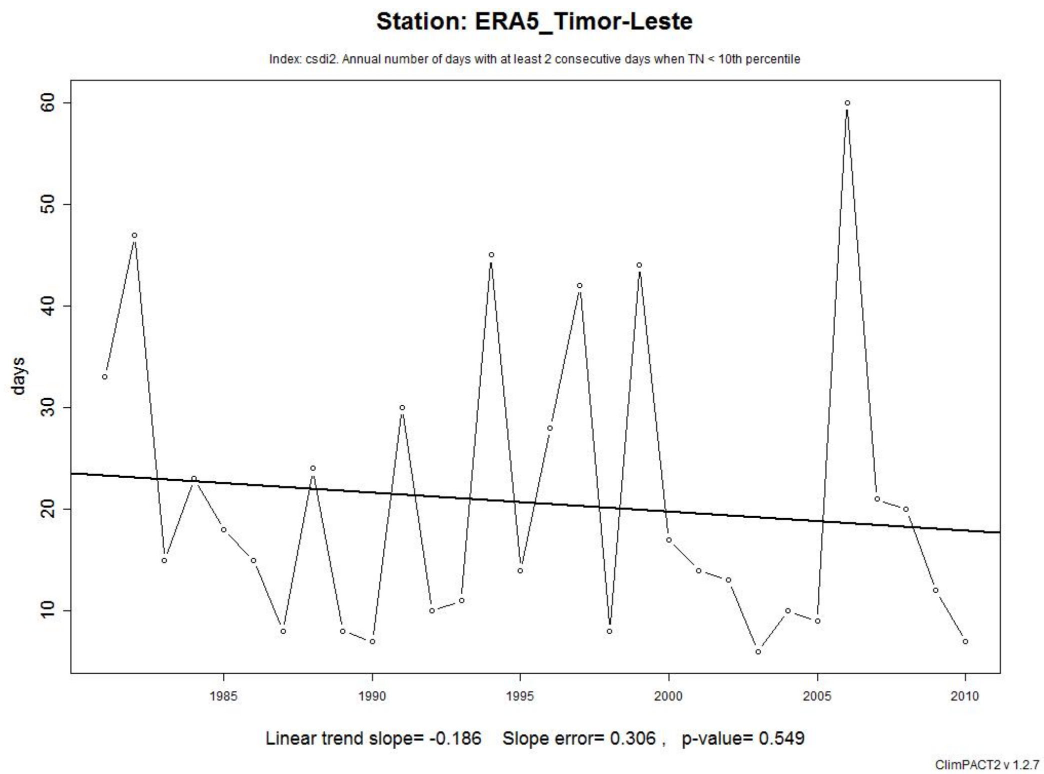

Figure A4.3: User-defined Cold Spell Duration Indicator. Annual number of days contributing to events where d or more consecutive days experience minimum temperature < 10th percentile. In this case, d is defined as default 2. [ERA5 data].

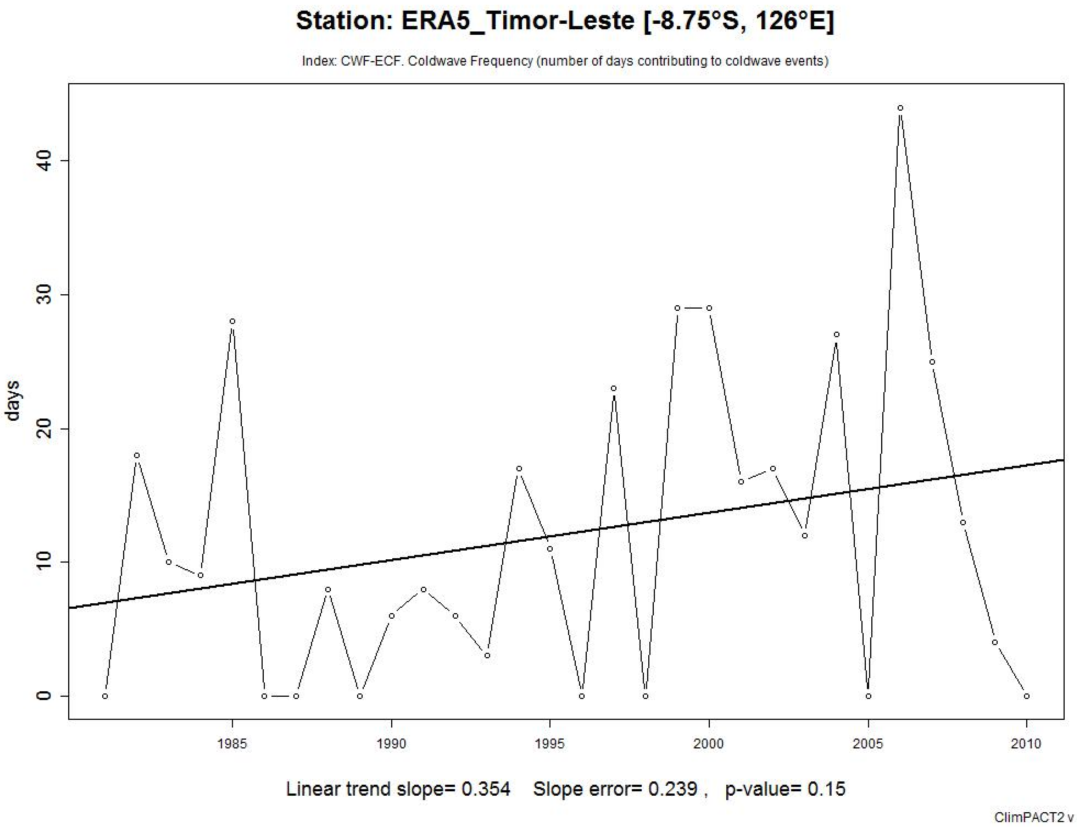

Figure A4.4: Coldwave Frequency as defined by the Excess Cold Factor. The number of days contributing to coldwave events. [ERA5 data].

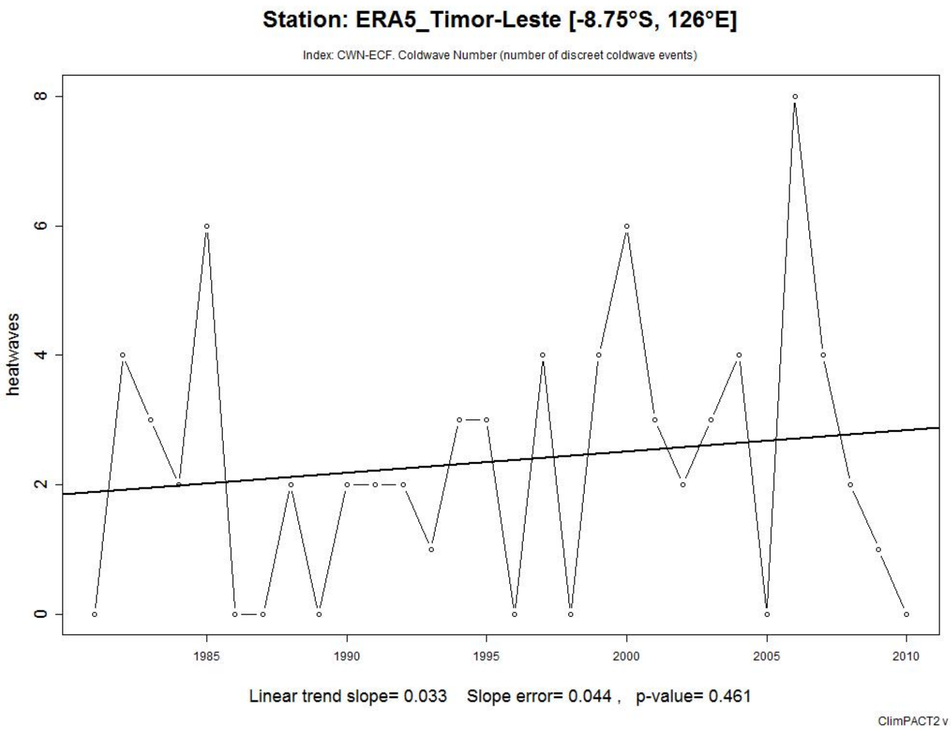

Figure A4.5: Coldwave Number as defined by the Excess Cold Factor. The number of individual coldwaves that occur each year. [ERA5 data].

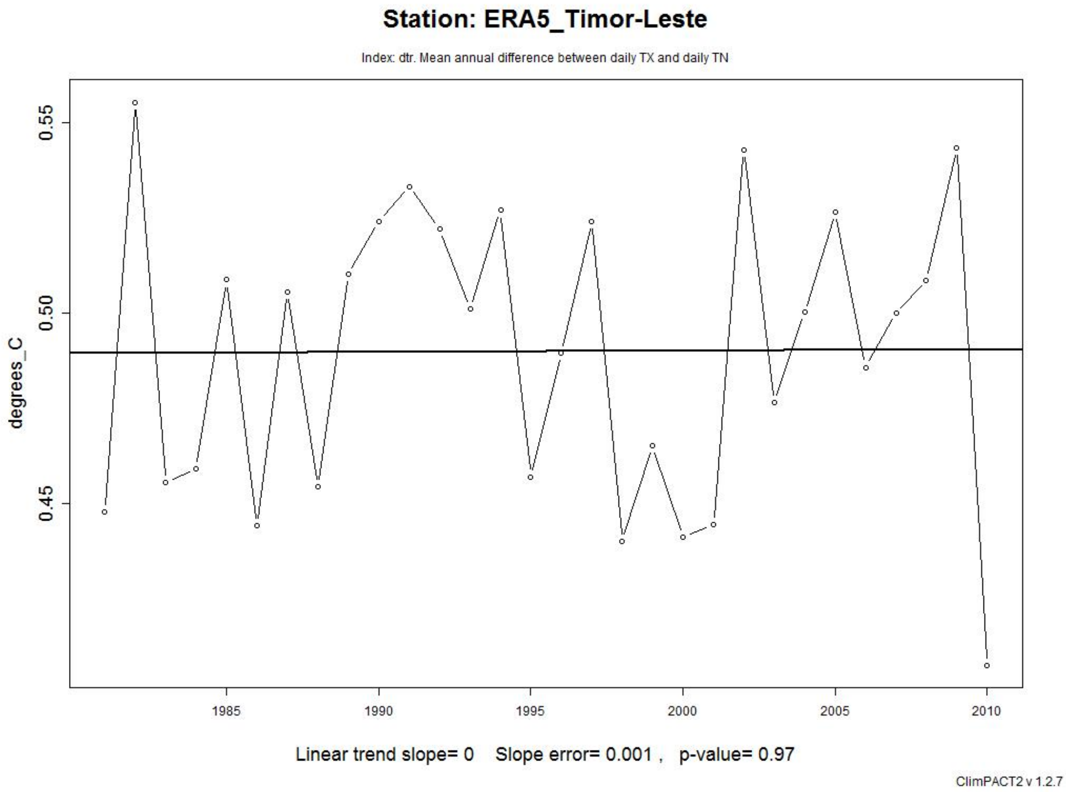

Figure A4.6: Daily Temperature Range. Mean annual difference between daily maximum temperature and daily minimum temperature. [ERA5 data].

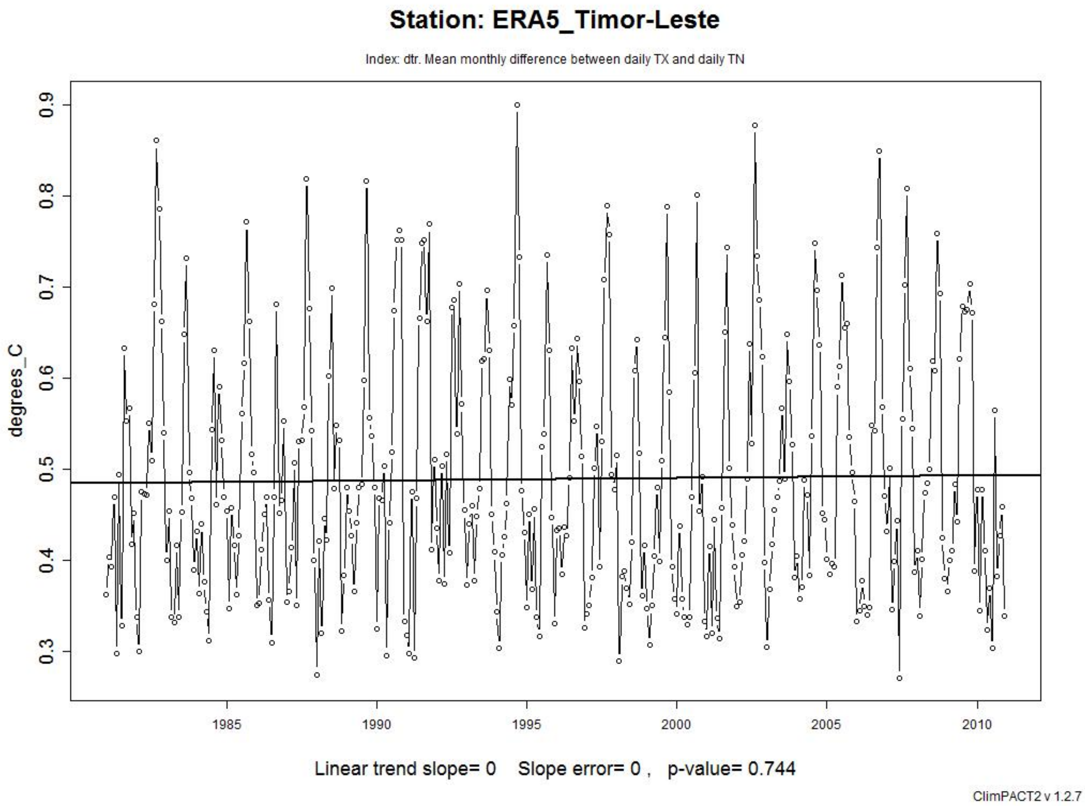

Figure A4.7: Daily Temperature Range. Mean monthly difference between daily maximum temperature and daily minimum temperature. [ERA5 data].

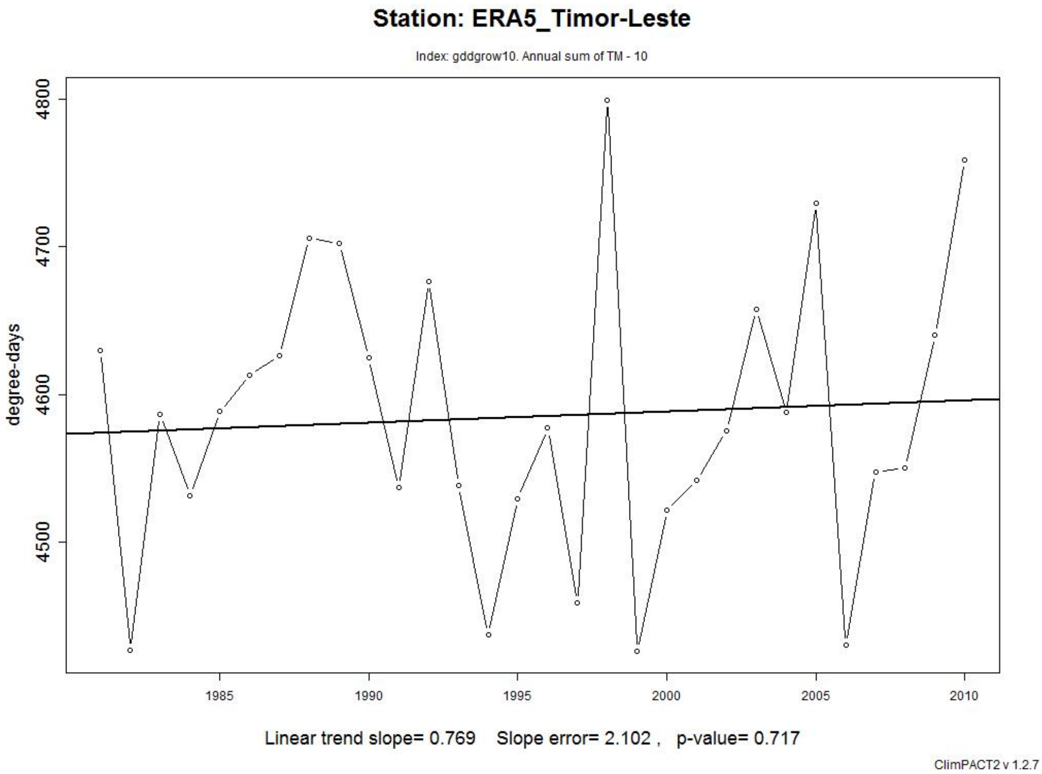

Figure A4.8: Growing Degree Days. Annual sum of mean temperature - n (where n is a user-defined location-specific base temperature and mean temperature > n). In this case n is defined as default as 10. [ERA5 data].

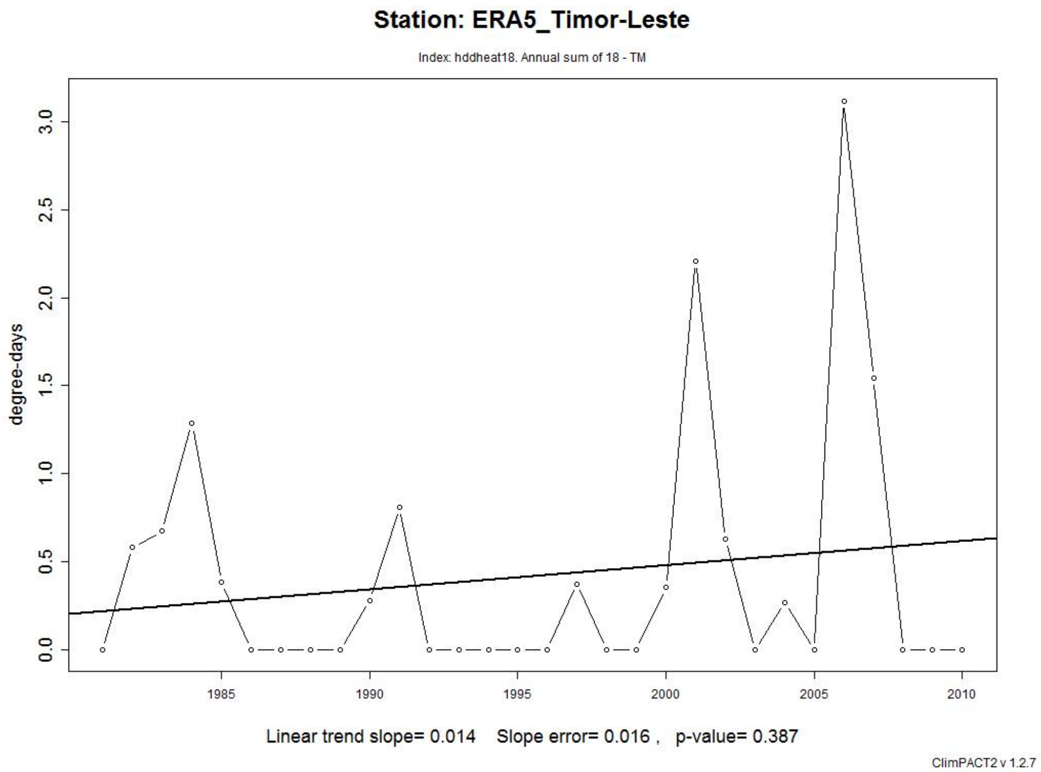

Figure A4.9: Heating Degree Days. Annual sum of n - mean temperature (where n is a user-defined location-specific base temperature and mean temperature < n). In this case n is defined as default as 18. [ERA5 data].

