Climate Risk and Vulnerability Assessment

Northern Laos

In the context of GIZ FP

April 7 2022

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Part A – Introduction

1. Context

This report contains the findings of a **climate risk and vulnerability assessment (CRVA)** that was undertaken as part of the development of Phase 2 of GIZ's project FP117: "Scaling up the Implementation of the Lao PDR Emission Reductions Program through improved governance and sustainable forest landscape management."

The purpose of the CRVA was to:

1. Inform the GCF FP on climate change issues, trends and projections in the project area
2. Determine the extent to which the observed climate risk / vulnerability of the target group in the target region is due to climate change (climate attribution; and,
3. Give recommendations on adaptation measures to decrease the vulnerability and risk of the target group.

An inception report was prepared in January 2022 and data collection undertaken with the support of the GIZ local office. Data was collected from various local and public sources and validated with local officials as needed. The CRVA team is thankful to the project design team, the local project management team and the GIZ regional experts for their support, guidance and information.

This report is structured as follows. Section 2 contains a description of the scope and methodology used, along with main data sources and any study limitations. Section 3 provides a reconstruction and analysis of the impact pathways that also illustrate key pathways of action for the program. Under Part B, the report includes an analysis of the climate risks for the region as a whole (Section 4), and for each province (Section 5). For each province and the targeted districts within it, the analysis includes past and projected climate trends for hazards and exposure, and an analysis of vulnerability (sensitivity, adaptive and coping capacity). In section 6, the report summarizes findings and recommendations are provided in Section 7

2. Scope and Methodology

2.1 Geographic and Thematic Scope

Project 1 was approved by the Green Climate Fund in 2019 (FP117). Originally conceived as a single project, it was reframed as a programme with three subprojects (Phase 1, 2, and 3. Phase 2 expands Phase 1's original three provinces (240 villages) to six, plus 50 additional villages in the initial 3 provinces.

Project 2 aims to improve governance, sustainable management of forests, landscapes, and agricultural resources, by implementation of the Lao PDR Emission Reductions Program in seventeen districts in three provinces of northern Lao PDR (Houaphan, Luang Prabang and Sayaboury). Working with national and sub-national authorities, as well as non-state actors, will improve conditions for sustainable forest management and specifically for Reducing Emissions from Deforestation and Forest Degradation (REDD+). The second project includes an adaptation component related to the need to adapt agriculture and land use practices to climate risks in the context of deforestation-free agriculture. The CRVA focuses on the 6 provinces and 31 districts included in the program area, through the lens of agriculture and forestry sector and strengthening the resilience of local livelihoods and ecosystems.

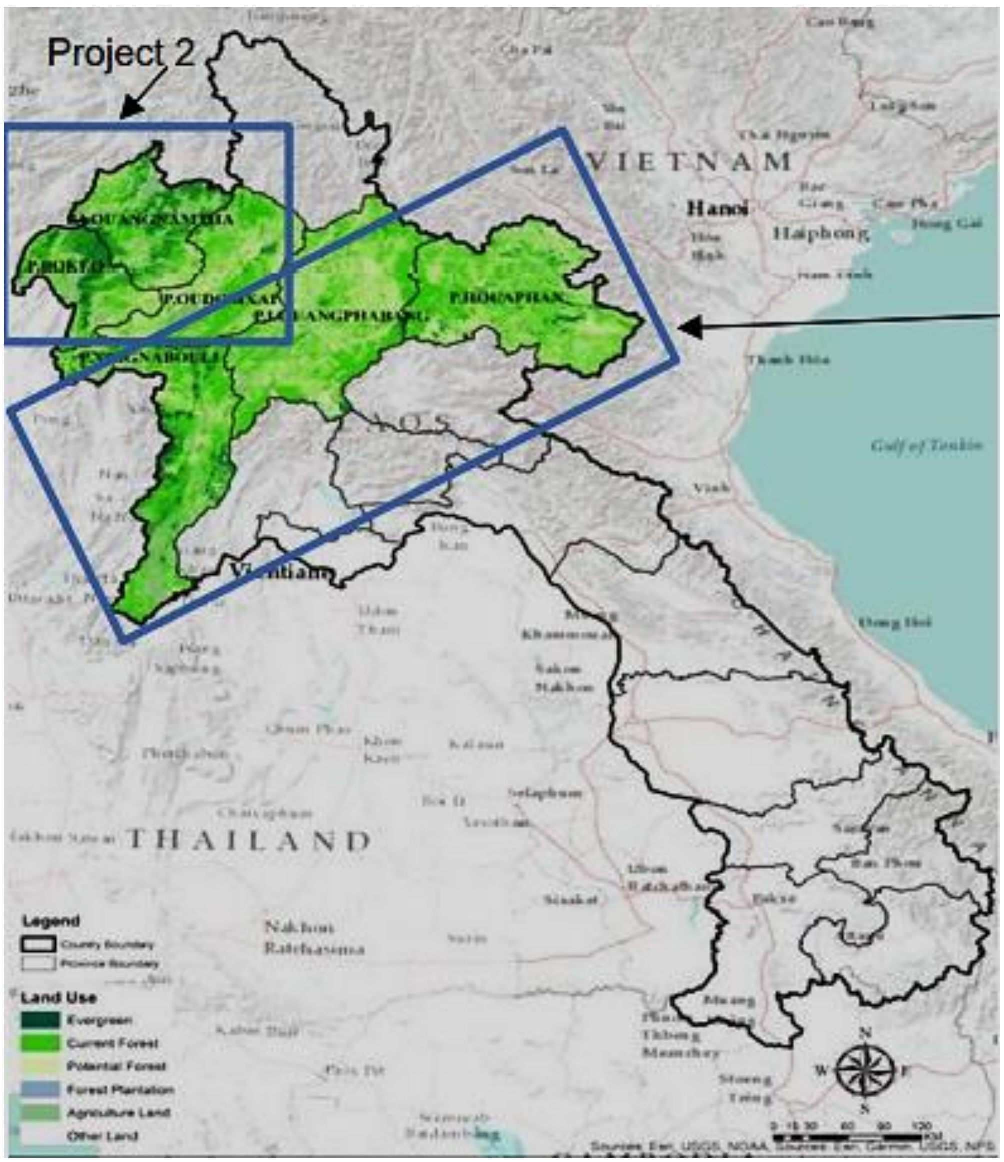

Figure 1: Map of the program area

2.2 Methodology

This CRVA was informed by the process delineated in the GIZ 2017 Vulnerability Sourcebook and accompanying Risk Supplement[1]. The assessment adopts the definitions of risks, vulnerability, exposure and sensitivity as outlined in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5) as seen in Figure 2: Illustration of the key concepts used in this report).[2]

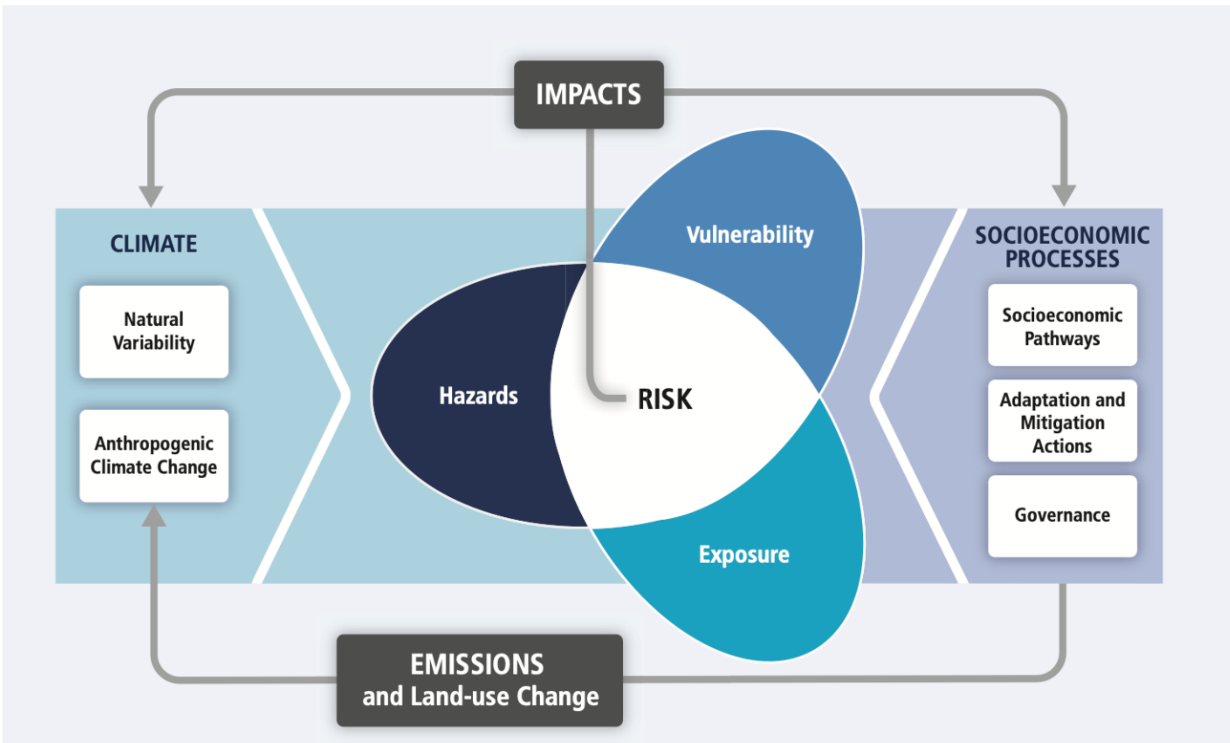

Figure 2: Illustration of the key concepts used in this report[3]