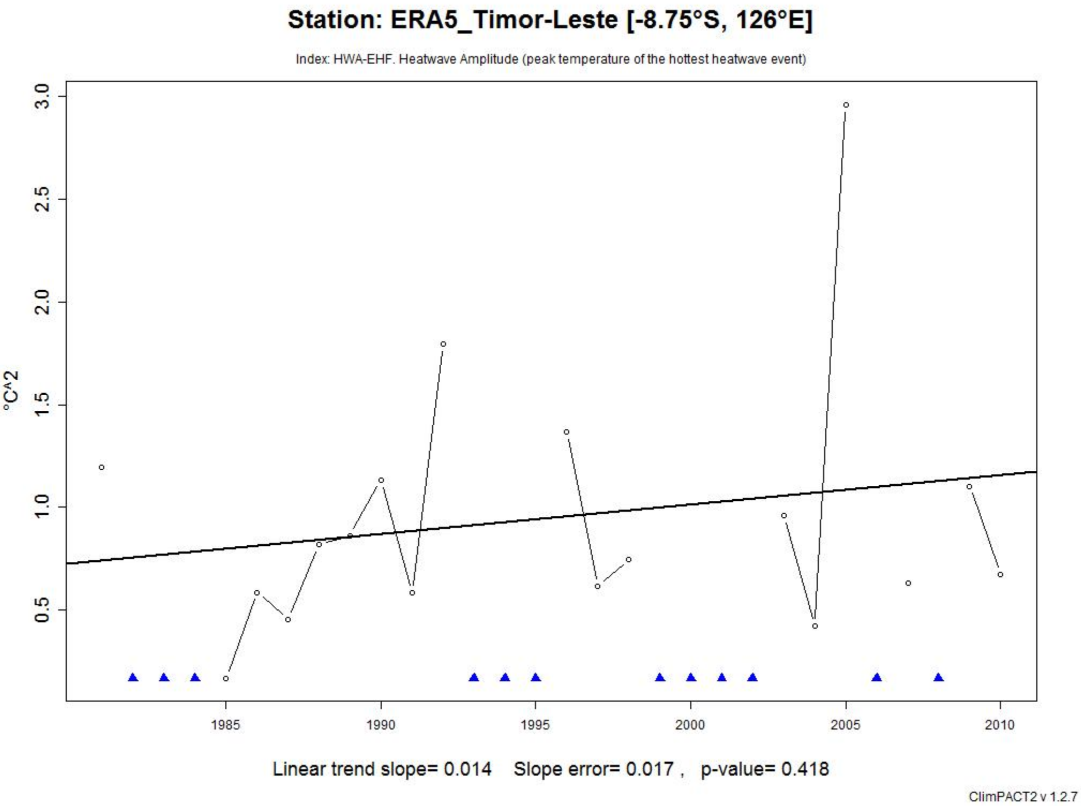

Figure A4.10: Heatwave Amplitude as defined by either the Excess Heat Factor, 90th percentile of maximum temperature or the 90th percentile of TN. The peak daily value in the hottest heatwave (defined as the heatwave with highest Heatwave Magnitude). [ERA5 data].

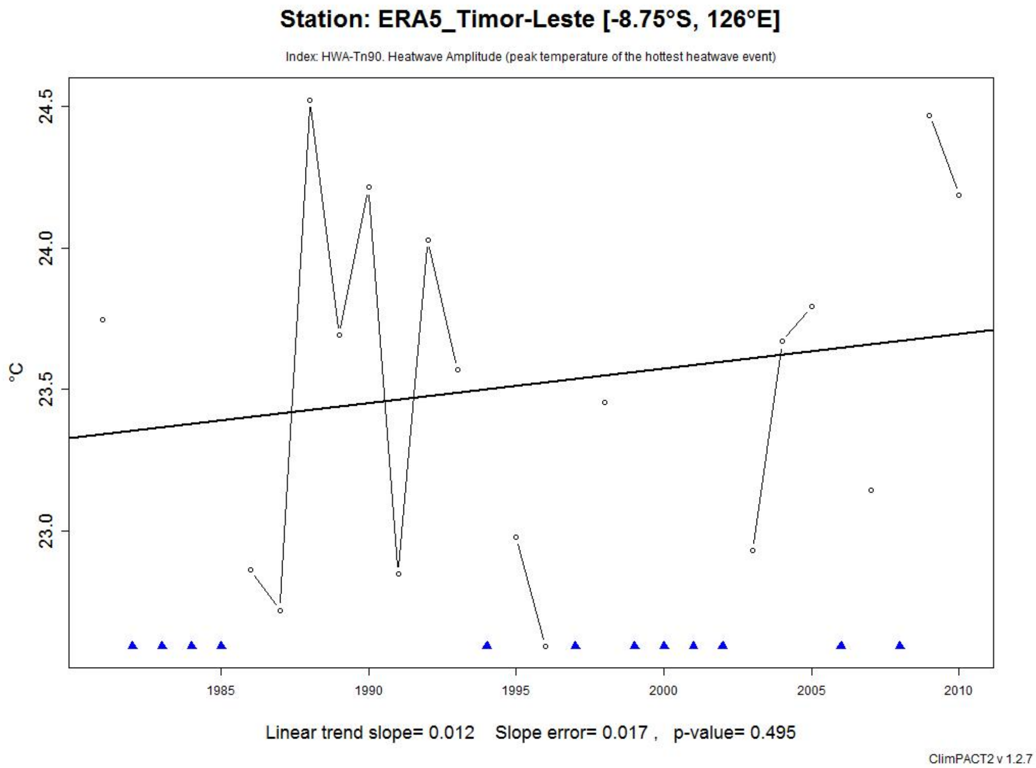

Figure A4.11: Heatwave Amplitude as defined by either the Excess Heat Factor, 90th percentile of minimum temperature. The peak daily value in the hottest heatwave [ERA5 data].

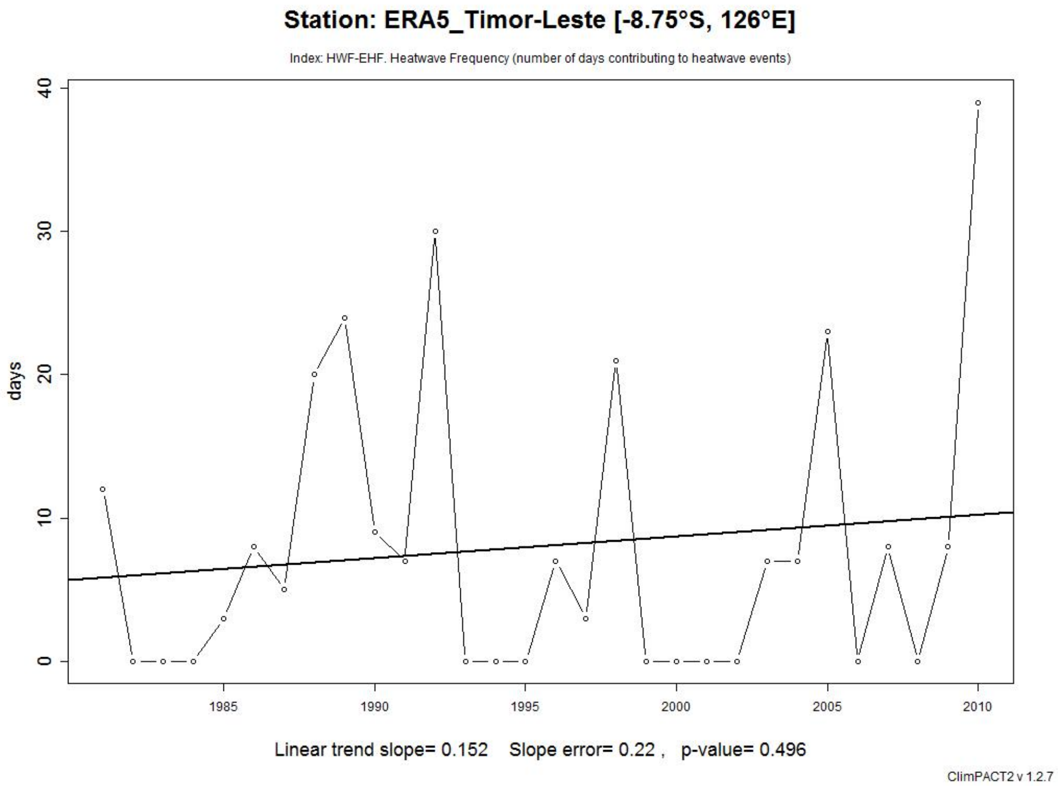

Figure A4.12: Heatwave Frequency as defined by either the Excess Heat Factor, 90th percentile of maximum temperature or the 90th percentile of minimum temperature. The number of days that contribute to heatwaves as identified by Heatwave Number. [ERA5 data].

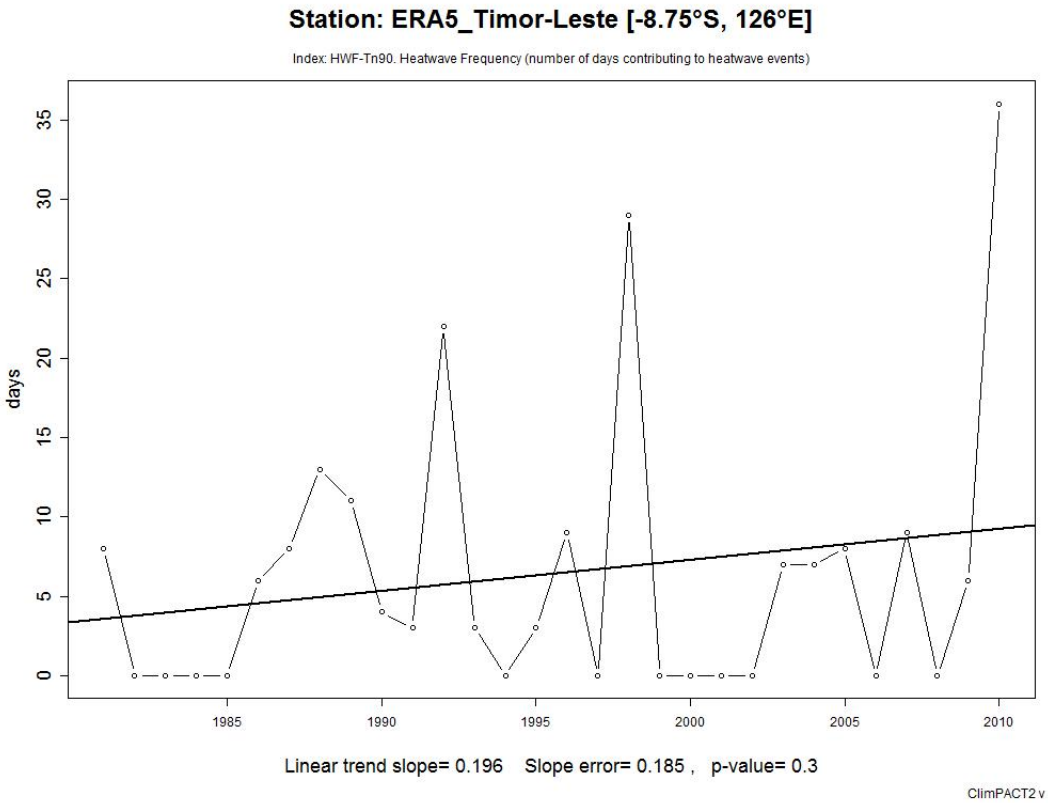

Figure A4.13: Heatwave Frequency as defined by either the Excess Heat Factor, 90th percentile of minimum temperature. The number of days that contribute to heatwaves as identified by Heatwave Number. [ERA5 data].

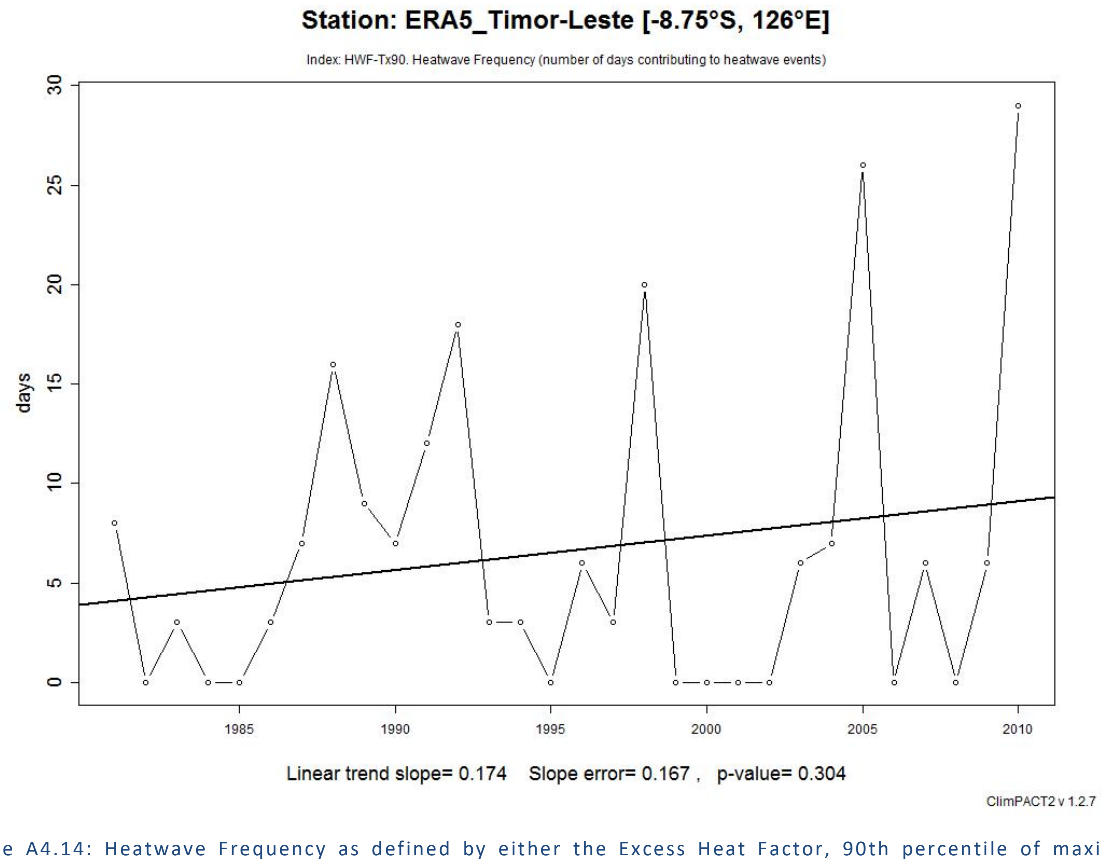

Figure A4.14: Heatwave Frequency as defined by either the Excess Heat Factor, 90th percentile of maximum temperature. The number of days that contribute to heatwaves as identified by Heatwave Number. [ERA5 data].

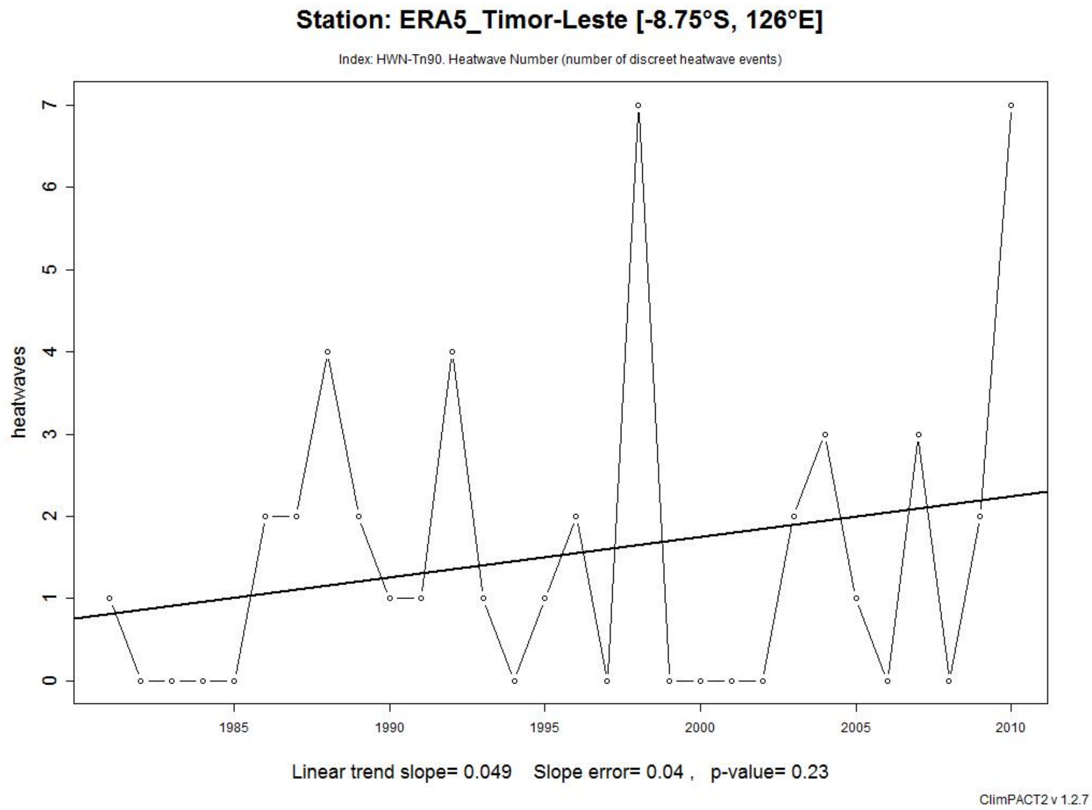

Figure A4.15: Heatwave Number as defined by either the Excess Heat Factor, 90th percentile of minimum temperature. The number of individual heatwaves that occur each summer. [ERA5 data].