2.2.1 Key definitions and indicators

[1] GIZ and EURAC, 2017, The Vulnerability Sourcebook: concept and guidelines for standardised assessments
GIZ and EURAC 2017: Risk Supplement to the Vulnerability Sourcebook: Guidance on how to apply the Vulnerability Sourcebook's approach with the new IPCC AR5 concept of climate risk. Bonn: GIZ
[2] IPCC, 2014, Impacts, Adaptation and Vulnerability. Retrieved from: https://www.ipcc.ch/report/ar5/wg2/

[3] *IPCC Technical summary. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects, p.37*

Climate Risk

In this report, we use the IPCC definition of climate risk, as outlined in the 5th Assessment Report. *Risk* is the likelihood of impact resulting from the combination of hazards and exposures, that cause a change in vulnerability.[4] Risks are external factors and a result of climate change impacts, both direct and/or indirect. Vulnerability is therefore directly influenced by risk, and risk can be thought of as 'active' elements that are continually defining a community's or system's vulnerability.

Impact

In this report we use the definition of impacts as "effects on natural and human systems" from a given set of climate factors. The term 'impacts' is used primarily to refer to the effects of climate change on natural and human systems of extreme weather and climate events.[5] We will refer to impacts as both already visible (impacts of climate change) and as projected, or likely (Risks).

Resilience

The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning, and transformation.[6]

Hazards

We adopted the following definition of hazard as explained in the IPCC AR5: "the potential occurrence of a climate-related physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources[7]." In this report, we use past climate trends and climate projections at different horizons to derive the likelihood of occurrence.

Under the Hazard category, we selected a number of indicators related to changes in rainfall and temperature, as well as the frequency of occurrence of extremes and natural hazards, as seen in Table 1. We considered trends over the past 30 years (most data sets range from 1990 to 2020, though some data sets are from 1980 to 2022) as well as some projected trends for the periods 2020-2040 (represented as the 2030 point), 2041-2070 (represented as 2050 point) and 2071-2090 (represented as the 2080 point) depending on two climate scenarios. Indicators 1 through 5

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[4] IPCC, 2014, Annex II: Glossary, pp 117-130. Retrieved from: https://www.ipcc.ch/site/assets/uploads/2019/01/SYRAR5-Glossary_en.pdf

[5] IPCC, 2014, Annex II: Glossary, pp 117-130. Retrieved from: https://www.ipcc.ch/site/assets/uploads/2019/01/SYRAR5-Glossary_en.pdf.

[6] Ibid.

[7] IPCC, 2014, Annex II: Glossary, pp 117-130. Retrieved from: https://www.ipcc.ch/site/assets/uploads/2019/01/SYRAR5-Glossary_en.pdf

represent past trends in terms of occurrence of climate related natural hazards and extremes such as floods, droughts or cyclones. Indicators 6 to 11 are focused on the changes in key climate parameters changes since the 1990s. Indicators 12 to 14 include projected changes in temperature, rainfall and evaporation for the two scenarios (RCP 4.5 and 8.5) and the three-time horizons (2030, 2050 and 2080).

Table 1: Hazards Sub-Indicators with definition, data unit, source and method of extraction.

	Indicator	Definition	Data Unit, aggregation/ disaggregation	Source and method of extraction,
H1	Number of droughts in the period 1990-2020	Drought: A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. (IPCC AR5)	# of reported events, province level	A query for all types of events was conducted using EM-DAT[8] database of reported events. It was cross-referenced with data available through DesInventar Sendai[9] and validated through local government. There was overall consistency between the sources of data at provincial level. However, Sendai provided district level data, but potentially overcounted incidences, while the locally sourced data was at provincial level and did not distinguish if incident within a year was part of a singular event that affected several districts or different events affecting different districts at different times within the same year. To avoid the potential for overcounting events, a maximum one event per year per province was counted and only provincial level aggregation was retained for index calculation.
H 2	Number of floods in the period 1990-2020	Flood: The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. Include river (fluvial) floods, flash floods, urban floods, pluvial floods	# of reported events, province level	A query for all types of events was conducted using EM-DAT[10] database of reported events. It was cross-referenced with data available through DesInventar Sendai[11] and validated through local government. There was overall consistency between the sources of data at provincial level. However, Sendai provided district level data, but potentially overcounted incidences, while the locally sourced data[12] was at provincial level and did not distinguish if incident

[8] https://emdat.be
[9] https://www.desinventar.net
[10] https://emdat.be
[11] https://www.desinventar.net
[12] Government of Lao PDR

				within a year was part of a singular event that affected several districts or different events affecting different districts at different times within the same year. To avoid the potential for overcounting events, a maximum one event per year per province was counted and only provincial level aggregation was retained for index calculation.
H 3	Number of cyclones, storms in the period 1990-2020	A tropical storm is a tropical cyclone with 1-minute average surface winds between 18 and 32 m s–1.	# of reported events, province level	The data was sourced through local meteorological offices in each province[13]. The tally does not distinguish if each incident within a year is part of a singular event or if there were different events at different times within the same year. To avoid the potential for overcounting events, only one event per year per district is counted.
H 4	Number of landslides in the period 1990-2020	Event in which rainfall or erosion leads to rapid and significant sediment transfer from uphill areas	# of reported events, province level	The data was sourced through local offices in each province (PONRE). The tally does not distinguish if each incident within a year is part of a singular event or if there were different events at different times within the same year. To avoid the potential for overcounting events, only one event per year per district is counted.
H 5	Number of wildfires in the period 1990-2020	Fire that affects a significant area of forest, agricultural land, rangeland or pasture.	# of reported events, province level	Includes forest fires of involuntary nature only. Provincial tally is a mix of EMDAT data, GIZ-provided tally, and Sendai DesInventar. Sendai provided district level data, but potentially overcounted incidences and locally sourced tally did not distinguish if incident within a year is part of a singular event that affected several districts or different events affecting different districts at different times within the same year. To avoid the

[13] Government of Lao PDR, PONRE

				potential for overcounting events, only one event per year per province is counted.
H 6	Number of occurrences of temperature extremes (2000-2020)	Average # of days per year above 32 °C from 2000 - 2020	Average # of days per year above 32 °C from 2000 - 2020	Data extracted from earthmap.org[14] using ECMWF ERA5 Land updated hourly. The maximum of 32oC was retained as the heat stress threshold as this represents a temperature approximately 30% above the average in Lao PDR, which can be assumed to have significant impacts on plant growth, animals and humans.
H 7	Number of occurrences of precipitation extremes	Monthly precipitation greater than 90% of the range of precipitation values for that month	Average Days per year from 2000 - 2020	Data was extracted from earthmap.org, using the ECMWF ERA5 Land hourly reanalysis dataset that is reduced to daily maximums. For the precipitation threshold we opted for 10 mms to keep in line with the range of daily precipitation for Lao PDR.
H 8	Change in mean annual surface temperature in the period 1979-2022	Annual rate of change in the mean temperature.	change in degrees Celsius (+ or -; rounded to nearest hundredth)	The 'Mean Temperature' change was extracted from earthmap.org processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. The total change would be the multiplication of this number by the total number of years).
H9	Change in the mean annual precipitation in the period 1990-2020	Annual change in the mean precipitation rate.	Annual change in mms (+ or -; rounded to the nearest hundredth)	Earthmap.org using Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS v2) grids at 5-day temporal resolution.
H10	Change in aridity in the period 2001-2020	Using aridity as a proxy for humidity, UNEP's aridity formula is used here, which is the ratio between annual precipitation and potential	Change per year in aridity index, at district level. Provincial level is the average of district values	Sourced using earthmap.org which is computed using the total precipitation product derived from ERA5-Land data from the European Centre for Medium-Range Weather Forecasts (ECMWF) and the

[14] www. Earthmap.org

		evapotranspiration - arid lands are lands with an AI of less than 0.65.		potential evapotranspiration product derived from MOD16A2 MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500m version 6 image collection.
H11	Change in evaporation rates in the period 2001-2019	The FAO definition of evapotranspiration is the loss of water vapour from plant to atmosphere through the soil and/or plant tissue.[15]	Change in PET rate expressed in kg/m2 over the period, at district level	From earthmap.org. The Potential Evapotranspiration product comes from MOD16A2 MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500m version. Potential evapotranspiration is defined as the amount of evaporation that would occur if a sufficient water source were available. A map was generated with pixels at ted the blocks and their associated values and averaged them together when necessary, as some districts had singular values while others were mixed.
H12	Anticipated change in mean annual temperature	Degree of anticipated change in mean annual temperature at a given time point under a given climate scenario.	Change in degrees Celsius (+ or -) at district level. Provincial values are the average of district values.	Data sourced from climateinformation.org for each district to aggregate various models. Calculated as the mean annual values of daily mean temperature averaged over a 30 year period. This index is given as a absolute change against the reference period of 1981-2010 (future period minus reference period).
H13	Anticipated change in mean annual precipitation	Degree of anticipated change in mean annual precipitation at a given time point under a given climate scenario.	Relative change in percentage of mean annual rainfall, at district level. Provincial values are averaged from district values.	Data sourced from climateinformation.org. Calculated as the mean annual values of daily precipitation averaged over a 30 year period compared to 1981–2010
H14	Anticipated change in aridity	Degree of anticipated change in aridity index at a given time point under a given climate scenario.	Relative change in percentage in aridity index	Data sourced from climateinformation.org. Calculated as mean annual values of the ratio between actual evapotranspiration and precipitation for a 30 years period.

[15] FAO: https://www.fao.org/3/x0490e/x0490e04.htm

Exposure

In this report, the term exposure refers to "the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected" (IPCC AR5). For the purposes of this CRVA, we have retained a series of indicators related to population (density) and ecosystems (forests and land), compounded by past trends in terms of exposure to droughts and floods and topographical features specific to the local landscape (slopes), as listed in Table 2. These indicators are meant to give an account of the extent to which local communities and ecosystems are situated in places or settings that expose them to the climate signals listed above. While the indicators H1 and H2 give an idea of the purely climatological occurrence of droughts and floods, the indicators E2 and E3 are intended to provide an idea of exposure to such events. This becomes particularly relevant when considering the values as disaggregated by gender or belonging to ethnic group.

Furthermore, as can be seen from the list below, the indicators are directly related to the project's areas of intervention and theory of change (forest degradation, extent of forest cover). This means that changes created by the project's interventions are intended to act on exposure to some degree.

Table 2 Exposure Indicators with definition, data type, and source

	Indicator	Definition	Data Unit and disaggregation	Source of information
E1	Population Density	Refers to the number of people per a specific unit of geographic area. In this case, it will refer to the amount of people per sq kilometer	n/1 sq km	2015 Lao Census[16]. Converting the total hectares for each district provided by GIZ with population provided by the 2015 Lao Census, gave the estimated population density for each district.
E2	# of people affected by droughts and flood over period 1990-2021	Number of people affected between 1991 and 2021 from droughts and floods as defined by IPCC AR5.	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	2015 Lao Census, Sendai DeSinventar, and data validated by provincial government offices. The 2015 Lao Census provides data on ethnic groups but it is not disaggregated at the provincial and district level. Using the national ethnic group percentages means that disaggregating the Sendai DesInventar data will most likely lead to the ethnic groups column is being overestimated. For this report we assume that percentage of non-Lao ethnic group Lao citizens mirror the national level percentages. While the disaggregated may lack exactness, the numbers in and of themselves matter less than showing the magnitude of effect. That is, given that not all provinces have the same populations and/or are affected the same by drought and flood, what is demonstrated are which provinces are affected the most.
E3	% of land with an incline of over 10%	Area of land in Km2 with an incline of over 10% divided by area of land in district	% of district	Earthmap.org sourced from Shuttle Radar Topography Mission (SRTM) digital elevation dataset.

[16] Lao Census of Population, 2015, https://ghdx.healthdata.org/record/laos-population-and-housing-census-2015 and also direct communication from Government of Lao PDR for raw data.

E4	% of land developed or constructed	includes urban centers, cities, major roads	% of district	GIZ Data collected on site (Hansen dataset)
E5	% area under forest cover	% of provincial/district area under forest	% of forests	GIZ Data collected on site (Hansen dataset)
E6	Extent of forest degradation	Forest degradation: a reduction of canopy cover or stocking within the forest. State the area of forest that is considered more than mildly degraded.	% of forests	GIZ Data collected on site (Hansen dataset)
E7	Extent of land degradation	area of land expressed as % of district total area that is considered as more than lightly degraded, as per FAO definition of "temporary or permanent lowering of the productive capacity"	% of district land	Data extracted from earthmap.org using the land productivity dynamics indicator. Land Productivity Dynamics - MODIS LPD is a map of persistent decline/stress, stability and gain of land productivity, strictly during the observation period from 2001 to 2018 generated through the interaction of three NDVI-based indicators: Steadiness, Initial standing biomass, and Standing biomass at change .

Vulnerability

For the indicators related to vulnerability, we used the definition of the IPCC, but slightly adapted it to the needs of this project, as follows: "the propensity or predisposition to be adversely affected, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt"[17].

Our indicators are situated within the scope of the project and local context, and related to the sub-category of sensitivity and adaptive capacity. We also selected indicators designed to give an idea of the communities' current ability to cope and adapt to climate variability and climate change. It should be noted that the ability of ecosystems to adapt is also a factor of the indicators listed under exposure, in this case, forest and land degradation, however for simplification it was decided not to duplicate them under vulnerability.
Given that the program intends to act on these variables, any change in the measure of these indicators (sensitivity, coping capacity or adaptive capacity) would lead to a change in vulnerability.

IPCC's AR5 definition of **adaptive or coping capacity** is the 'ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.'[18] Adaptation measures can vary, but the bottom line is that a successful adaptative measure is one that allows stakeholders to cope or even benefit from climate change impacts. Our definition of adaptive capacity is context-specific, meaning that it considers the nature of the specific project beneficiaries (smallholder farmers, forest users) and what would be needed for them to adapt to climate change in the context of this project.

In AR4 and 5, **sensitivity** is a component of vulnerability that refers to *the susceptibility to harm*.[19] For the purposes of this assessment, using the GIZ's *Risk Supplement to the Vulnerability Sourcebook,* sensitivity will be defined as the degree to which a system is likely to be adversely affected by climate change exposure. Natural and/or physical attributes can define sensitivity, e.g. topography, soil types, but also socio-economic factors that are beyond the individual's control, for example gender and poverty status.

Indicators retained, as illustrated in Table 3 and

[17] IPCC, 2014, Annex II: Glossary, pp 117-130. Retrieved from: https://www.ipcc.ch/site/assets/uploads/2019/01/SYRAR5-Glossary_en.pdf
[18] IPCC, 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability; Summary for Policymakers.* Retrieved from: https://www.ipcc.ch/site/assets/uploads/2018/02/ar5_wgII_spm_en.pdf.
[19] IPCC, 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability; Summary for Policymakers.* Retrieved from: https://www.ipcc.ch/site/assets/uploads/2018/02/ar5_wgII_spm_en.pdf

Table 4, were also directly related to the thematic scope (forestry and agriculture) and the main impact pathways (for example those related to the impacts of climate change on the hydrological cycle). Additionally, the indicators in this category were disaggregated by gender and by belonging to ethnic group, to give an account of the differentiated vulnerability and capacity to adapt among the different socio-economic statuses. This will help inform a gender-sensitive and socially inclusive strategy for the program.

Table 3 Coping and adaptive capacity indicators with definition, data unit, and source

	Indicator	**Definition**	**Data Unit and disaggregation**	**Source**
V1	# of local population with access to non-farm income	# of people exercising a paid profession that is not dependent on agriculture or forest use	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	2015 Lao Census. Using data from Table 9.3 (pg 76) and Table 9.6 (pg 80); multiplied the population of the province/district by the provincial active employment rate and then by the national non-agricultural employment percentage (only national values were given for industry type of employment), then divide the result by 2 to gender disaggregate the data, and then multiply that result by .532/.468 to get ethnic group disaggregation.
V2	% of local population with year round access to roads	% of population within km of a road	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	2015 Lao Census.
V3	% of population with year-round access to safe drinking water and sanitation facilities	Only include population with year-round access	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	2015 Lao Census. Using data from Table P8.12 and summed categories 'Piped water,' 'Well/borhehold protected,' 'bottled or canned water,' and 'Tank;' multiplying the result by the average persons per household from Table P8.1. The result from this calculation was then divided by total pop for province - from Table P1.1 and disaggregated for gender, ethnicity. District numbers were generated by first calculating by using the

				household population numbers and finding the percentage of the provincial population living in households (for example Bokeo has 81630 people living in households out of a total population of 179243 or 46%) . After generating the percentage, multiplied the district population by that estimate and then disaggregate the numbers. While some discrepancies exist between the sum of the district percentages and the provincial percentages, the fact that the estimates approximate the Census numbers lends viability to this method. Since only persons in households are considered, it should be noted that any population that isn't a part of a household is not captured in this calculation - which isn't large, but needs to be noted.
V4	# of local population relying on rainfed crops for livelihood	# of local farmers relying on any rainfed crop for food security or income	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	Earthmap.org using earthmap.org uses GFSAD1000 to show crop types and distribution. Using the GFSAD1000 model, the populations for the districts were first disaggregated for ethnicity and then gender, and then comparing with the GFSAD1000 map model, an estimate was derived for the population. Where no data exists, a 0 is inputted.