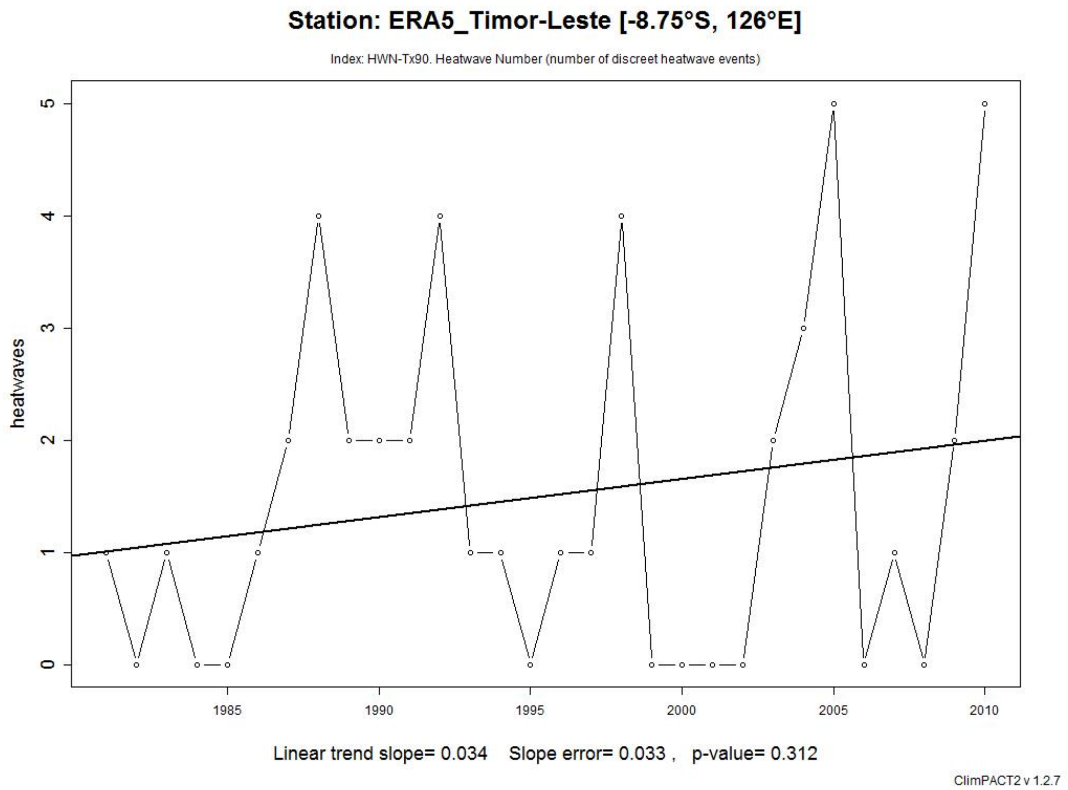

Figure A4.16: Heatwave Number as defined by either the Excess Heat Factor, 90th percentile of maximum temperature. The number of individual heatwaves that occur each summer. [ERA5 data].

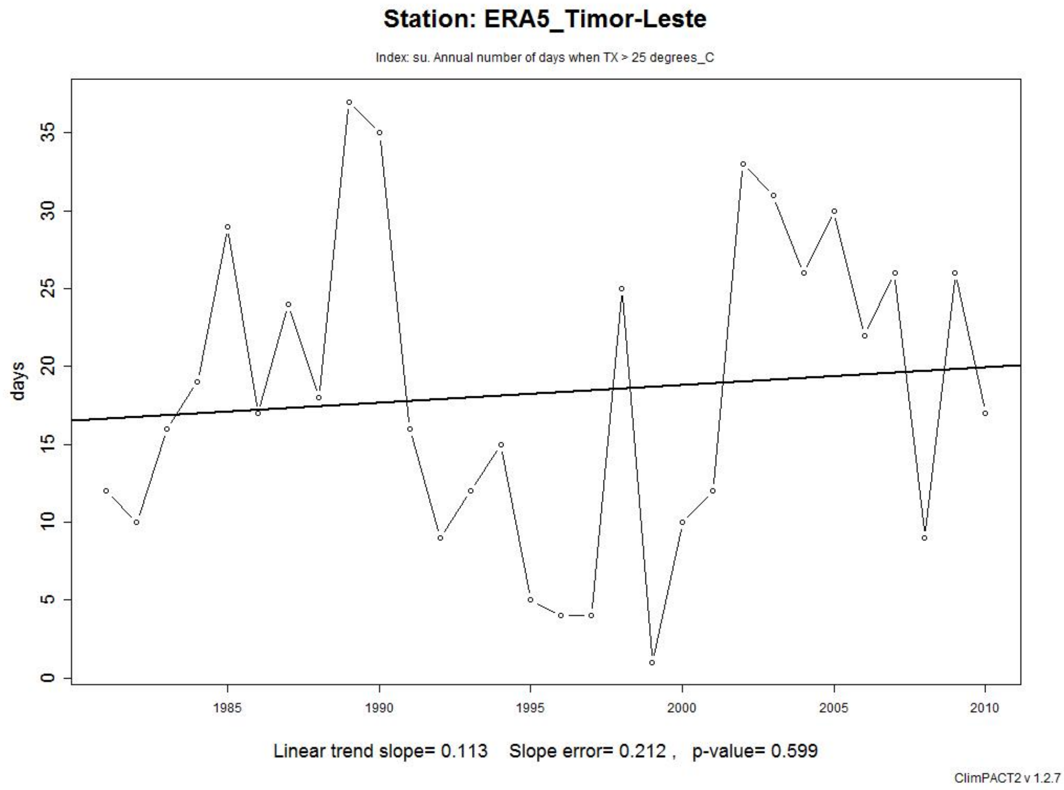

Figure A4.17: Summer days. Annual number of days when maximum temperature > 25 °C. [ERA5 data].

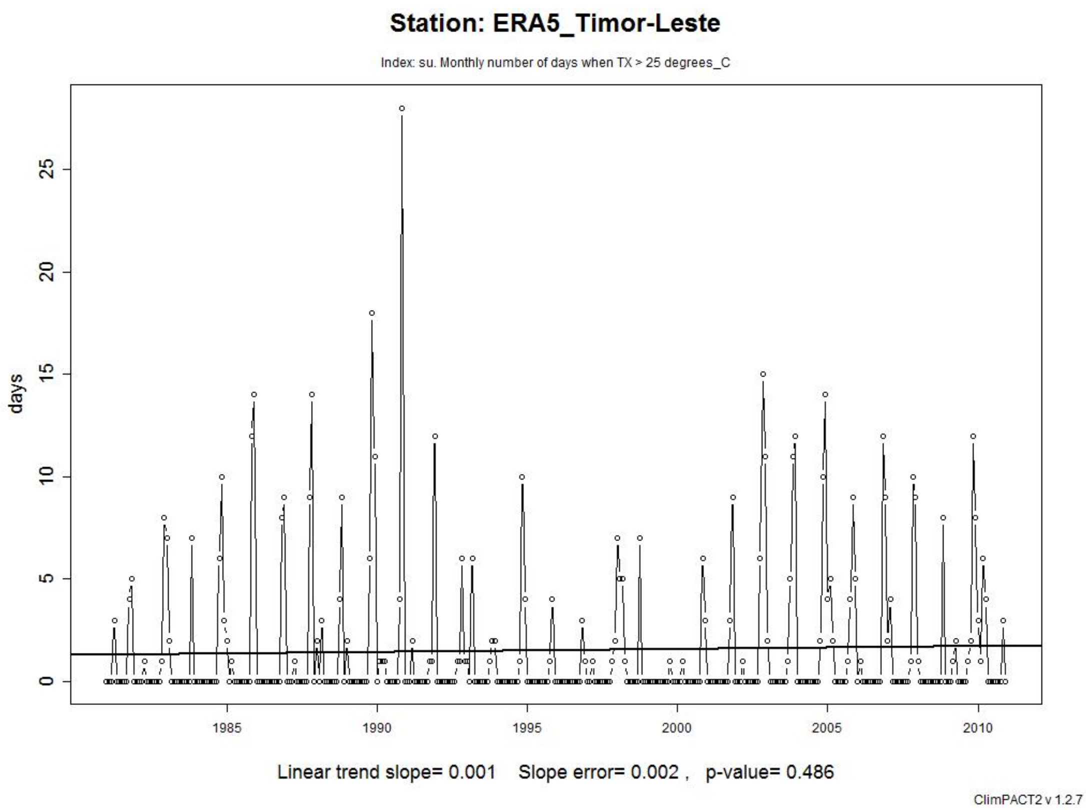

Figure A4.18: Summer days. Monthly number of days when maximum temperature > 25 °C. [ERA5 data].

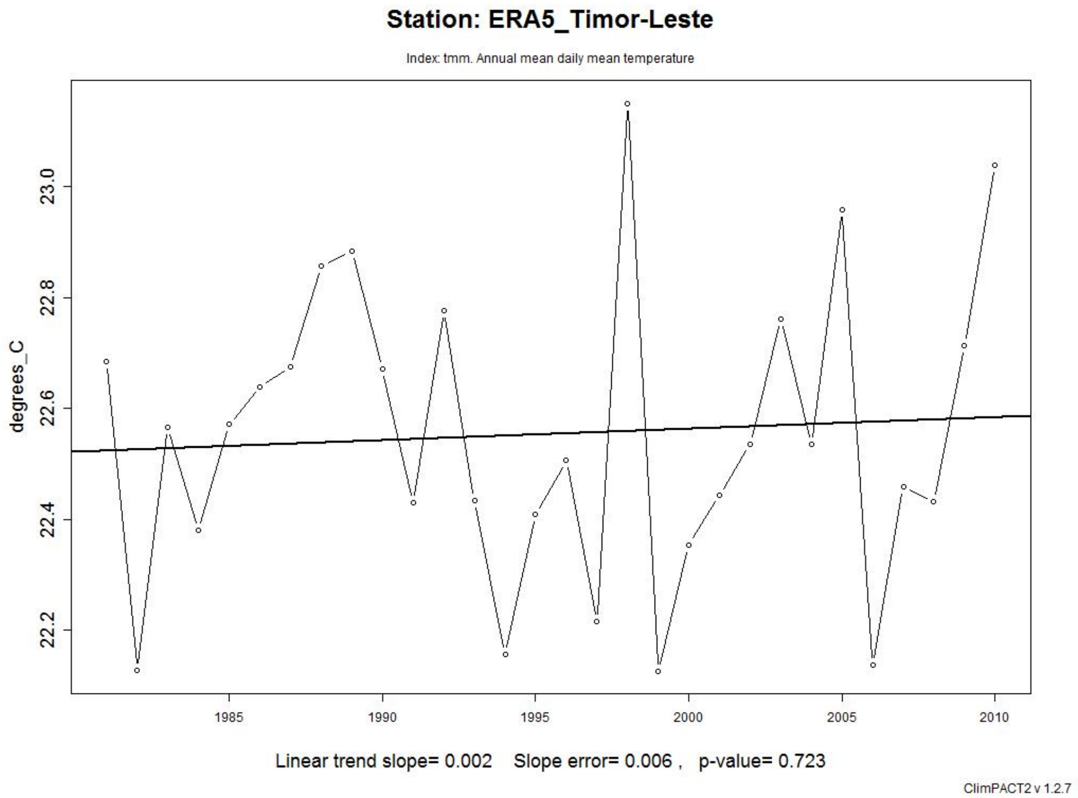

Figure A4.19: Mean mean temperature. Annual mean daily mean temperature. [ERA5 data].

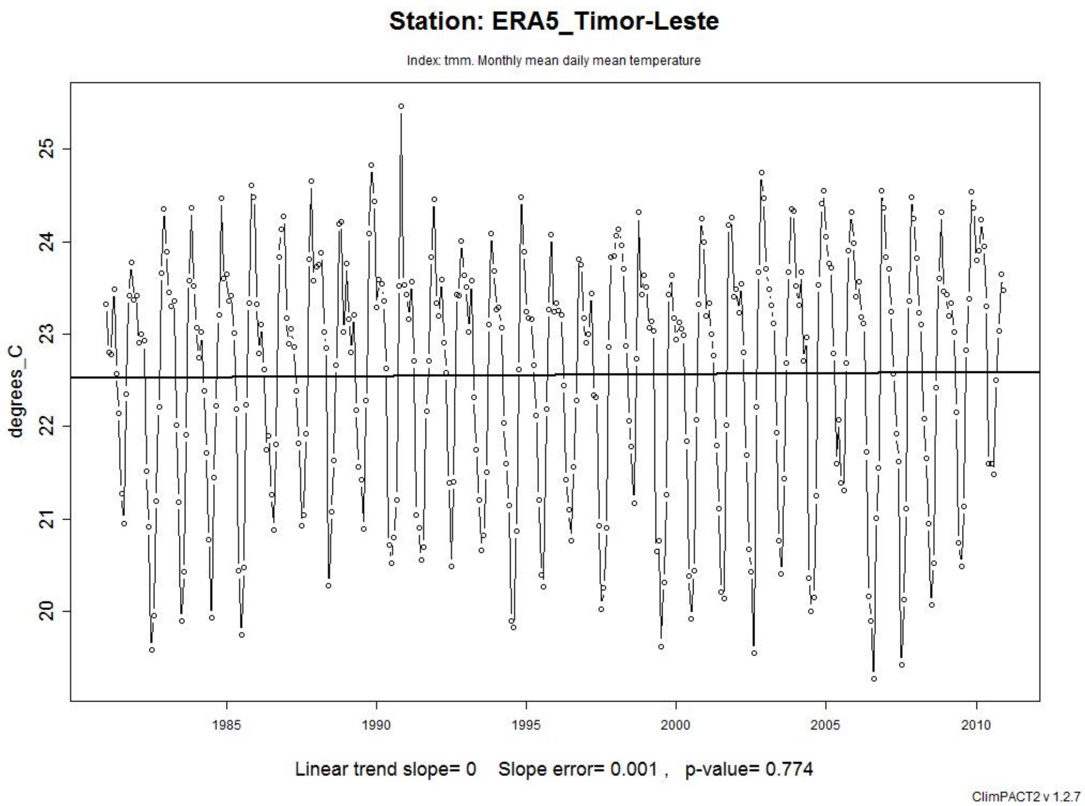

Figure A4.20: Mean mean temperature. Monthly mean daily mean temperature. [ERA5 data].

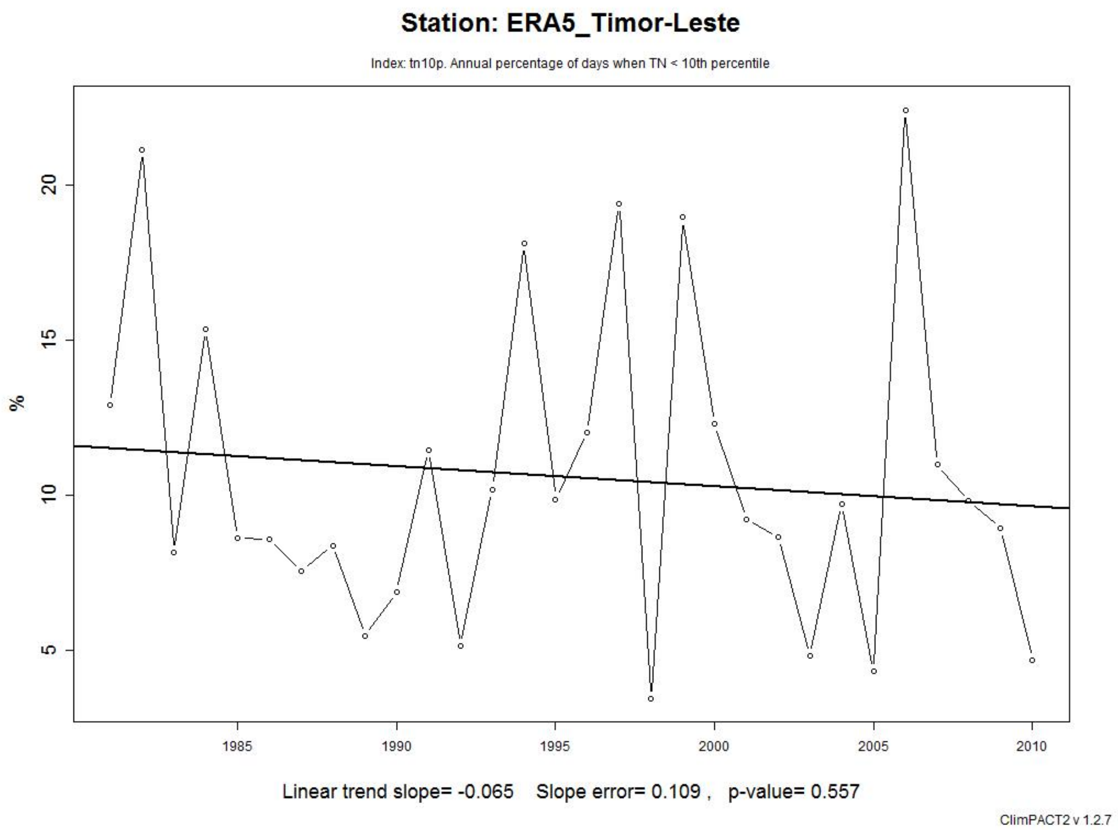

Figure A4.21: Amount of cold nights. Annual percentage of days when minimum temperature < 10th percentile. [ERA5 data].

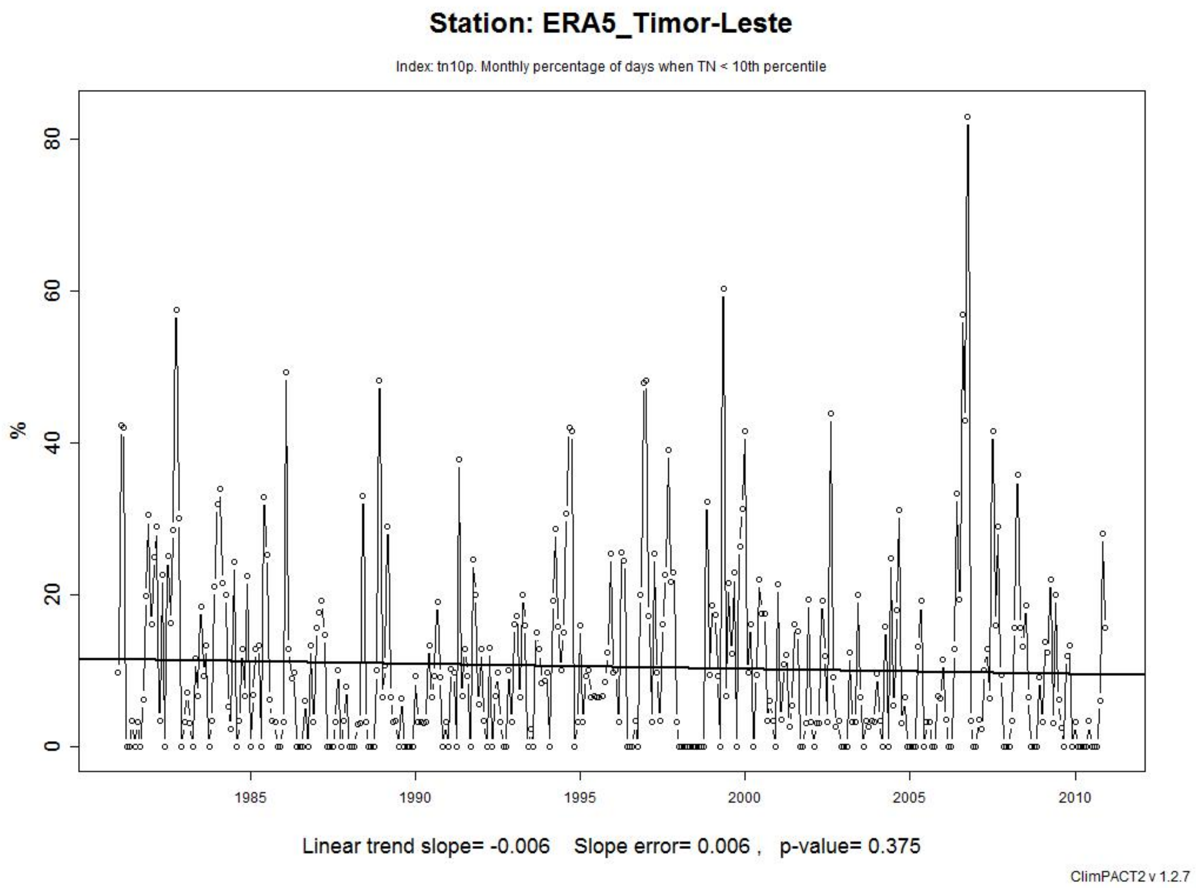

Figure A4.22: Amount of cold nights. Monthly percentage of days when minimum temperature < 10th percentile. [ERA5 data].