V5	% of local population with access to climate information/EWS	Includes agronomic advice, extension, last mile climate services as well as early warnings and seasonal warnings	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	Data collected by survey from provincial meterorological offices (Government of Lao PDR)
V6	# of access to communication media	# of people with access to phone, TV, radio, internet	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	Data collected by survey from provincial meterorological offices (Government of Lao PDR)

Table 4 Sensitivity Sub-Indicators with definitions, data unit, and sources

	Indicator	Definition	Data Unit	Source
V7	# of female-led households	households where the main source of income and food is derived from a woman's activity	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	2015 Lao Census. Combining together proportion of female-led households in urban and rural, yielded 12.65%, which was then used to multiply the number of households in each province to produce estimates of female led households. Discrepancies exist between the district totals and the province numbers as the provincial household numbers include districts that are not included in the project. The province's estimates will always be greater than the sums of the districts.
V8	# of people with a disability	Includes physical disability as well as intellectual disability	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	2015 Lao Census. To get the a rough estimate of disability, each province was multiplied by its disability percentage, as provided in the Lao Census. The result was then divided again in half, to match the national percentage difference of male and female (50%). Given that district level disability percentages were not given and any estimate would be akin to throwing a dart at a board, it was not pursued. Likewise with Ethnic Groups,

				given that ethnic groups cover several non-Laotian groups and are not gender-disaggregated, any estimate would be an over estimate and would give an impression that ethnic groups had severe disability numbers. While non-Laotian groups may have disability figures higher than Laotian groups for any number of reasons, without any data to verify the accuracy of the estimate, the potential for grossly exaggerated estimates is too high to justify conducting the estimates in the first place.
V9	# of local population living with food insecurity	FAO defines FI as "a person is food insecure when they lack regular access to enough safe and nutritious food for normal growth and development and an active and healthy life."[20]	- # of people from non-Laotian ethnic groups - # of Lao ethnic group women - # of Lao ethnic group men	FAO[21], WFP[22]

20 https://www.fao.org/hunger/en/
21 FAO, Special Report, Crop and Food Security Assessment Mission to the Lao People's Democratic Republic, 2020
22 World Food Programme, Consolidated Livelihoods Exercise for Analysing Resilience, Lao PDR, 2017.

2.2.2 The Climate Risk Assessment Tool and Indices

The CRVA was informed through a mix of desk-based literature review and field level data collection in the six project provinces. Desk-based data came from the Lao Census, Lao Agriculture Census, Climateinformation.org, IPCC Dashboard, Desinventar disaster database, and Earthmap.org, among others. To the extent possible, data was also collected or validated through local authorities and the GIZ program offices, with triangulation across different sources (for example, WFP Comprehensive Livelihoods Assessment Report or UNESCO databases on water). (see section 2.2.3 for more discussion on data sources and availability.)

Following the compilation of data points, indices were attributed to each of the main indicators and calculated for each of the main categories of Hazards, Exposure and Vulnerability to allow for ranking and comparison across districts and provinces. Indices were calculated for the 2 RCP scenarios (4.5 and 8.5) at 3 different time points so that the program team would see the difference in scores according to which climate scenarios would materialize. Each district then has 6 potentially different Risk scores.

To calculate the indices, some normalizing and harmonizing of data was necessary, because each indicator had a distinct range of possible values (minimum and maximum). For example, the indicator "% of population experiencing stunting and malnutrition" had values in a different range and of a different order of magnitude than the indicator "Number of droughts in the past 30 years."

While it would have been possible to generate an arbitrary standard to benchmark each indicator and derive a numerical score, too much variability between indicators made it methodologically difficult. Therefore, each indicator was 'translated' into a numerical value (1-5) that would then allow comparison of all indicators on the same scale and range. To achieve consistent results, scaled values were generated by normalizing raw data. Normalization comes from statistics and refers to values, after being scaled, generating a set of values that makes a binomial distribution, also known as a normal distribution.

This 'normal' distribution is visually seen as a single 'mound' or 'hump' with most of the values coalescing around a central point and trail out at either end or tail. This distribution represents where the majority of values lie, what is the most common pattern seen. In excel, the scoring formula is given as follows: = (A1 - MIN(A:A)) / (MAX(A:A) - MIN(A:A)). This formula generates a scaled valued, similar to statistical 'z-scores," by generating a value on a scale of 0 to 1 by comparing the value of the district or province being calculated, against the range of district, province values for that indicator. In other words, if this value is X out of 100, how does it compare to all the other values on that same scale? How much more vulnerable or less is it compared to all the other districts, provinces for that indicator?

Scaled values then had to be scored. While it would seem that the scaled value can be used as is, however, these scaled values generated came in the form of 0.35, 0.17, etc. Tallying such values can make it harder to distinguish the magnitude of difference that may emerge between districts and districts, district and province, and province to province. Scale values were thus 'translated' into whole values or scores. The excel formula " = IFS(A1>0.9,"9",A1>0.8,"8",A1>0.7,"7", A1>0.6,"6", A1>0.5,"5", A1>0.4,"4", A1>0.3,"3", A1>0.2,"2", A1>0.1,"1", A1=0,"0")" was used to generate these scores. The 'ifs' function determines the value of a cell by comparing it to a rule, in this case, if the value in column A, row1 was greater than several values. If A1 had a value of 0.36, for example, it would generate a score of "3." This formula was repeated for each indicator and generated for each district and each province.

The resulting indices and ranking should be read not as absolute indicators and scale of vulnerability but as program-specific indications. However, because the project intends to act on some of the indicators included in the database, the indices can be integrated in the project's Monitoring and Evaluation framework, to track program-induced changes.

2.2.3 Challenges and Limitations

Data sources and extraction methods are indicated in section 2.1 for each of the indicators. Unless specified otherwise, all data referred to in this report originates from these harmonized data sets, and references were not repeated to alleviate the reading.

This CRVA has some inherent limitations. First, data collection was a challenge, as it was not always possible to obtain coherent, harmonized data for each indicator in each district. In some cases, data was only available at the provincial level. In those cases, we used the provincial level data as an average for all the districts, so as to not leave any blanks and ensure the indices were calculated on comparable bases. The CRAT database in Annex 1 contains notes and explanations of data when necessary.

As seen in Figure 3, Northern Lao PDR is covered by 8 automated weather stations and 7 manual stations and there are agrometeorological stations in Tonpheyng, Houay Xai, Houn, Sing, Luang Namtha, though part of these were newly established as part of the FAO-GEF supported SAMIS project. Data sources for rainfall and temperature used in this report are mostly sourced from non-local databases, because historical datasets from meteorological stations are not harmonized and many are available for only limited time-periods. Furthermore, because many projections and models have been conducted in the past few years for Lao PDR, it was preferred to leverage existing datasets and cross-reference existing models. However, data from Oudomxai and Luang Namtha rainfall stations were compiled for a study conducted in 2019[23] that may be used to benchmark and further validate projections.

We also encountered other limitations related to the modeling tools. For example, for indicators related to extremes and disasters, different databases counted extreme events differently, and some only gave data at provincial level while others also gave district level, and in the case of the Sendai DesInventar database, there was concern about double counting. To avoid confusion

[23] Tadross, M. Trends and Simulated Future changes in climate and crop suitability in Lao PDR, 2019. Reproduced with permission by the author.

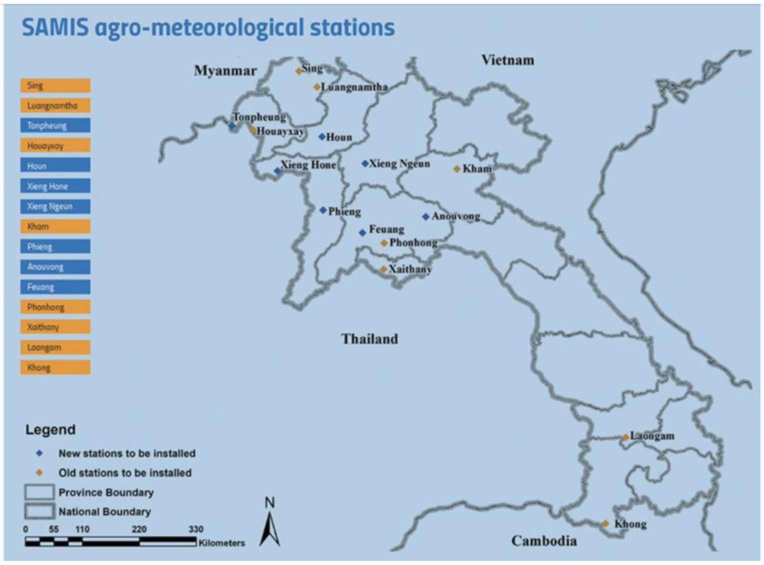

Figure 3: Agrometeorological stations

on the tally, any district level count was subsumed into the provincial tally and any count, and only one event per year per district/province were counted, so the district level numbers are equal to the provincial level tally.

Finally, as noted earlier, because data was not collected for districts outside the scope of the project and because of the methodology we used to calculate indices, the ranking obtained should be interpreted as a ranking of districts and provinces *among themselves*, **and not as an absolute ranking of risk or vulnerability**. The purpose of the ranking and indices is to better to understand the differences in impact pathways from one project site to another, for better targeting.

Part B - Climate Risks and Vulnerability Analysis

In this second part of the report, we first begin by presenting impact pathways (Section 3) according to both 4.5 and 8.5 scenarios, then present findings of the climate risk and vulnerability analysis at national level, then gradually zooming in to the concerned region (Northern Laos) (section 4), followed by provincial and district-level findings (Section 5). Section 6 contains conclusions and recommendations.

3. Analysis of Impact Pathways

In order to provide a general understanding of the various manners in which climate and climate change is impacting local communities and ecosystems, we first reconstructed a "theory of change" model in which all key climate variables are represented, to illustrate the potential pathways. On the basis of data analysed and collected for this report (refer to Section 2 for data sources and models), we then compared the pathways according to RCP 4.5 or RCP 8.5 scenario at the 2080 point. We selected this time point to illustrate the long-term trends, bearing in mind – as will also be illustrated later – that data for Northern Lao PDR shows that current trends are likely to show a reversal starting in 2040. The exercise illustrates the impact pathways without adaptation, and a depiction of impact pathways with adaptation is included in Section 6, mapping project interventions to the different pathways.

3.1 Impact Pathways

In Figure 4, increasing global GHG emissions are driving change along three distinct, but interconnected, "branches": increasing temperatures (for our targeted area this ranges between 1 to 1.34ºC); erratic rainfall (delayed onset of June, July, August rains); and increased rainfall (up to 20% in certain locations depending on the scenario). Each of these in turn drives a series of further changes: increased temperature leads to increased evapotranspiration, and therefore increased aridity, which fuels increased crop water demand. In addition, the sharp increases in rainfall drastically increase run-off and the likelihood of flooding, which accelerate erosion and decrease available soil moisture. This leads to decreased soil fertility, short-term crop loss, and decreased long-term crop suitability, which drives decreased food production and therefore increases the likelihood of food insecurity and poverty (two key manifestations of vulnerability).

There are also other impact pathways, such as for example increased temperature and heatwaves leading to increased disease burden on local population and livestock and exacerbating the risk of crop loss and yield reductions due to wilting and drying. The combination of temperature and rainfall modifications also contribute to a potential increase in pests and disease outbreak for humans and livestock, and the proliferation of plant pathogens that may have been easier to control (mildew, mold, rot, etc.) under normal conditions, particularly at post-harvest stage.

The increased rainfall and the disrupted rainfall patterns, increased runoff and flooding have direct impacts on populations, infrastructure, leading to often rapid and immediate losses of property, livelihoods and lives in some cases.

In turn, the food insecurity and increased poverty in which local populations will find themselves (without adaptation) leads to land expansion (to compensate for lower food production) and deforestation, which further drives GHG emissions.

In Figure 4 below, the non-climate drivers that exacerbate the “mechanistic” cascade of climate problems are also represented. For example, increased rainfall leads to increased flooding, but that dynamic is significantly exacerbated by topography (slope), deforestation, forest degradation and land degradation. While the project cannot act on topography, it does intend to act on deforestation and land degradation by promoting sustainable deforestation-free agriculture. Similarly, the link between increased temperature and evapotranspiration and decreased food production is bolstered by maladapted agricultural practices such as unsustainable tillage, monoculture, lack of water management, or use of unsuited varieties. Ultimately, the program’s interventions on deforestation, land degradation and maladapted agricultural practices will reduce the likelihood of impact regardless of the climate scenario.

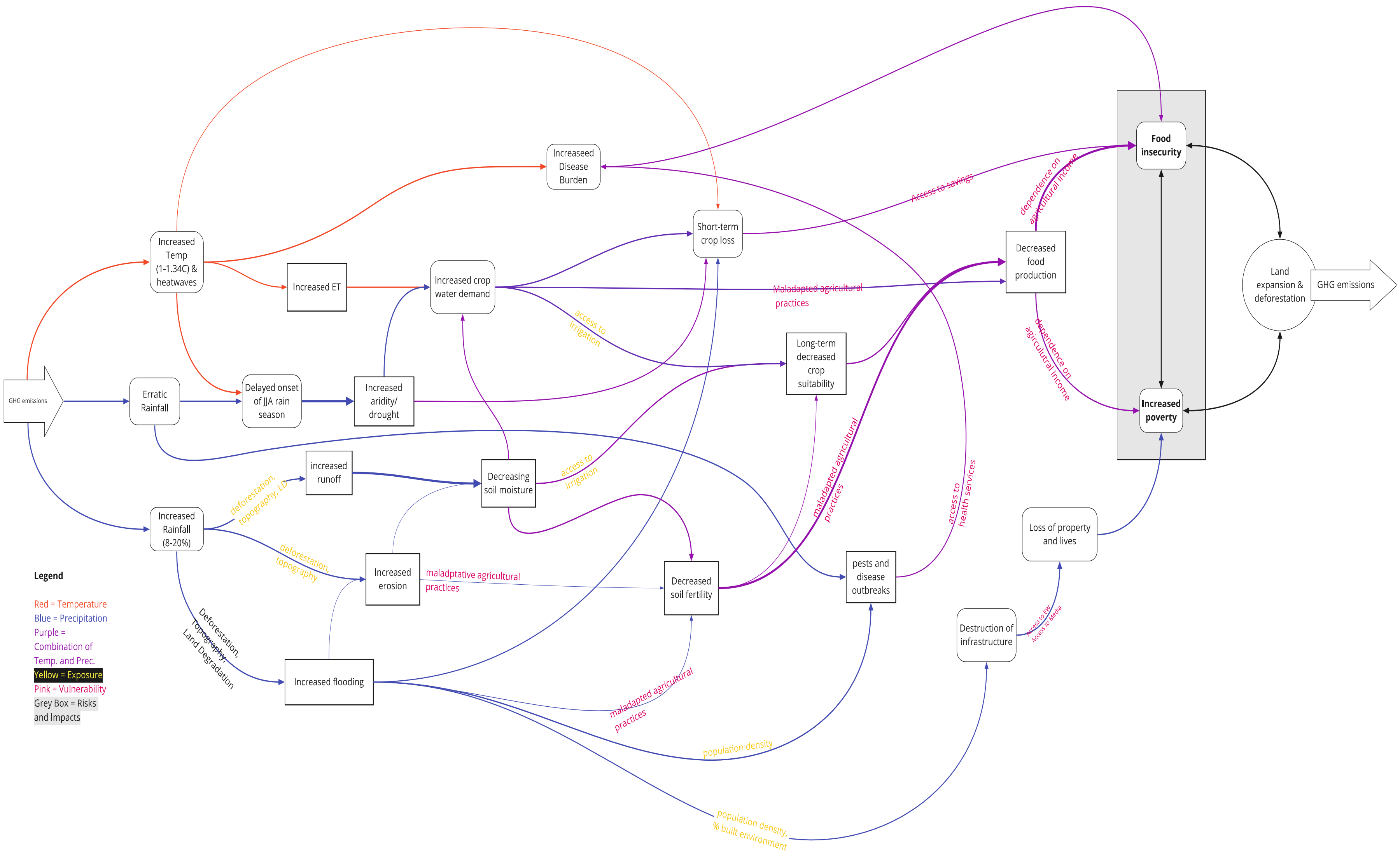

Figure 4: Illustration of the theory of impact pathways for Northern Lao PDR. Click [here](#) for a larger screen version.

3.2 Impact Pathways under different climate scenarios

Under the two different climate projections (RCP 4.5, Figure 5 and RCP 8.5, Figure 6) at the 2080 horizon, different “branches” take on different significance depending on the climate scenario. In both scenarios, the short-term crop losses caused by temperature increases and rainfall pattern modifications appear as a key pathway to vulnerability and impacts. In addition, we can conclude from available data (please refer to Annex 1 for data tables) that this short-term crop loss is a significant driver of land expansion and deforestation, more so than the long-term trends, if taken separately. The key difference between the two scenarios is the relative percentage of change: RCP 8.5's magnitude-of-effect is much greater than that seen under the RCP 4.5 scenario, illustrating the likely tipping points that would be crossed in such a scenario.