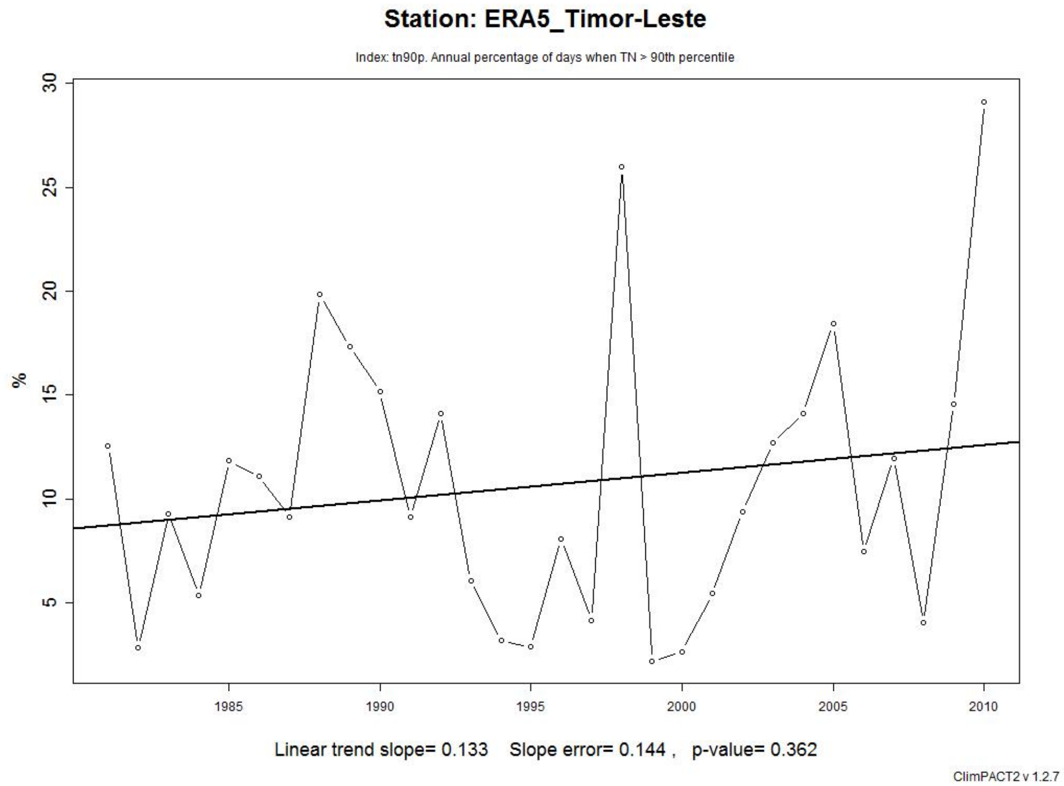

Figure A4.23: Amount of warm nights. Annual percentage of days when minimum temperature > 90th percentile. [ERA5 data].

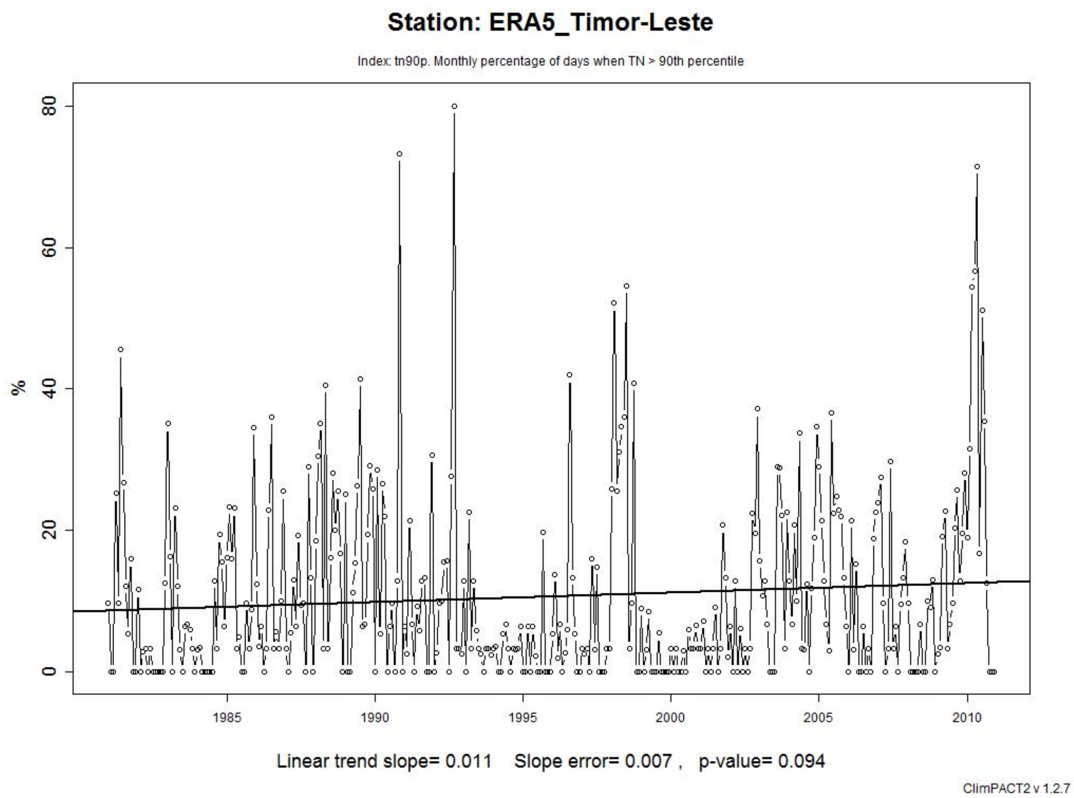

Figure A4.24: Amount of warm nights. Monthly percentage of days when minimum temperature > 90th percentile. [ERA5 data].

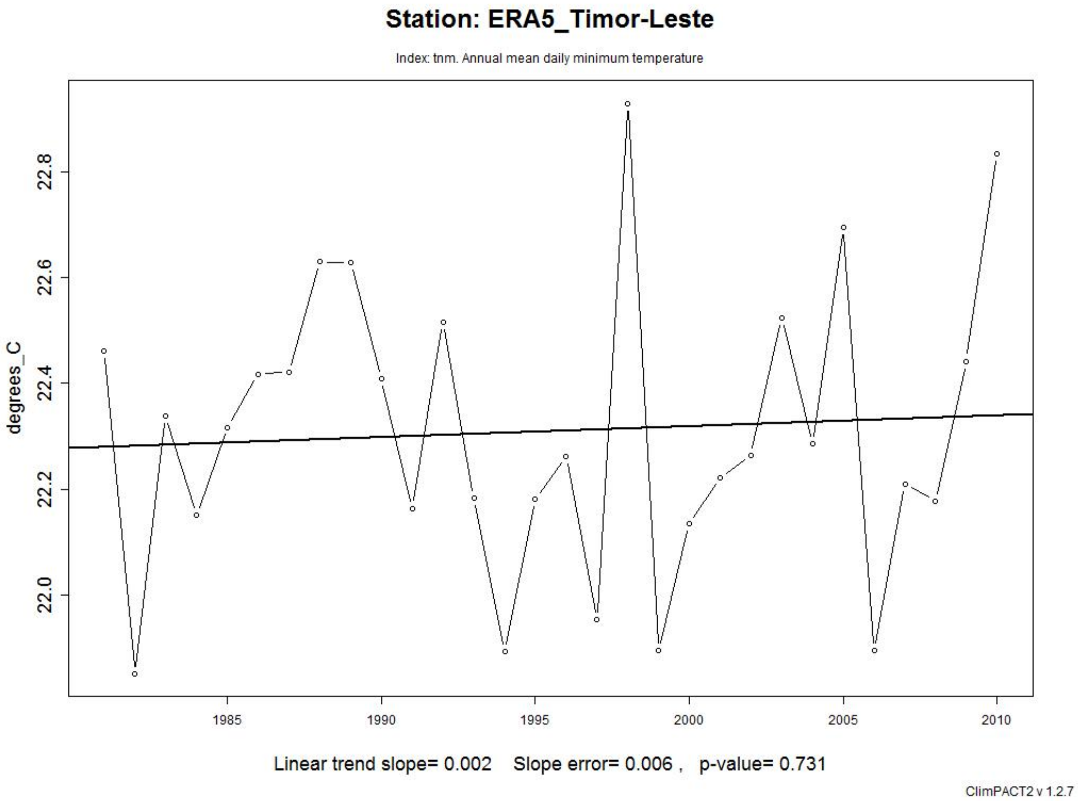

Figure A4.25: Mean Minimum temperature. Annual mean daily minimum temperature. [ERA5 data].

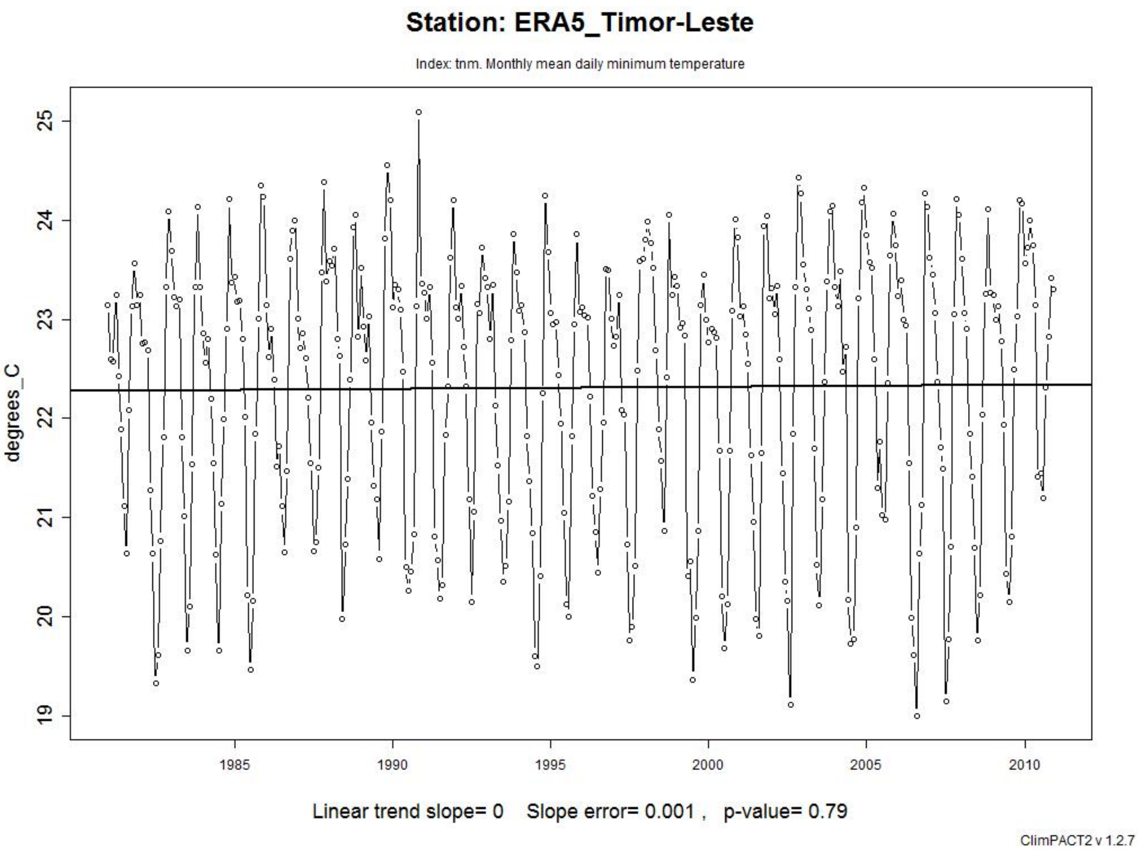

Figure A4.26: Mean Minimum temperature. Monthly mean daily minimum temperature. [ERA5 data].

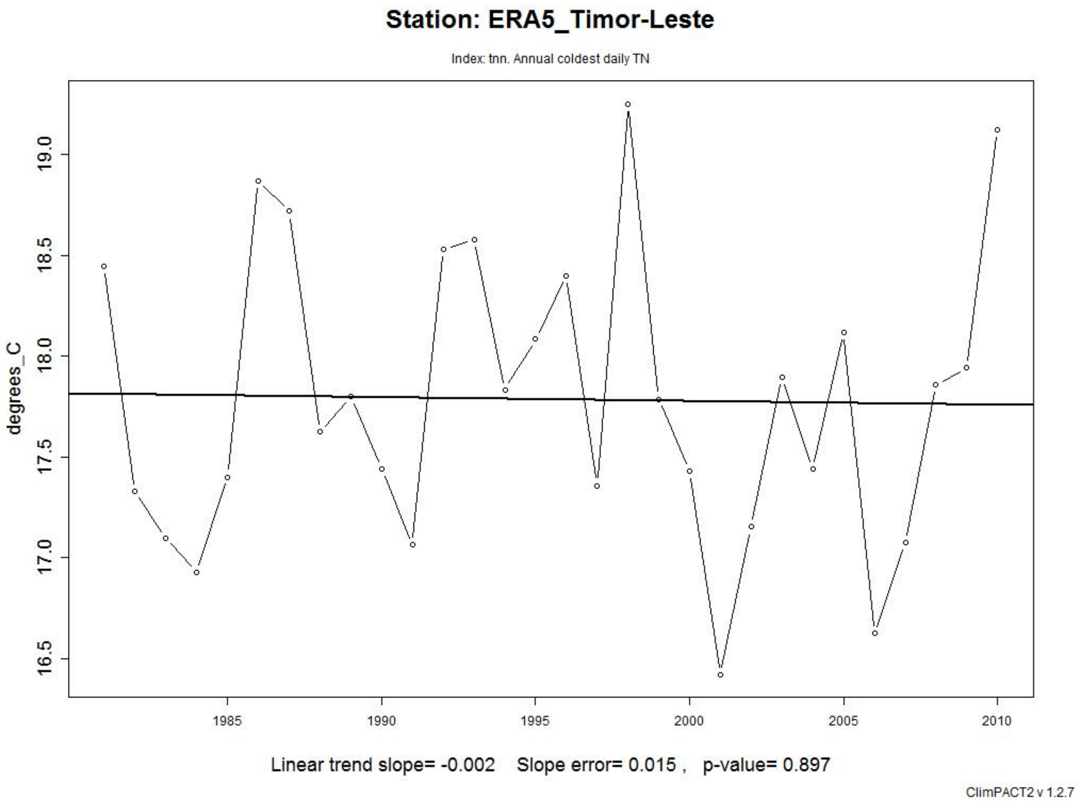

Figure A4.27: Min minimum temperature. Annual coldest daily minimum temperature. [ERA5 data].

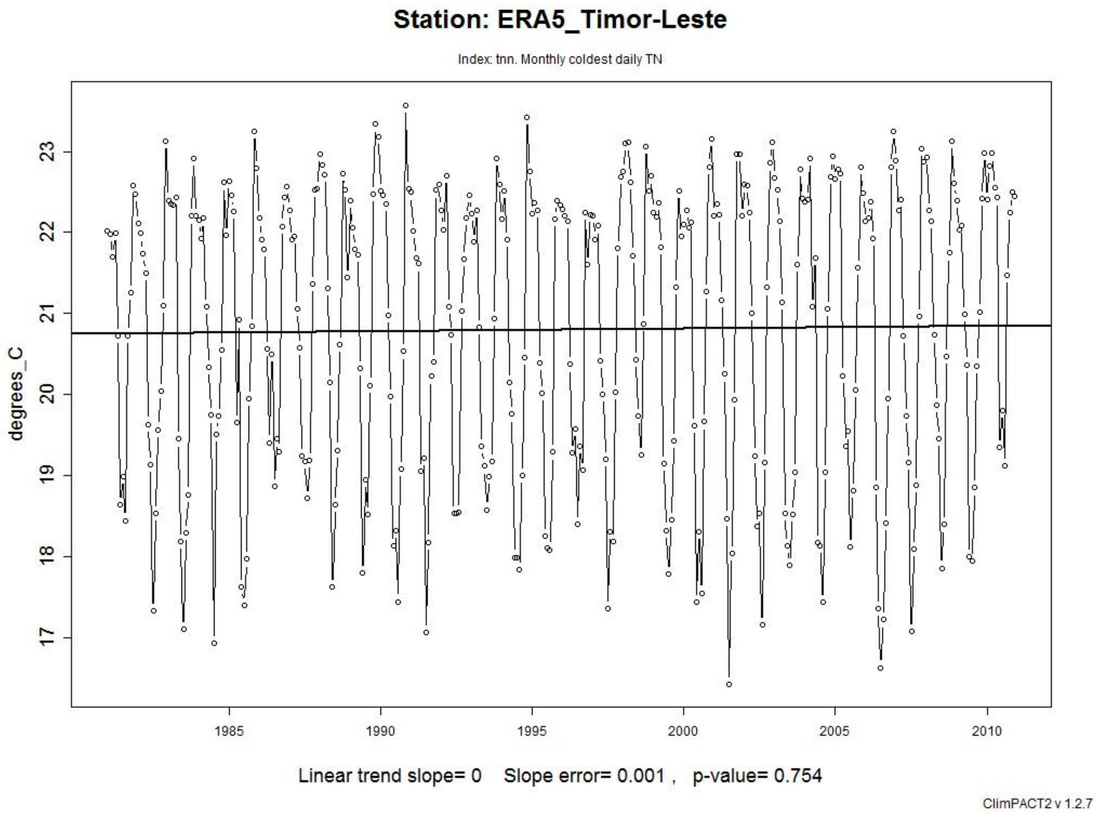

Figure A4.28: Min minimum temperature. Monthly coldest daily minimum temperature. [ERA5 data].