Under the 4.5 scenario already, the impact pathway that runs through increased temperatures and increased crop water demand takes on its full significance, and that does not change when considering the 8.5 scenario (the magnitude of change remains the same). This corroborates some of the findings explained in Sections 4 and 5, that in some provinces the brunt of the impact is already being felt, or would be felt under a 4.5 scenario, and that the marginal rate of change after 2040-2070 even if the 8.5 scenario materializes, would be relatively less severe (but only relatively).

However, under the 8.5 scenario, the likelihood of losses in terms of long-term crop suitability appear more significant than under the 4.5 scenario. This is because of the magnitude of expected accelerated run-off under the 8.5 scenario, which leads to more important or more rapid losses in terms of soil fertility and productivity. Similarly, the pathway running from rainfall increases to destruction of infrastructure (roads, post harvest, etc.) also takes on more magnitude under the 8.5 scenario than in the 4.5 scenario.

The pace of expected change across the different pathways is not fully represented in the figures. For example, some changes appear to lead to slower appearance of impacts, such as for instance the pathway flowing from erratic rainfall and increased dry spells to short-term crop loss, as opposed to the ones flowing through increased rainfall and flood. This means that, in the field, the perception of risk may differ: local communities may perceive the risk of impacts due to flooding as more significant because it appears faster and leaves less time to adapt, although the risk of drought and dry spells may be more significant than anticipated, over time. Communities may be inclined to invest more in “quick fixes” related to infrastructure as a response to flooding than they are to modify agricultural practices in response to slower temperature changes. It will be crucial to devise adaptation strategies that weigh the costs and benefits of both sets of rapid and slow responses.

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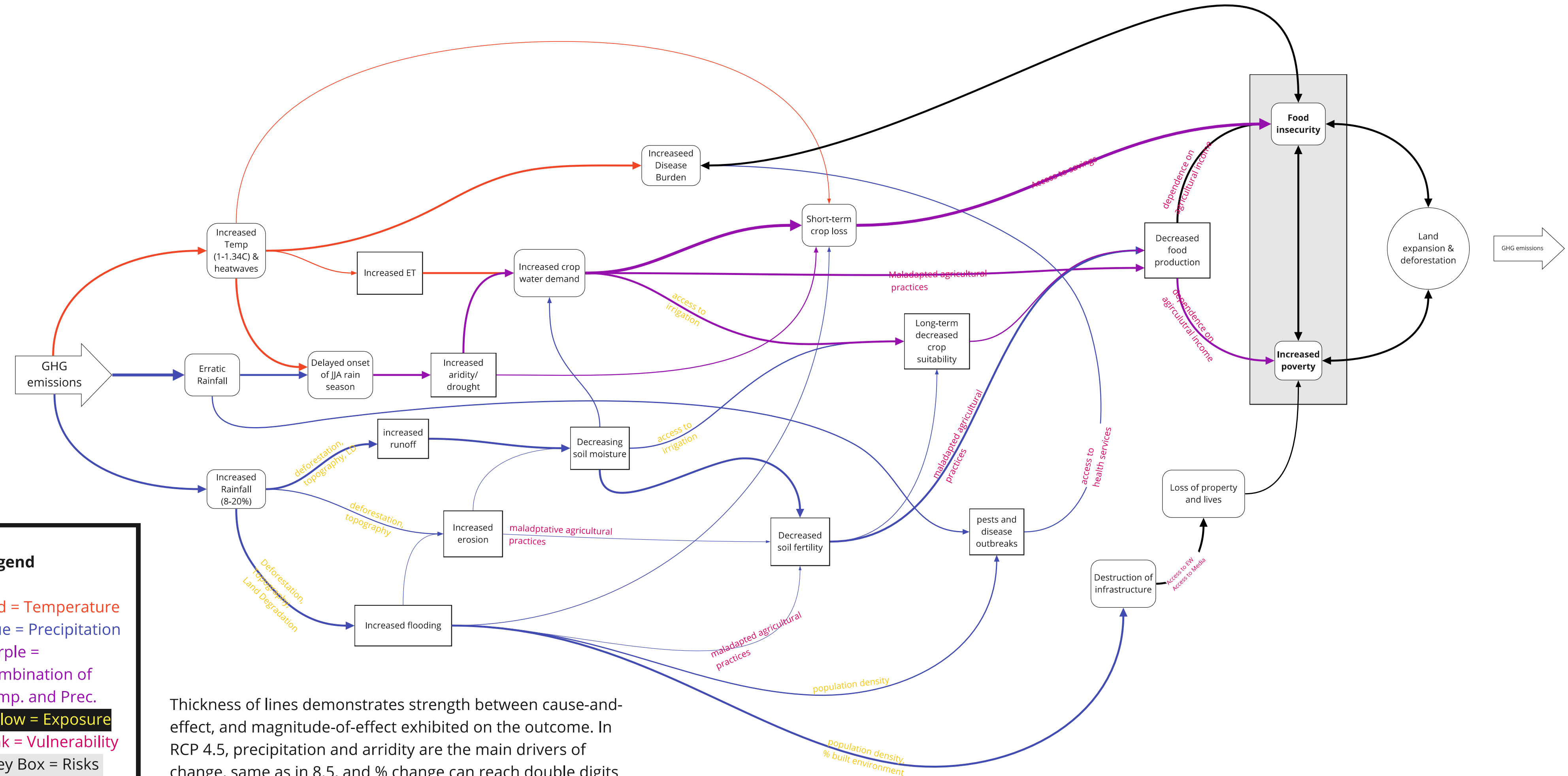

Legend

Red = Temperature
Blue = Precipitation
Purple = Combination of Temp. and Prec.
Yellow = Exposure
Pink = Vulnerability
Grey Box = Risks and Impacts

Thickness of lines demonstrates strength between cause-and-effect, and magnitude-of-effect exhibited on the outcome. In RCP 4.5, precipitation and arridity are the main drivers of change, same as in 8.5, and % change can reach double digits depending on the district, however RCP 8.5's magnitude-of-effect is much greater than 4.5.

Figure 5: Mapping of impact pathways under a 4.5 scenario. Please click here for a larger screen version

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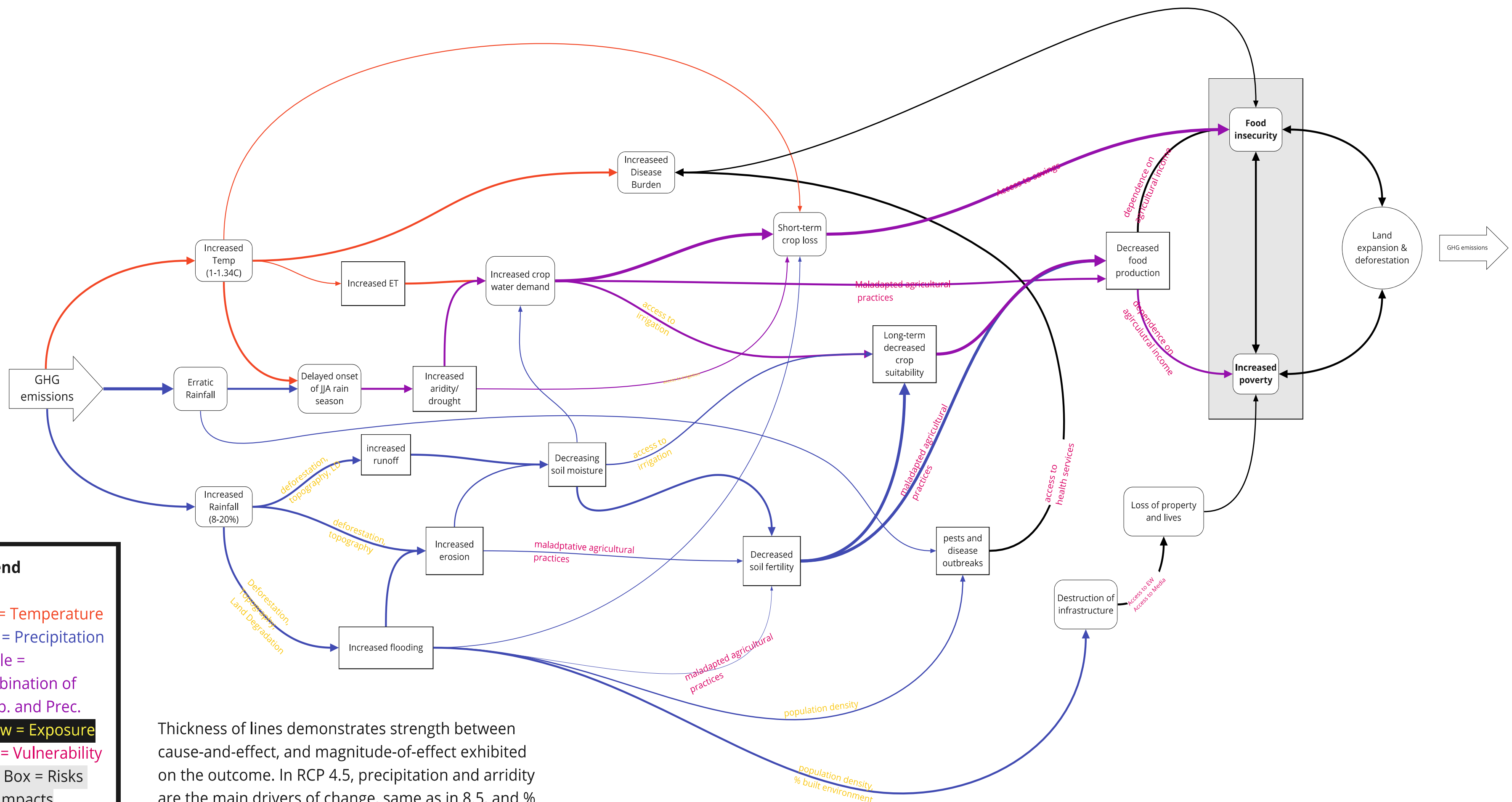

Legend

Red = Temperature
Blue = Precipitation
Purple = Combination of Temp. and Prec.
Yellow = Exposure
Pink = Vulnerability
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Thickness of lines demonstrates strength between cause-and-effect, and magnitude-of-effect exhibited on the outcome. In RCP 4.5, precipitation and arridity are the main drivers of change, same as in 8.5, and % change can reach double digits depending on the district, however RCP 8.5's magnitude-of-effect is much greater than 4.5.

Figure 6: Mapping of impact pathways under a 8.5 scenario. Please click [here]() for a larger screen version.

4. National level profile

In this chapter, we present findings from the analysis of available climate data for Lao PDR as a whole, and the Northern Region as an area of focus, given that larger trends will also be applicable to districts and villages. Chapter 5 presents a more granular analysis of impacts and vulnerability at district level, in order to better inform project activity selection strategies later on.

4.1 General Climate Profile

Lao PDR has a tropical climate with two distinct seasons: i) the May to mid-October rainy/monsoon season and ii) the mid-October to April dry season. From 1901 – 1985, Lao's mean annual surface temperature oscillated around 23.5 ºC, increasing to 23.75 ºC from 1986 – 2010, and since 2010, increased steadily (Figure 4).[24] The mean annual surface temperature ranges from 21ºC to 24ºC in the Northern and Eastern mountainous areas and plateaus (see Table 5[25]), cooler than the central and southern regions which average 25ºC to 27ºC.[26] Precipitation ranges from 1,300 to 1950 mm (Table 5;Figure 8 Average accumulated annual rainfall in Lao PDR during the period from 2010-2019; Source: DALAM and DMH in FAO 2021 Figure 7 WFP and Lao MoNRE, 2016; Source: FAO/WFP 2019 Special Report), which is lower that the far south and north-central region of the country (especially Luang Prabang, Xiengkhuang and Vientiane); which can get up 3000 mm annually (see Figure 3, 5).[27]

Province	Temperature		Precipitation	
	Period	Average annual temperature (ºC)	Period	Annual average precipitation (mm)
Luang Namtha	1991 – 2020	21.9	1991 – 2020	1,450
Oudomxay	1991 – 2020	22.32	1991 – 2020	1510
Bokeo	1991 – 2020	23.7	1991 – 2020	1,396.2
Luang Prabang	1991 – 2020	22.22	1991 – 2020	1600
Houaphan	1991 – 2020	22.28	1991 – 2020	1,841
Sayabouri	1991 - 2020	23.78	1991 - 2020	1,489.6

Table 5 Lao's Annual Temperature and Precipitation, 1991 – 2020; Source: World Bank CCKP, 2022

[24] World Bank. 2022. Climate Change Knowledge Portal. Retrieved from: https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical
[25] World Bank. 2022. Climate Change Knowledge Portal. Retrieved from: https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical.
[26] World Bank. 2022. Climate Change Knowledge Portal. Retrieved from: https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical.
[27] FAO 2021; Government of Lao PDR [*forthcoming*]

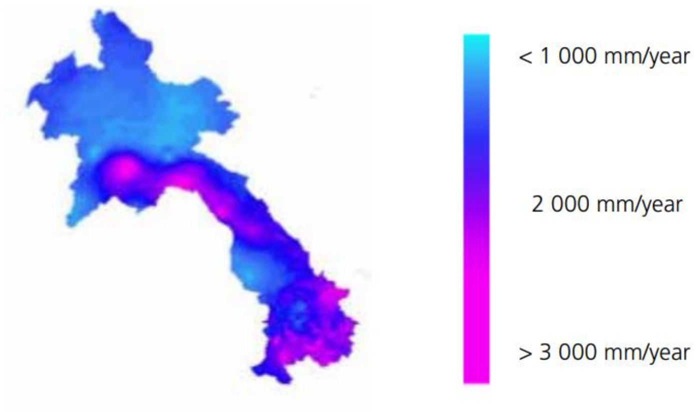

Figure 7 WFP and Lao MoNRE, 2016; Source: FAO/WFP 2019 Special Report

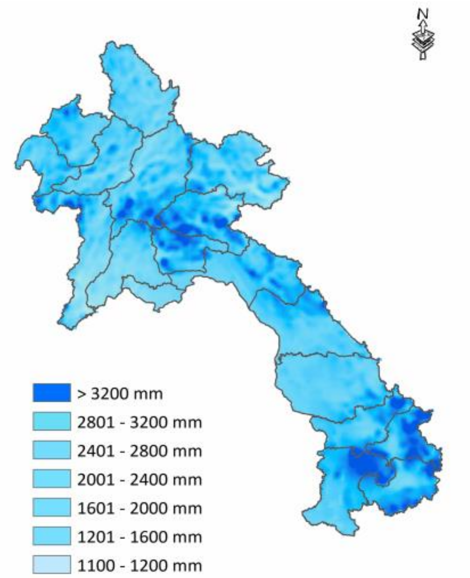

Figure 8 Average accumulated annual rainfall in Lao PDR during the period from 2010-2019; Source: DALAM and DMH in FAO 2021

4.2 Observed changes

Lao is undergoing shifts in temperature and precipitation patterns that are consistent with greater shifts seen in Southeast Asia. As seen in Figure 7 and 8 below, climate change impacts in Asia are altering terrestrial systems, increasing rates of malnutrition and may or may not improve or decrease agricultural production, water scarcity, and damage infrastructure, economic production.[28] Lao follows this pattern with increasing surface mean annual surface temperatures and decreasing short-term precipitation, and rising malnutrition. First, changes in observed precipitation will be presented, followed by temperature, and then changes in extreme events and hazards.

Lao is undergoing shifts in temperature and precipitation patterns that are consistent with greater shifts seen in Southeast Asia. As seen in Figure 10Figure 9 below, climate change impacts in Asia are altering terrestrial systems, and increasing rates of malnutrition.

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28 IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A.Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S.Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