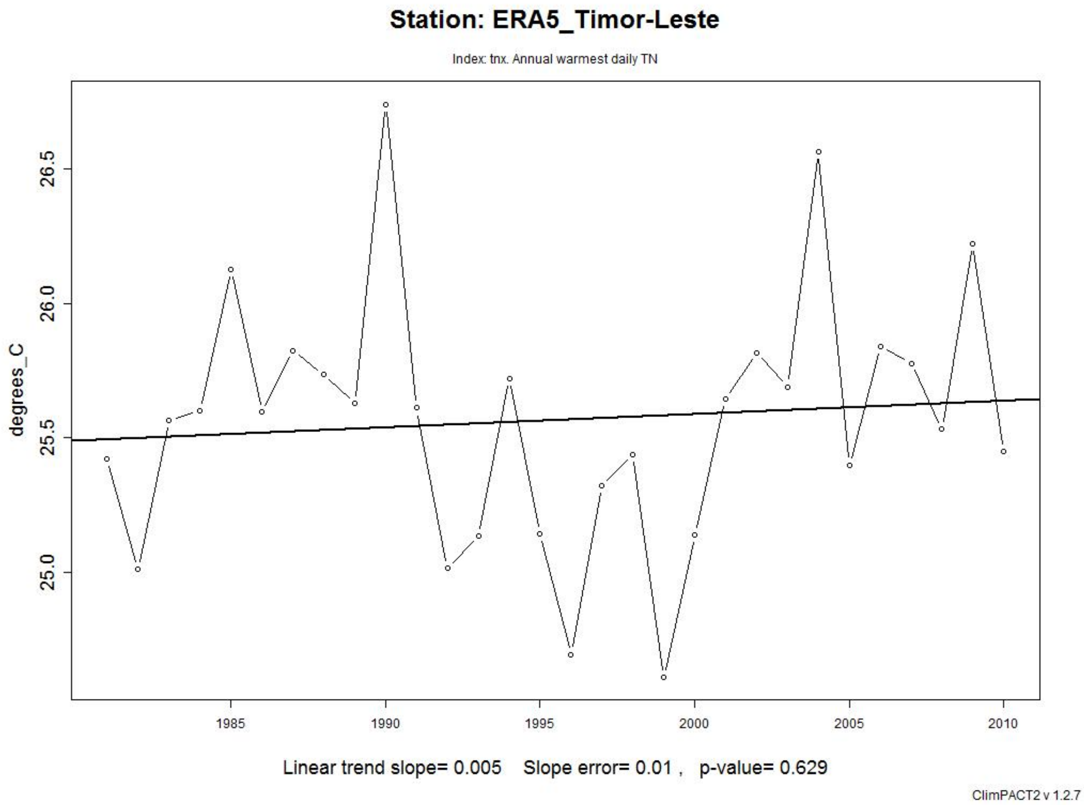

Figure A4.29: Max minimum temperature. Annual warmest daily minimum temperature. [ERA5 data].

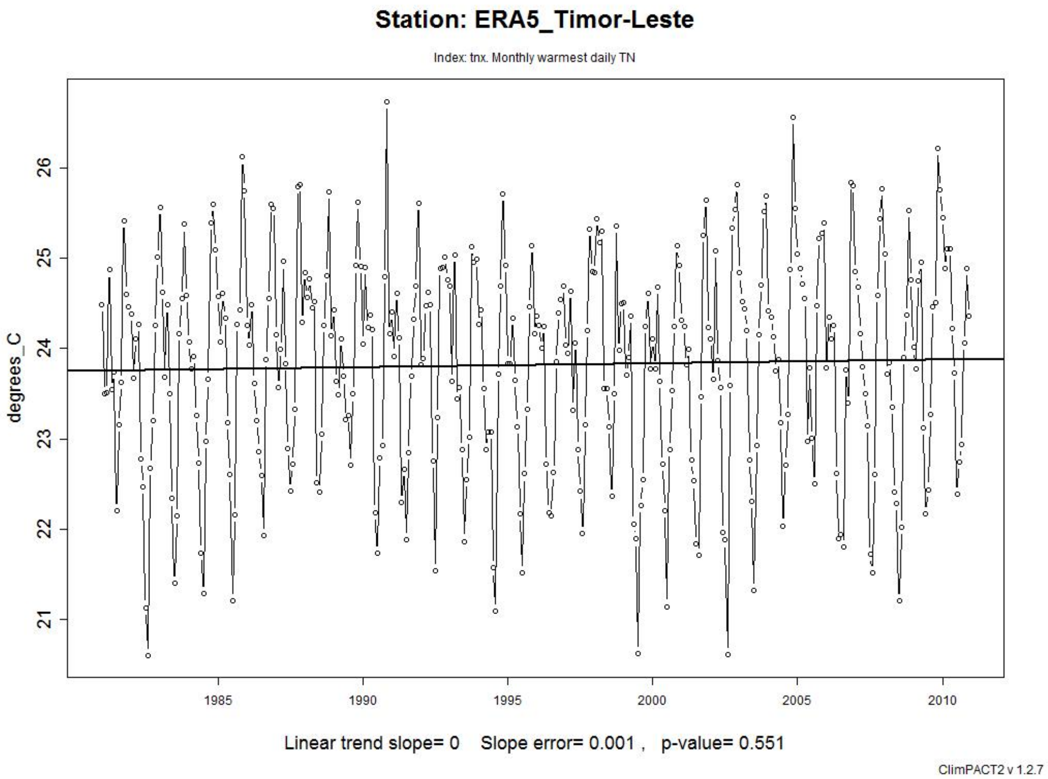

Figure A4.30: Max minimum temperature. Monthly warmest daily minimum temperature. [ERA5 data].

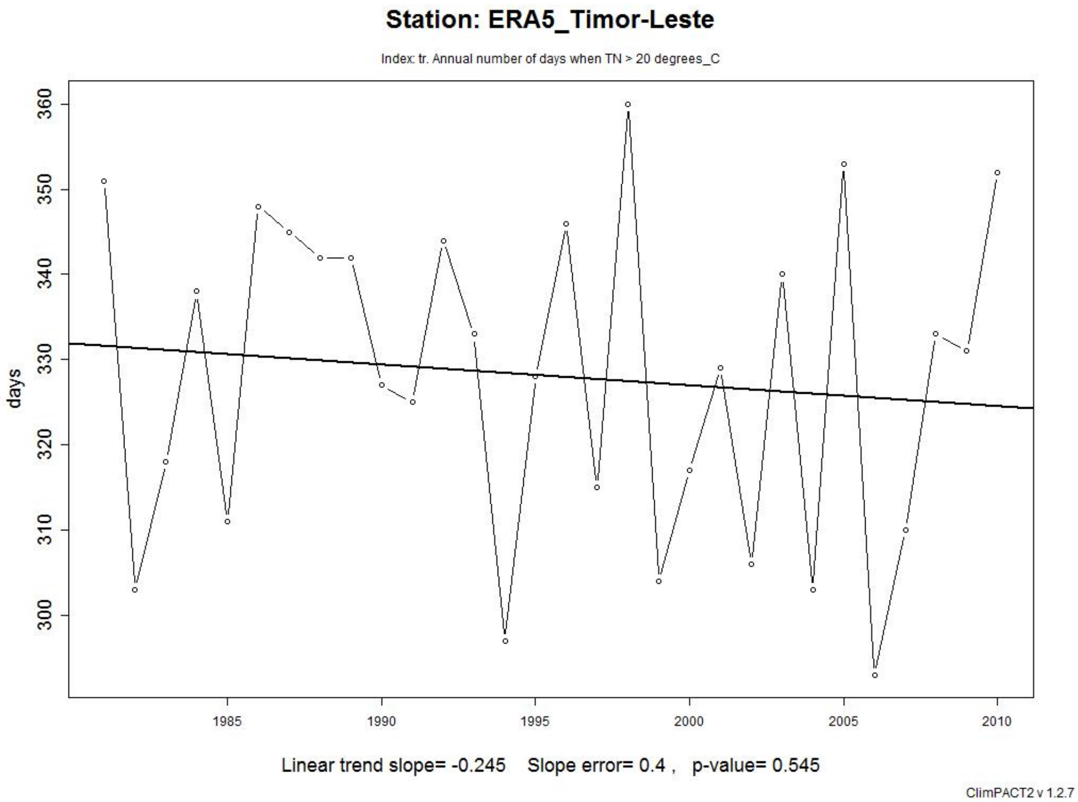

Figure A4.31: Tropical nights. Annual number of days when minimum temperature > 20 °C. [ERA5 data].

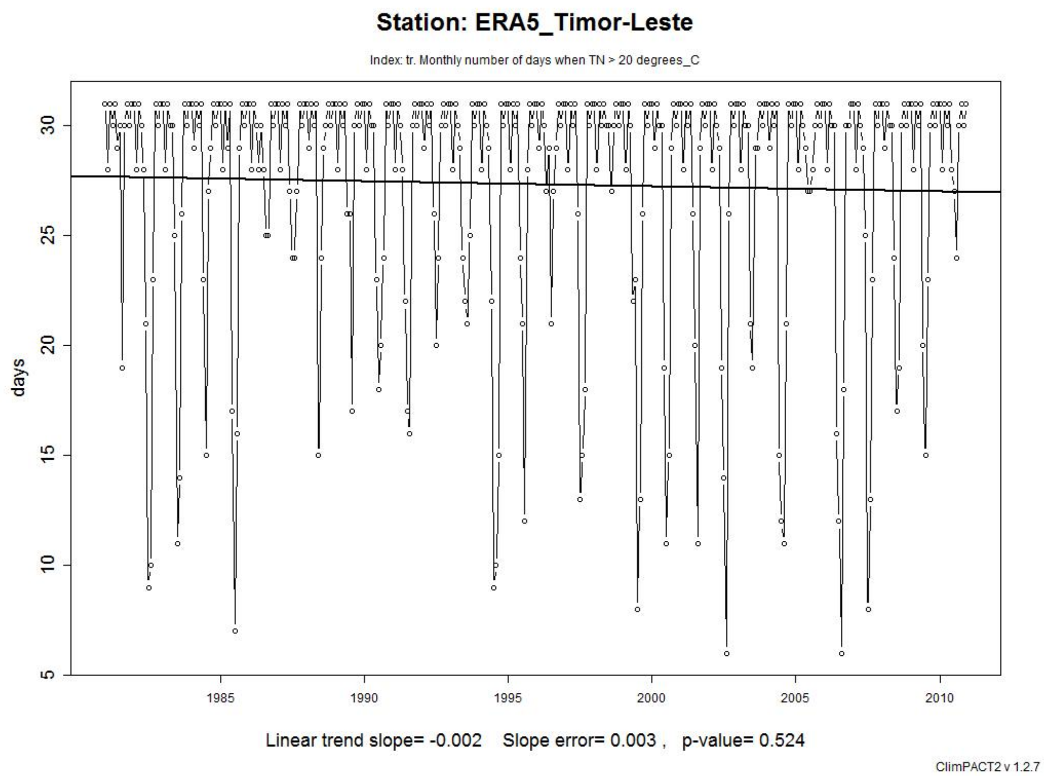

Figure A4.32: Tropical nights. Monthly number of days when minimum temperature > 20 °C. ERA5 data].

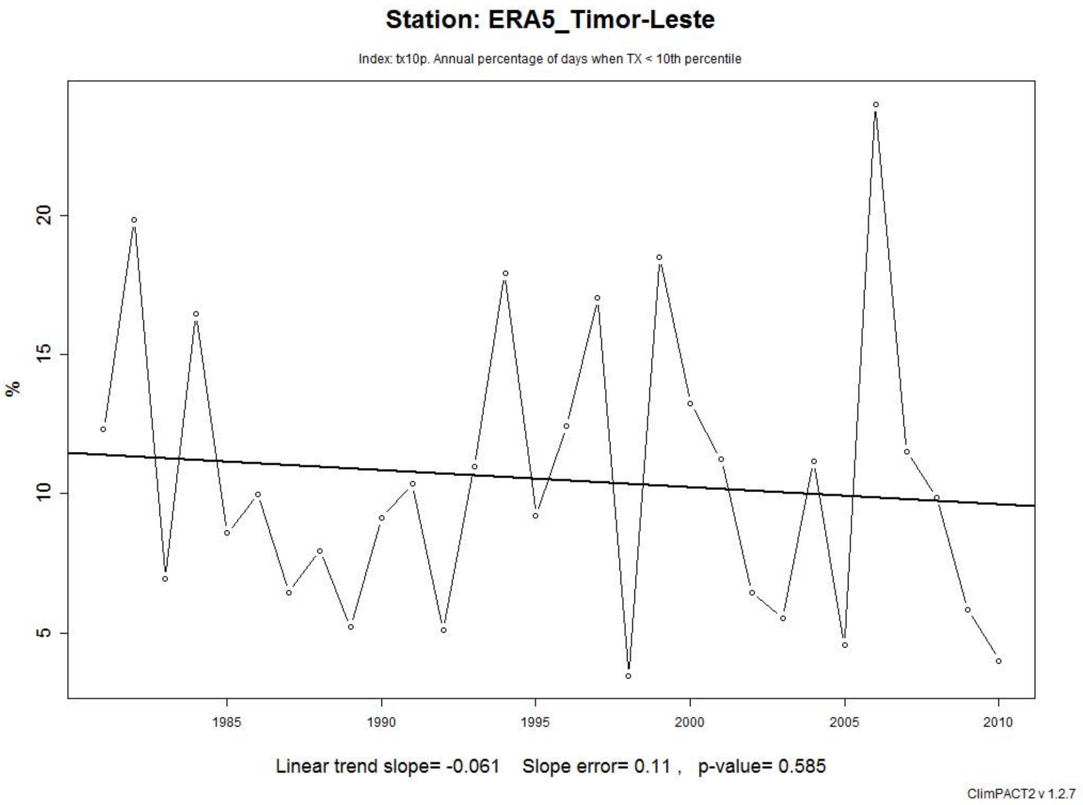

Figure A4.33: Amount of cool days. Annual percentage of days when maximum temperature < 10th percentile. [ERA5 data].

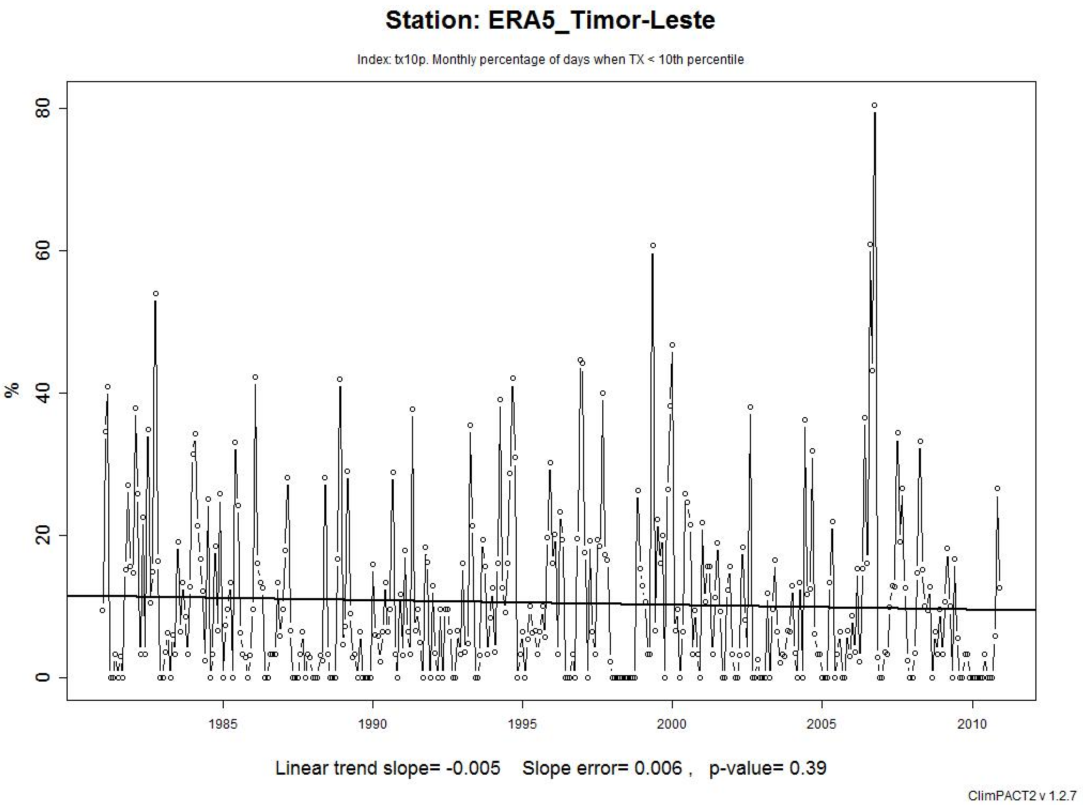

Figure A4.34: Amount of cool days. Monthly percentage of days when maximum temperature < 10th percentile. [ERA5 data].

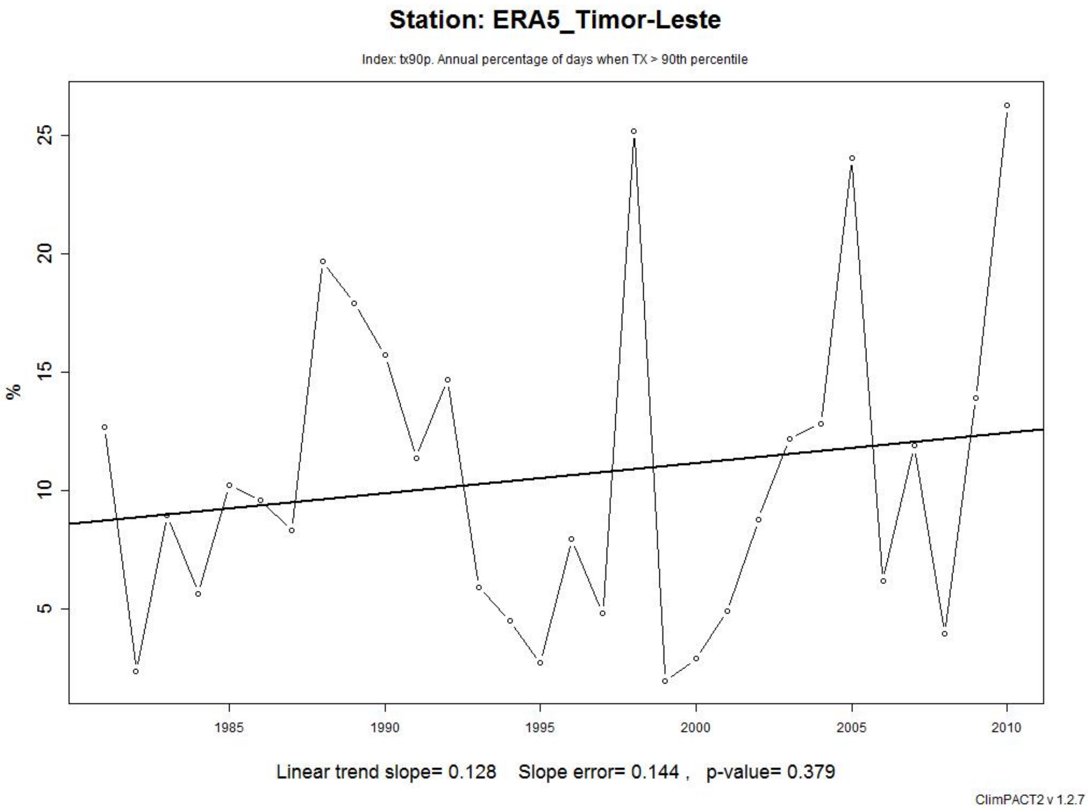

Figure A4.35: Amount of hot days. Annual percentage of days when maximum temperature < 90th percentile. [ERA5 data].

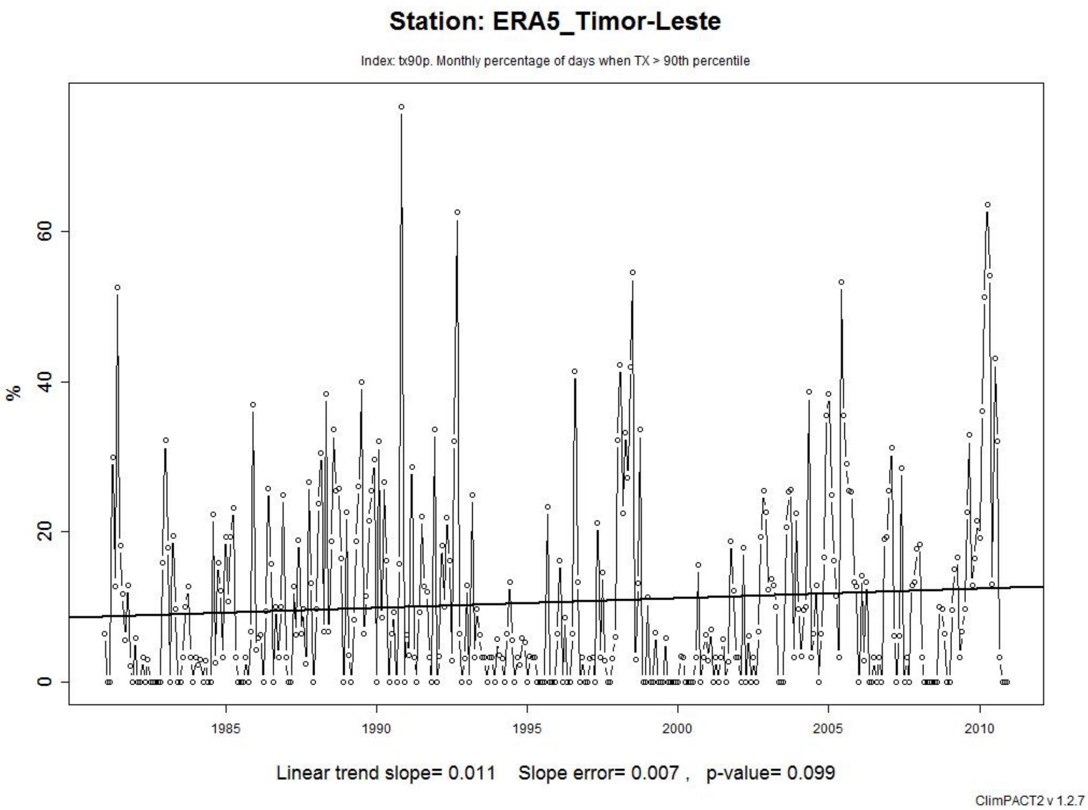

Figure A4.36: Amount of hot days. Monthly percentage of days when maximum temperature < 90th percentile. [ERA5 data].

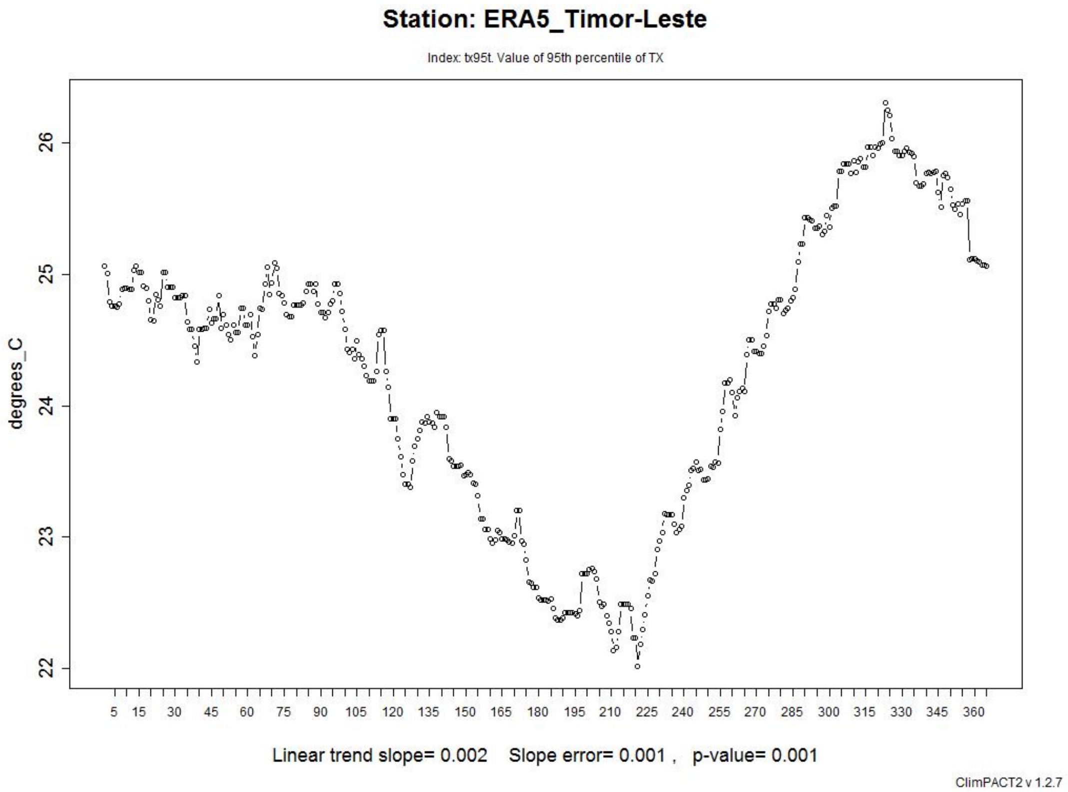

Figure A4.37: Very warm day threshold. Value of 95th percentile of maximum temperature. [ERA5 data].

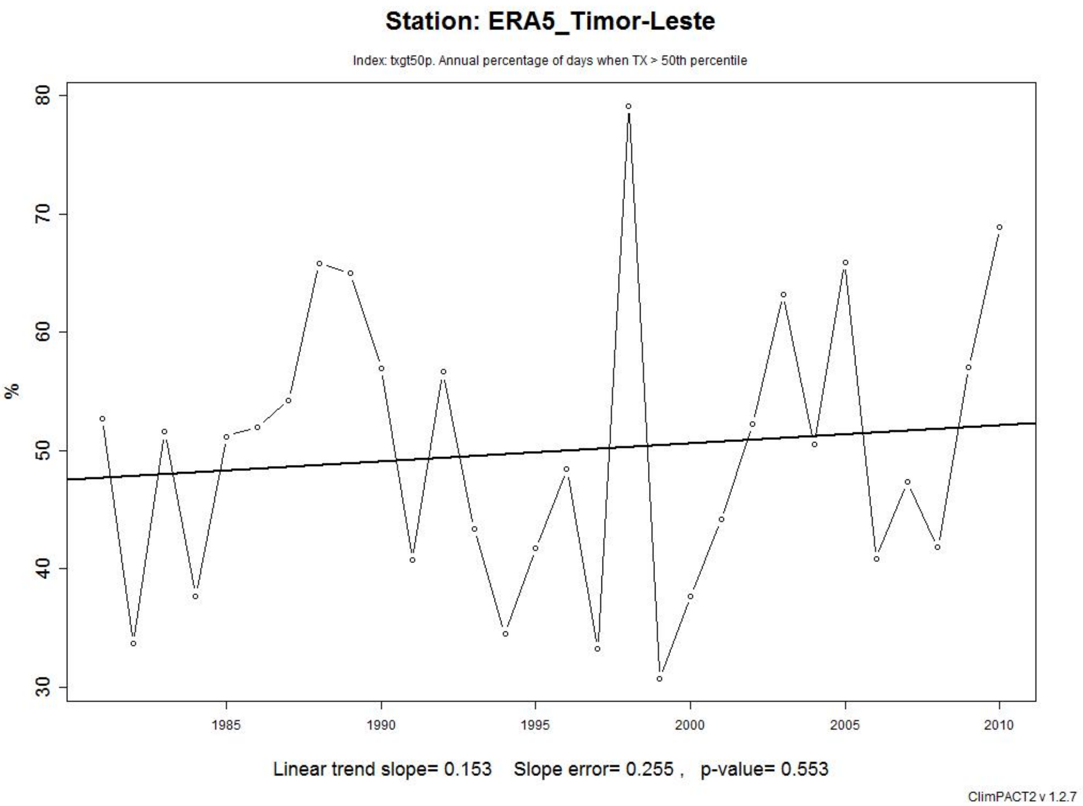

Figure A4.38: Fraction of days with above average temperature. Annual percentage of days where maximum temperature > 50th percentile. [ERA5 data].

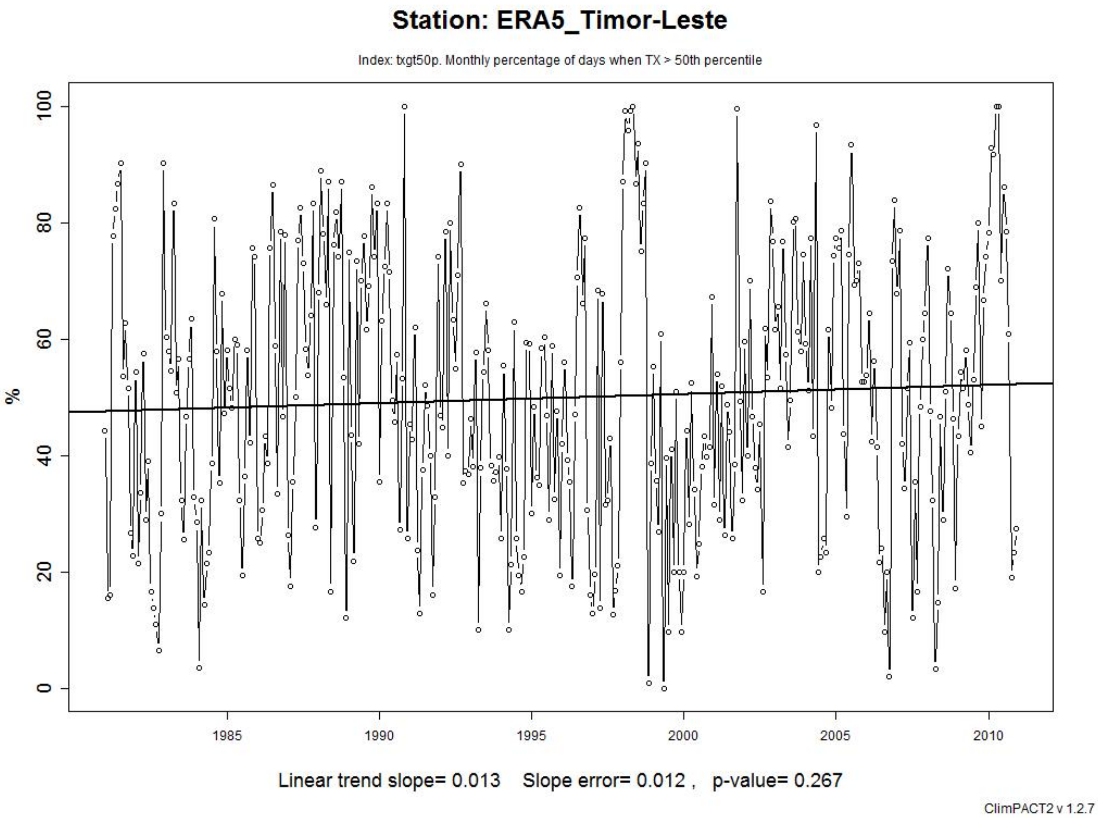

Figure A4.39: Fraction of days with above average temperature. Monthly percentage of days where maximum temperature > 50th percentile. [ERA5 data].

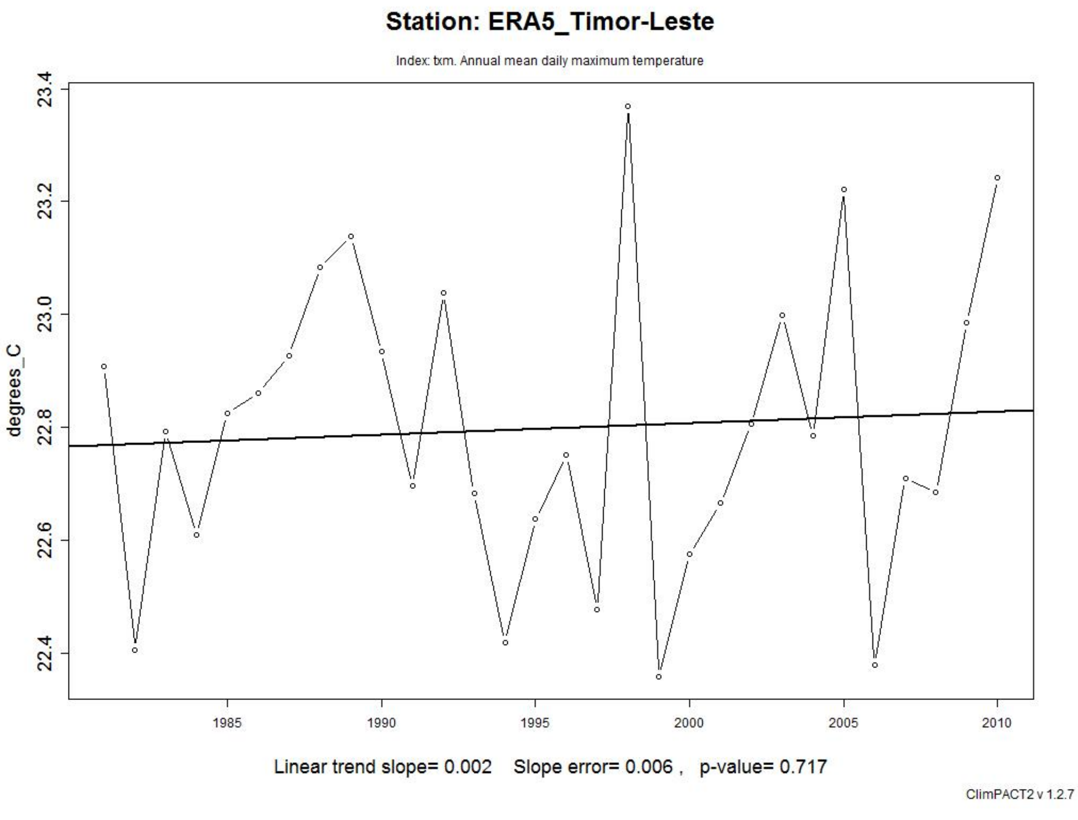

Figure A4.40: Mean maximum temperature. Annual mean daily maximum temperature. [ERA5 data].

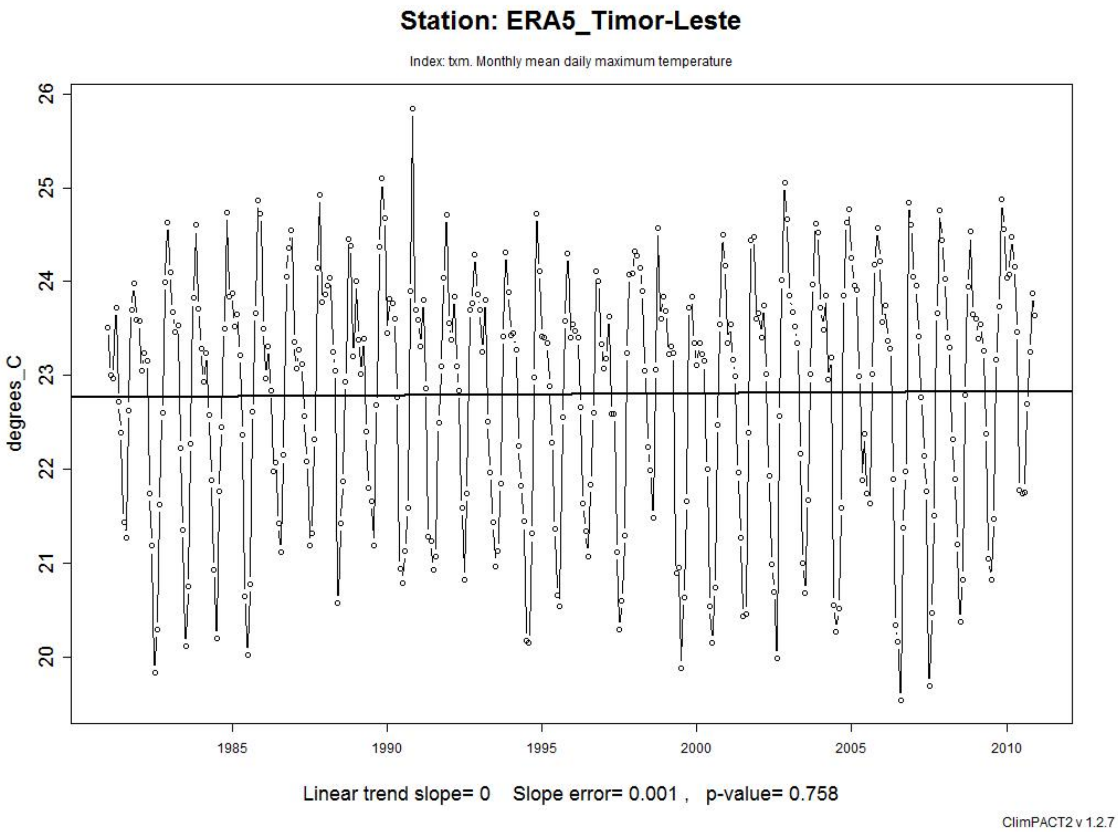

Figure A4.41: Mean maximum temperature. Monthly mean daily maximum temperature. [ERA5 data].

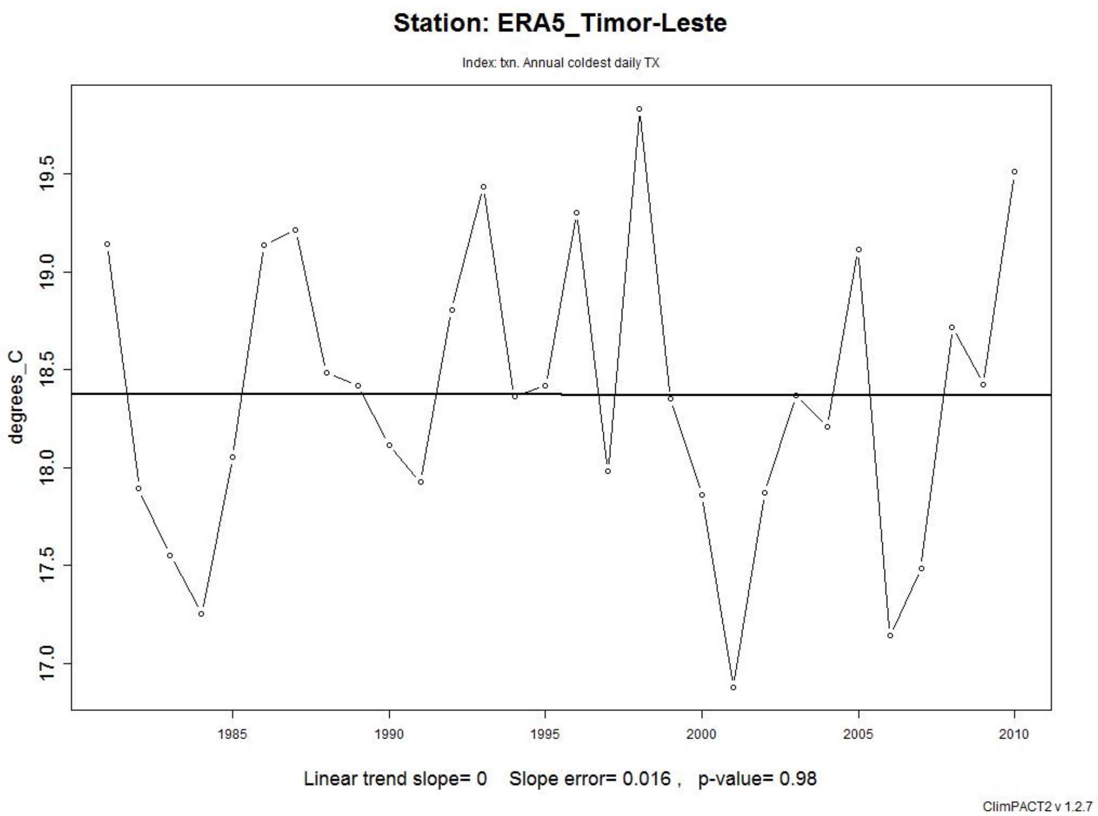

Figure A4.42: Min maximum temperature. Annual coldest daily maximum temperature. [ERA5 data].

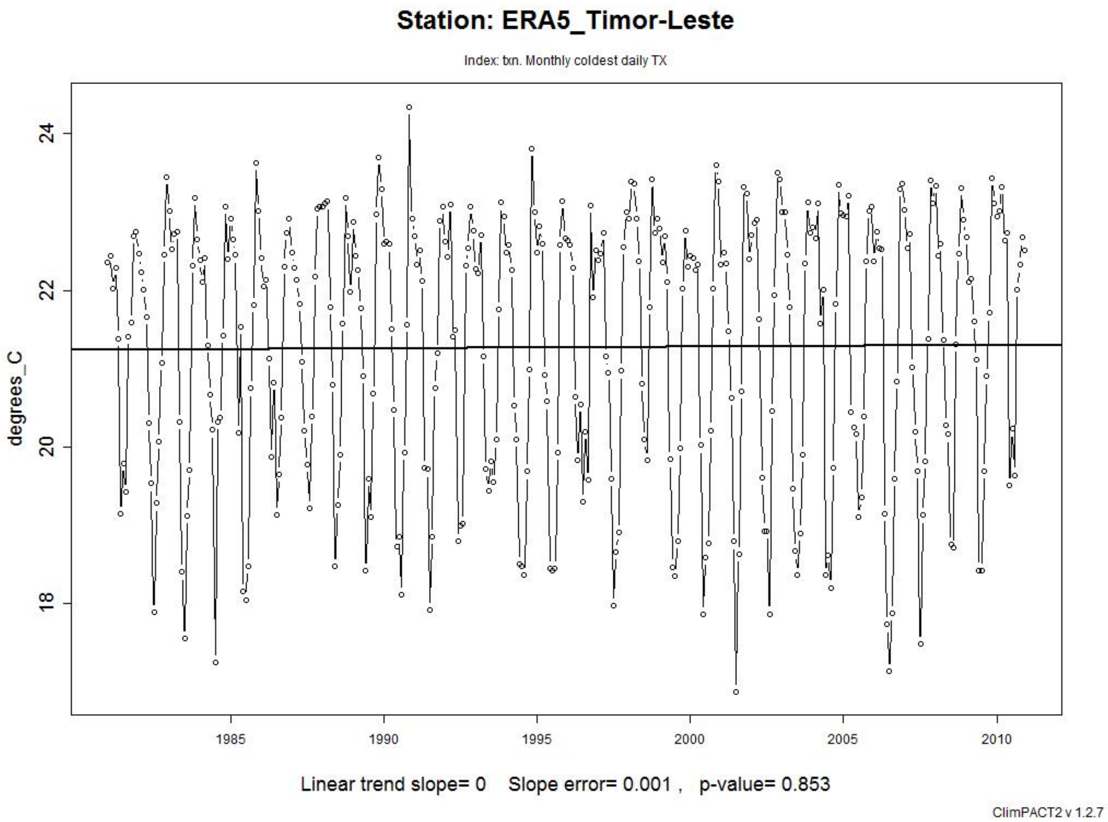

Figure A4.43: Min maximum temperature. Monthly coldest daily maximum temperature. [ERA5 data].

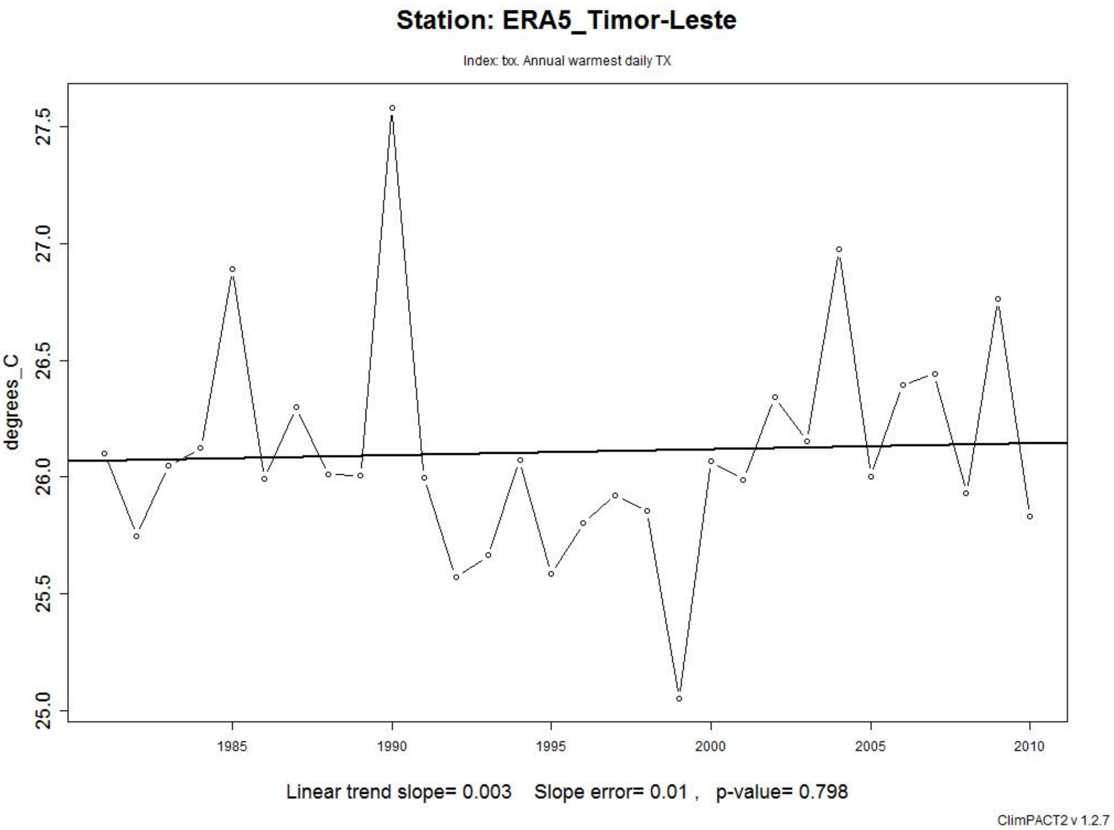

Figure A4.44: Max maximum temperature. Annual warmest daily maximum temperature. [ERA5 data].

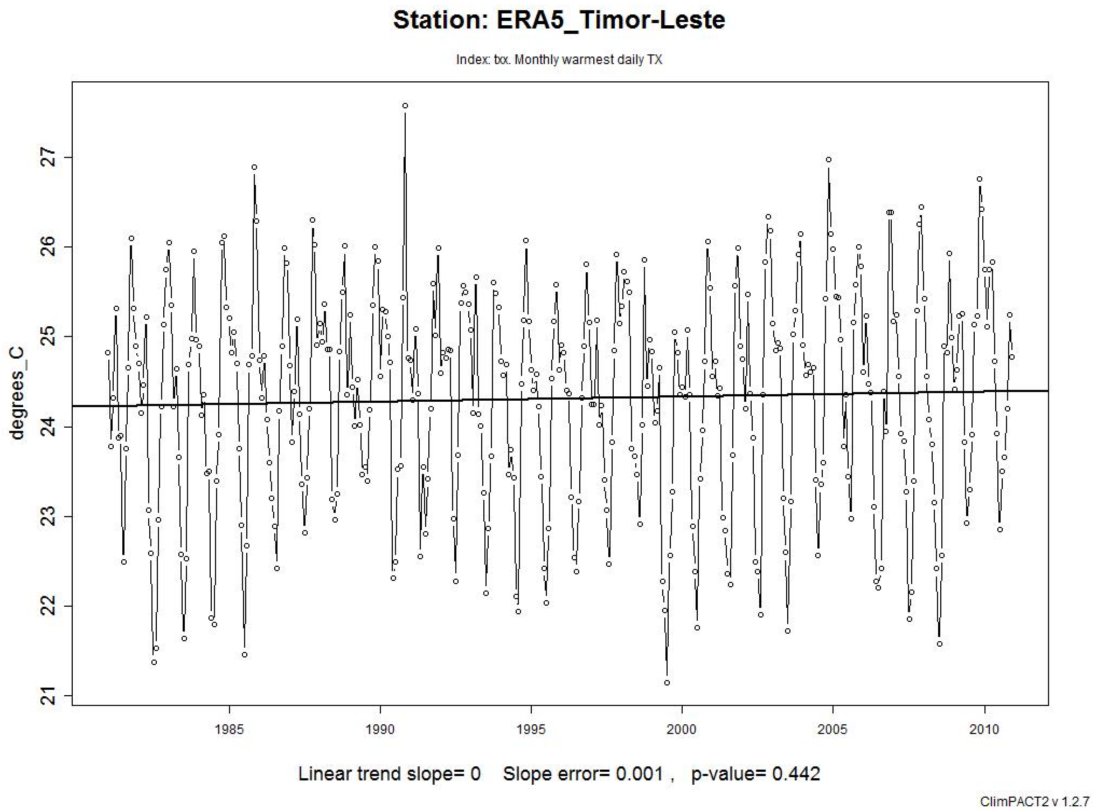

Figure A4.45: Max maximum temperature. Monthly warmest daily maximum temperature. [ERA5 data].

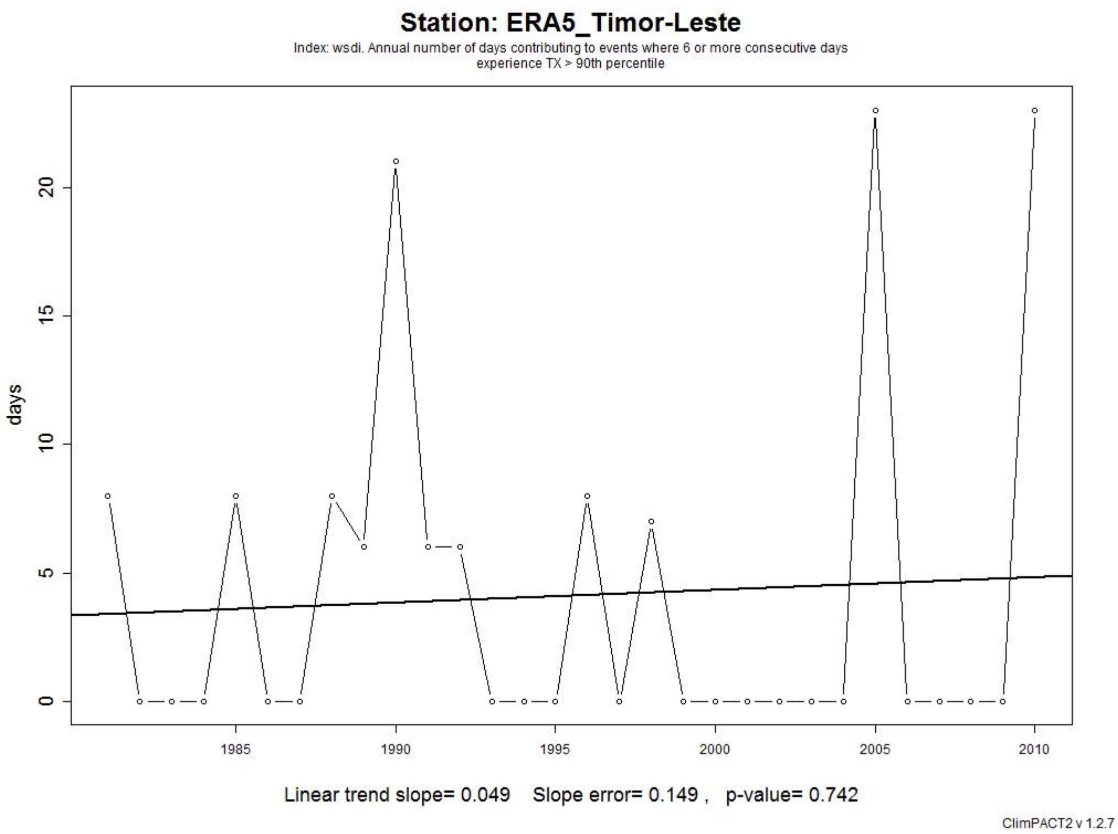

Figure A4.46: Warm spell duration indicator. Annual number of days contributing to events where 6 or more consecutive days experience maximum temperature > 90th percentile. [ERA5 data].

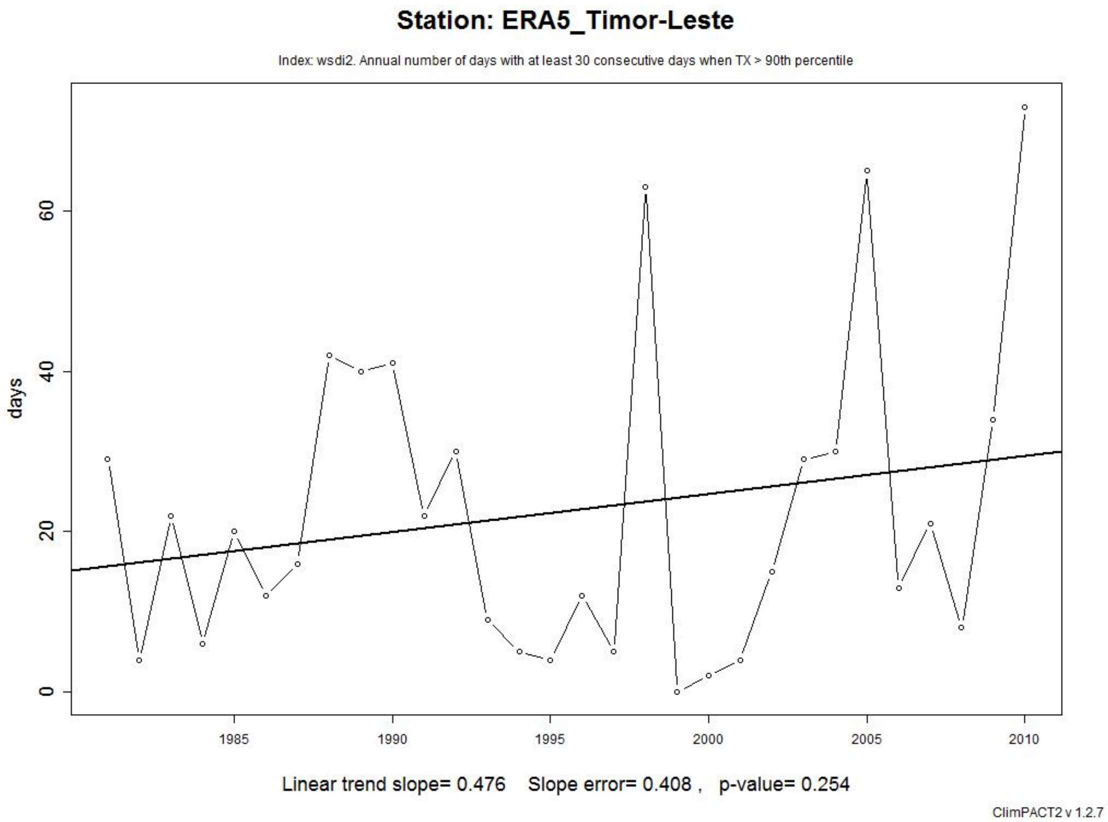

Figure A4.47: Warm spell duration indicator. Annual number of days contributing to events where where d or more consecutive days experience maximum temperature > 90th percentile. In this case d is defined as default as 2. [ERA5 data].

APPENDIX 5 – CLIMPACT 2.0 PLOTS FOR SEASONAL ANALYSES IN TIMOR-LESTE

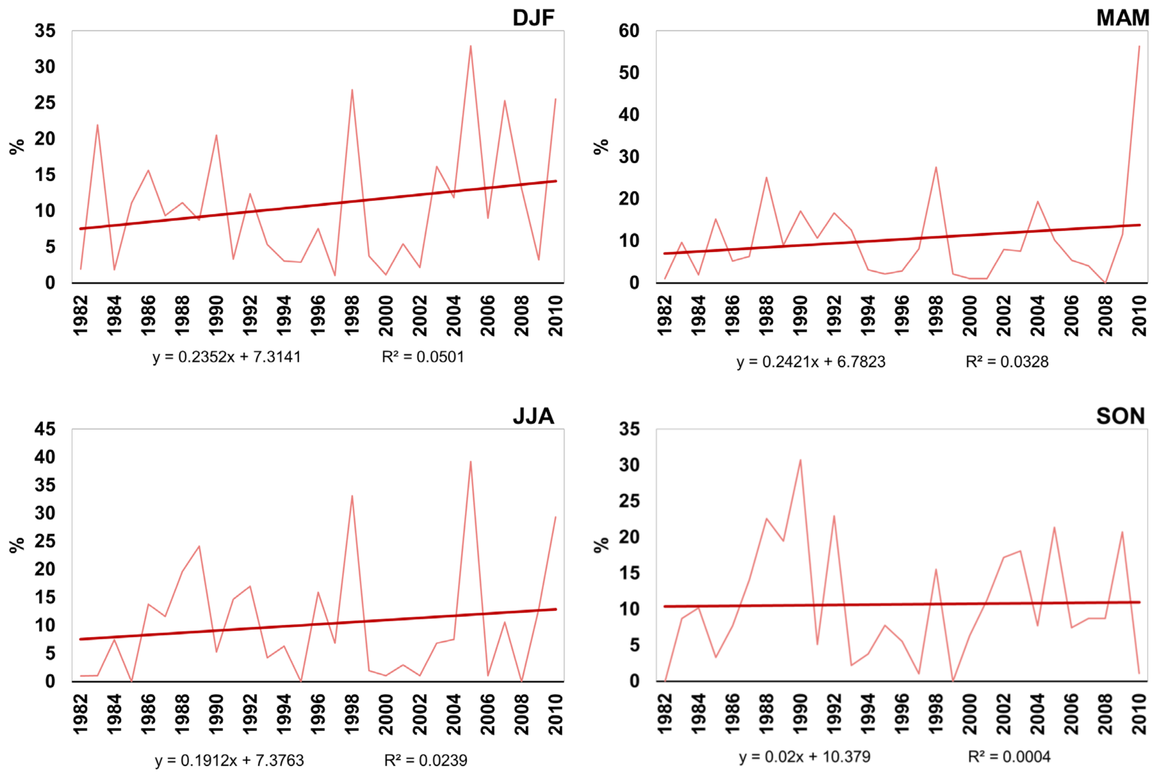

Figure A5.1: Amount of Hot Days. Seasonal percentage of days when TX > 90th percentile. [ERA5 data].

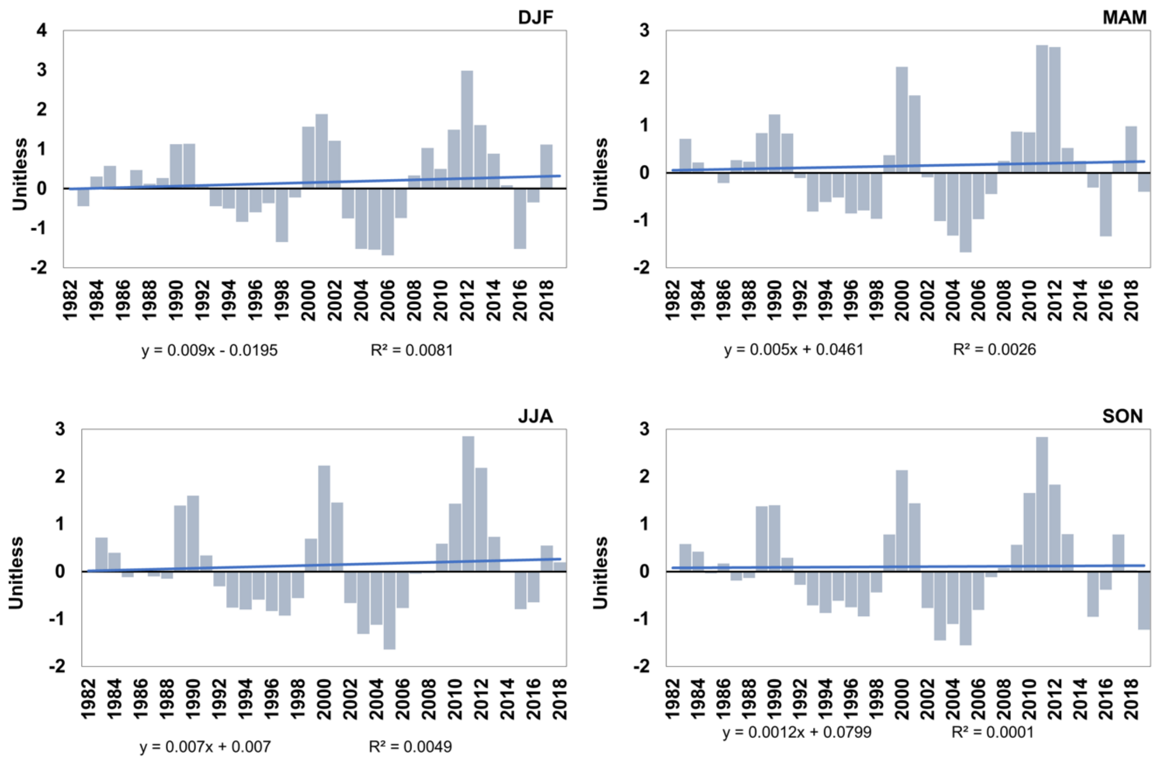

Figure A5.2: SPI 24-month index in Timor-Leste. Seasonal measure of “drought”. [CHIRPS data].

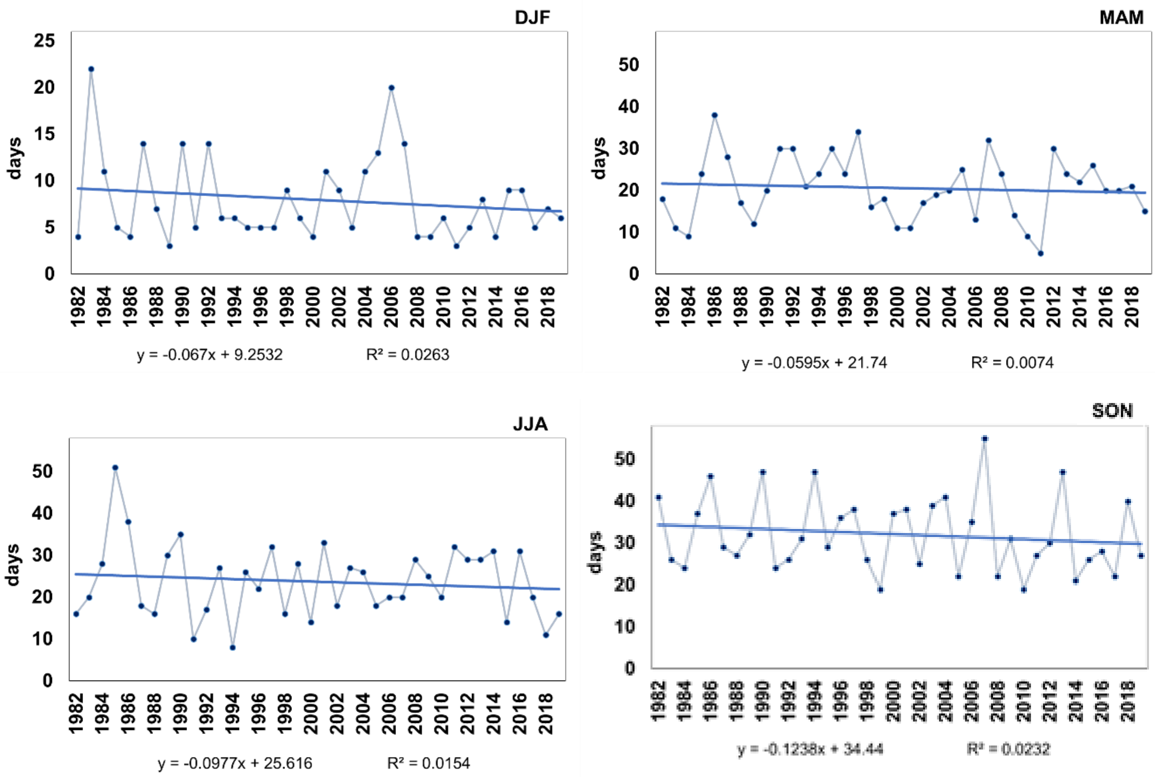

Figure A5.3: Consecutive Dry Days. Maximum seasonal number of consecutive dry days (when PR < 1.0 mm). [CHIRPS data].

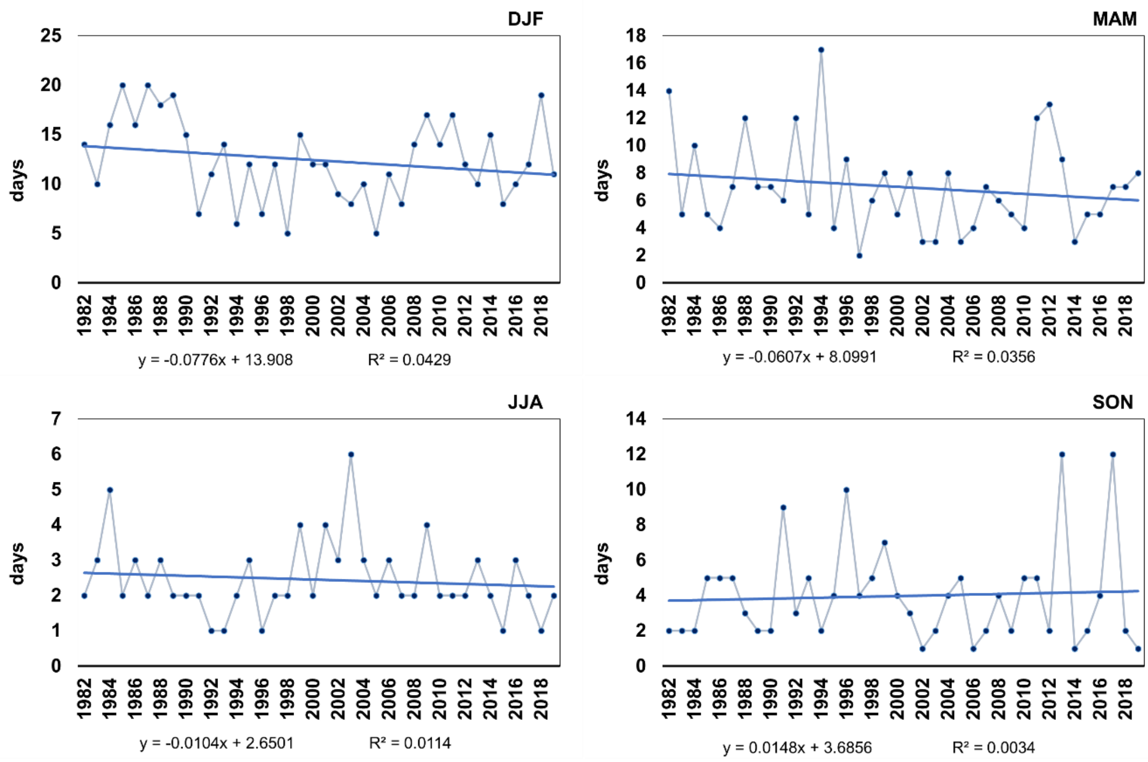

Figure A5.4: Consecutive Wet Days. Maximum seasonal number of consecutive wet days (when PR >= 1.0 mm). [CHIRPS data].

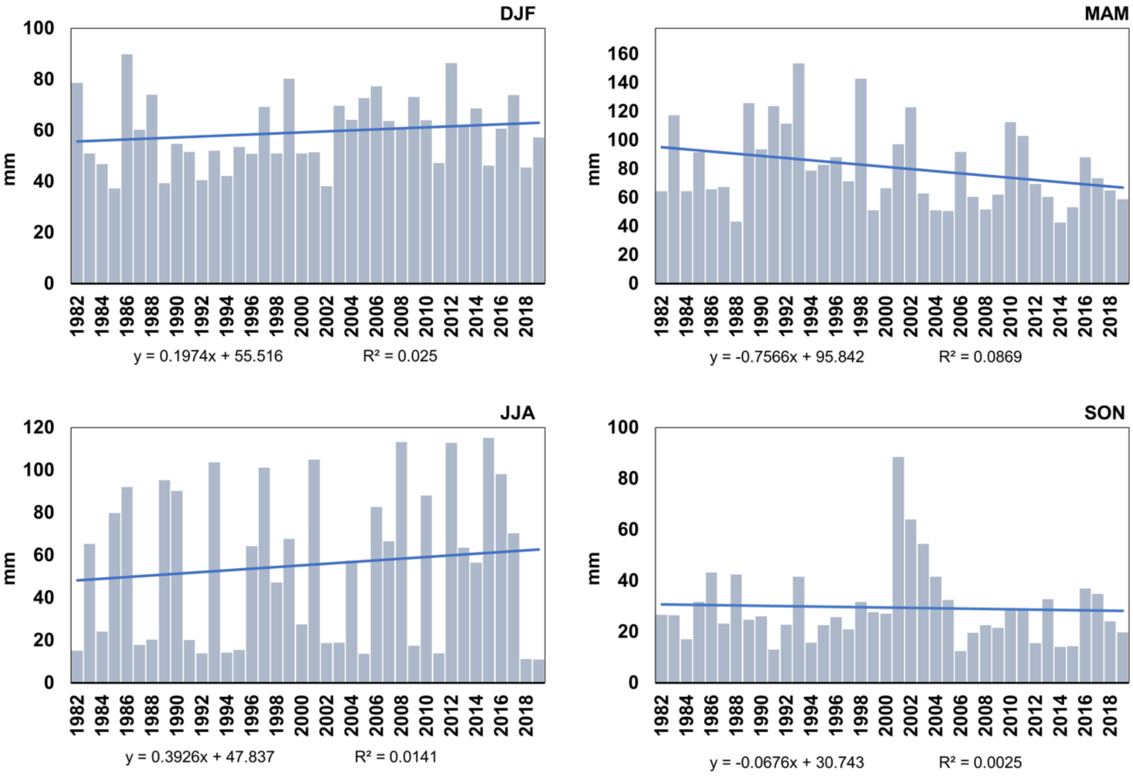

Figure A5.5: RX1day index in Timor-Leste. Seasonal maximum 1-day PR total. [CHIRPS data].

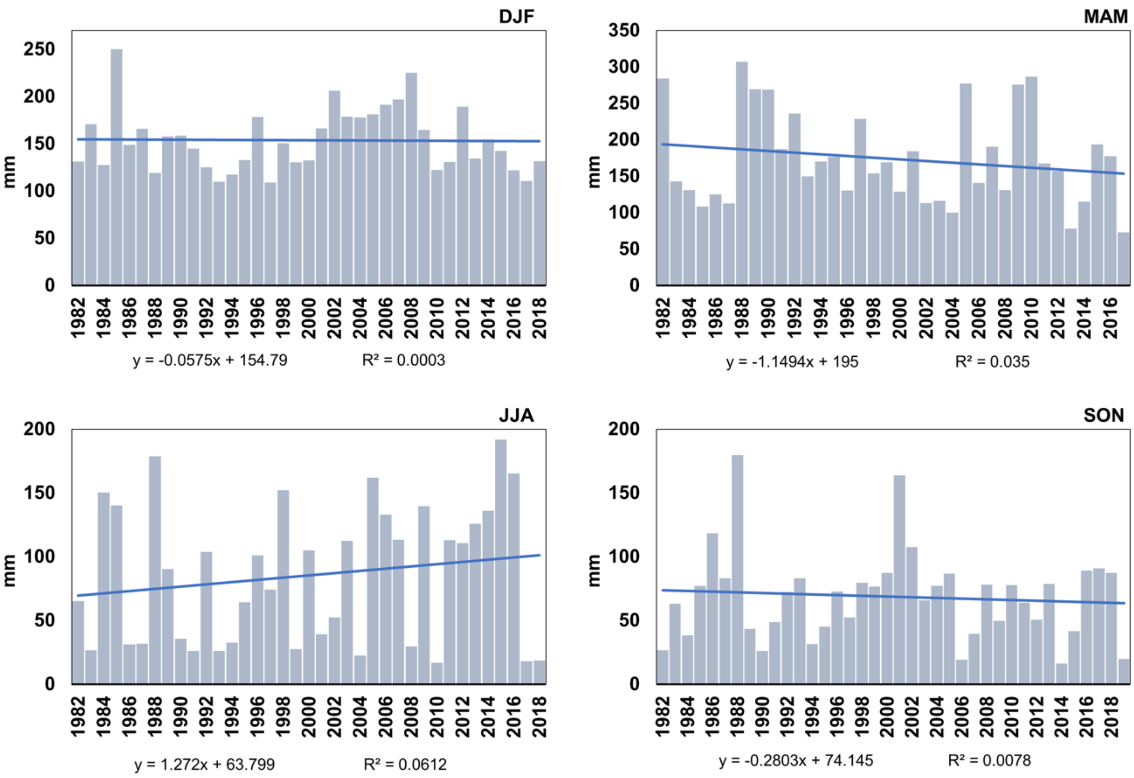

Figure A5.6: RX5day index in Timor-Leste. Seasonal maximum 5-day PR total. [CHIRPS data].

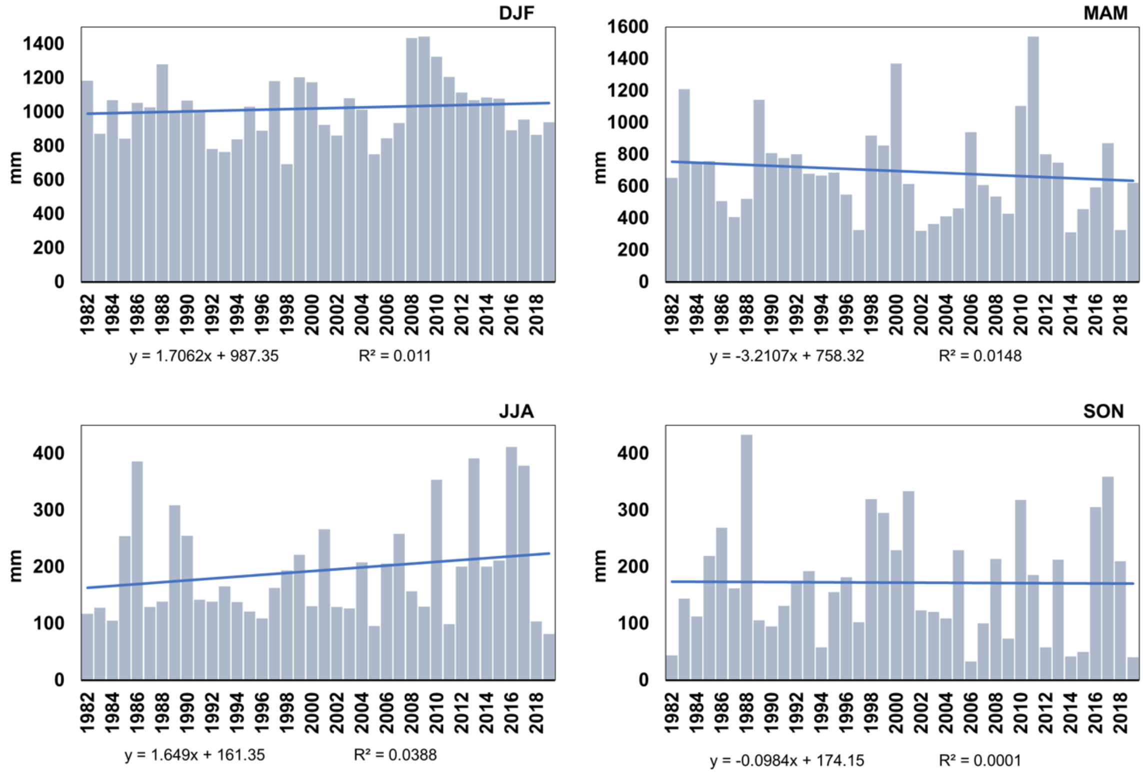

Figure A5.7: PRCPTOT index in Timor-Leste. Seasonal sum of daily PR >= 1.0 mm. [CHIRPS data].