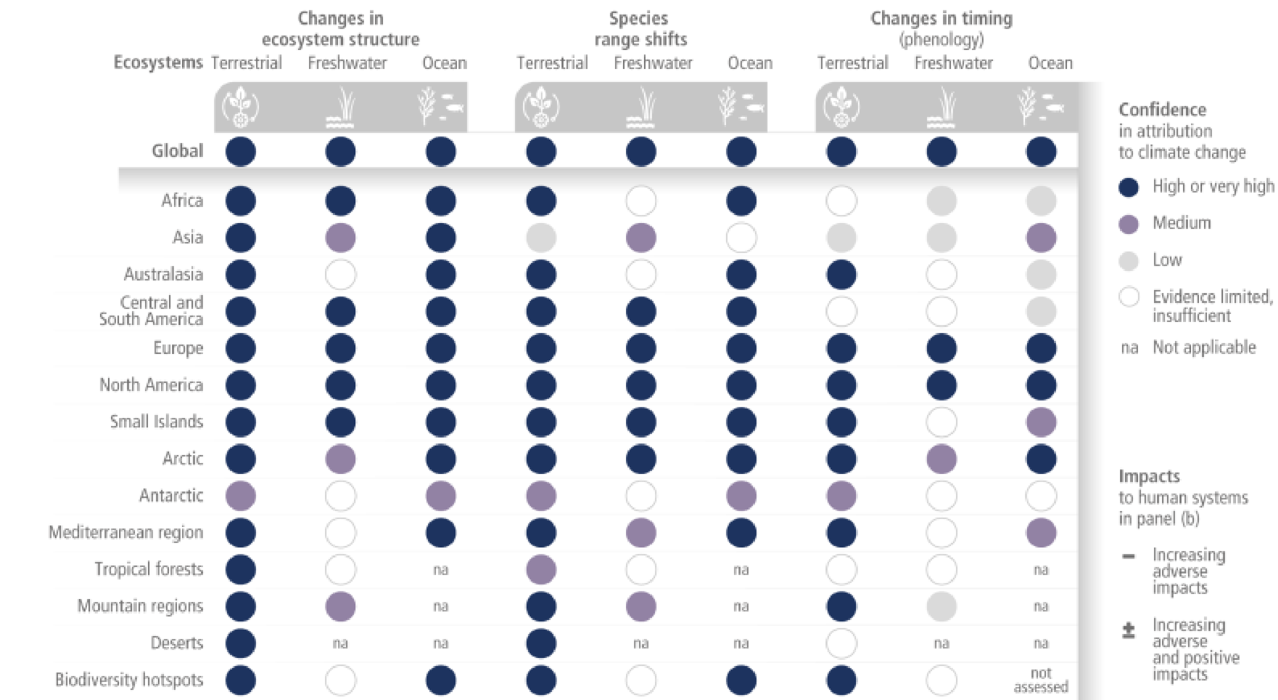


Figure 10 IPCC, AR6, Climate Change Impacts to Environmental Systems; Source: Climate Change 2022 - Impacts, Adaptation, and Vulnerability, pg. 9

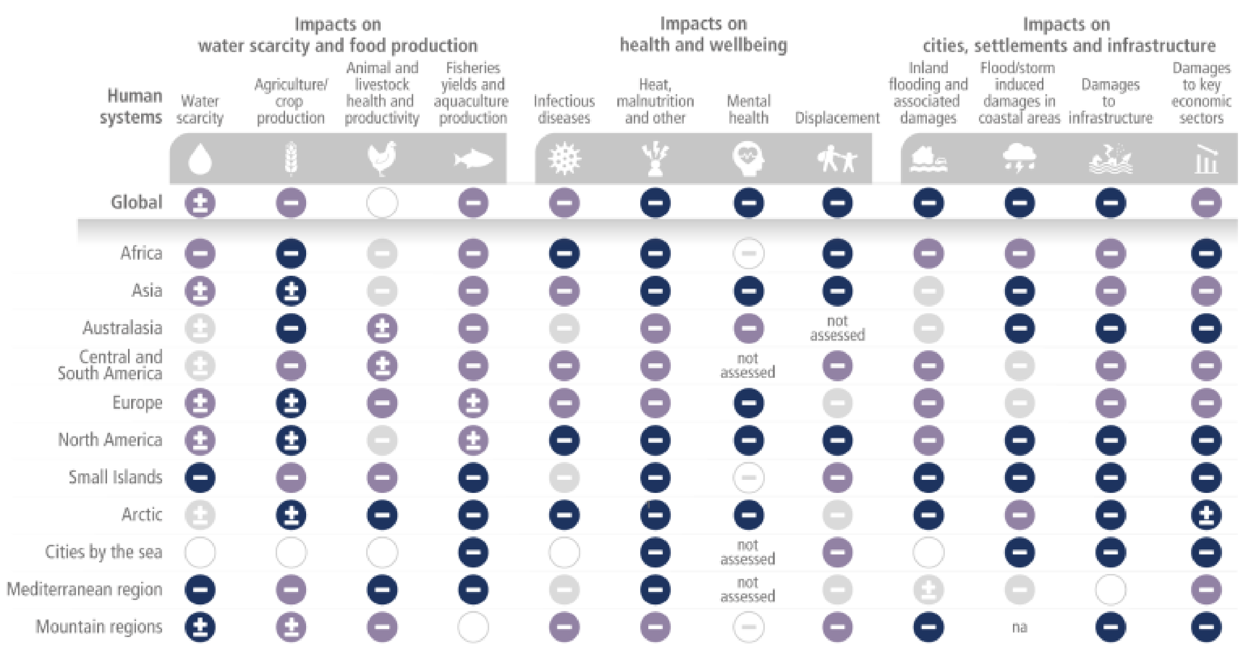


Figure 9 IPPC AR6, Climate Change Impacts to Human Activities; Source: Climate Change 2022 - Impacts, Adaptation, and Vulnerability, pg. 9

The recently released 6th Assessment Report of the IPCC[29] lists the following evident impacts for Asia, which have been seen in Lao PDR as well:

- Urban infrastructure damage and impacts on human well-being and health due to flooding
- Biodiversity loss and habitat shifts as well as associated disruptions in dependent human system
- Risk to food and water security due to increased temperature extremes, rainfall variability and drought

The report further states that terrestrial ecosystems change is driven by rising temperatures, precipitation and monsoon alterations, and more frequent extreme events. The combination of climate and non-climate drivers (s.g. population growth, urbanization, energy demand) have also created situations of water stress by impacting both demand and supply.[30]

Lao PDR is also affected by global patterns such as the El Niño Southern Oscillation (ENSO) and La Niña. ENSO's main impact in Lao PDR is felt on mean rainfall, which decreases during El Niño events (30% more than in non-ENSO periods) and increase during La Niña periods (approximately 16% higher than during neutral year spring months). A 2019 World Bank study illustrates how rainfall amounts vary through they tend to follow seasonality trends[31] (see Figure 11, which is based on CRU rainfall data from 1980 to 2015). The study shows that the North tends to be more affected by El Niño, while the south is more affected by La Niña.

[29] IPCC, 6th Assessment Report, Summary for Policy Makers, p17.
[30] IPCCC, 6th Assessment Report, 2021, chapter 9, pp. 10-3.
[31] Sutton, W. et al, Striking a balance: managing El Niño and La niña in Lao PDR's agriculture, World Bank , 2019. Accessed here

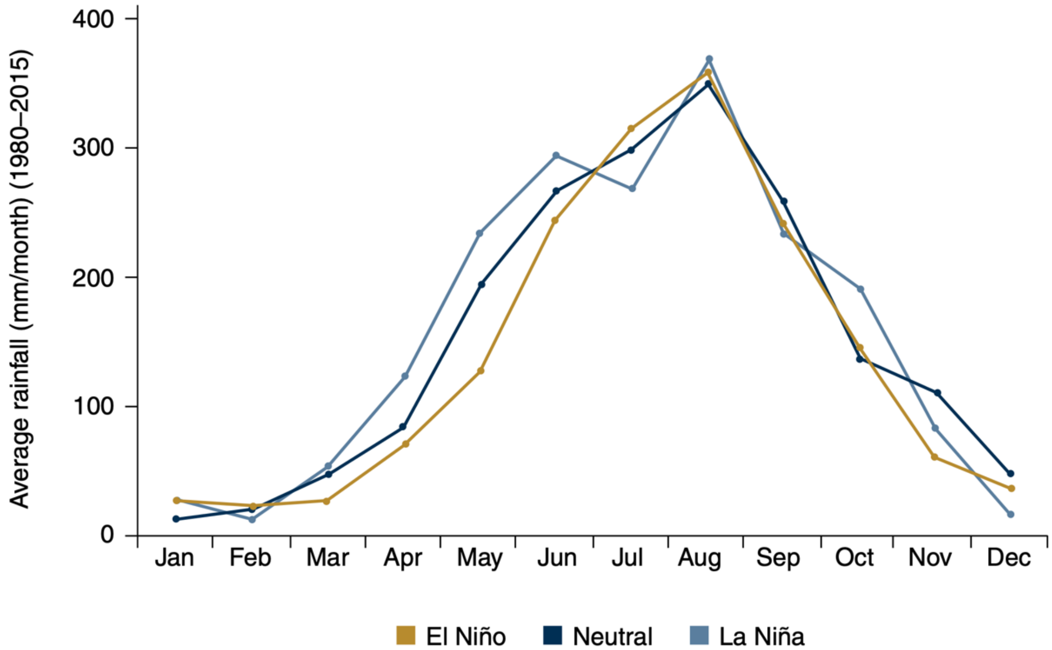


Figure 11: Rainfall distribution in El Nino, La Nina and neutral years. Source : World Bank

4.2.1 Observed changes in precipitation

From 1979 to 2019 (see Figure 12), rainfall decreased an average of 4.3 mm per year, except in south-east and central east Lao PDR where rainfall has already begun to increase. For the Northern area, receiving a normal mean annual rainfall of 2000 mm, this represents a total decrease of 172mm or 8% with sharper decreases seen in the North west areas[32] (See **Error! Reference source not found.**). Seasonal decreases in rainfall were the most significant in Northwest Lao PDR, especially during the planting season from June until August, which has a major impact on farmers dependent on rainfed agriculture (Figure 4).[33]

[32] World Food Programme, CLEAR, 2016.
[33] Ibid.

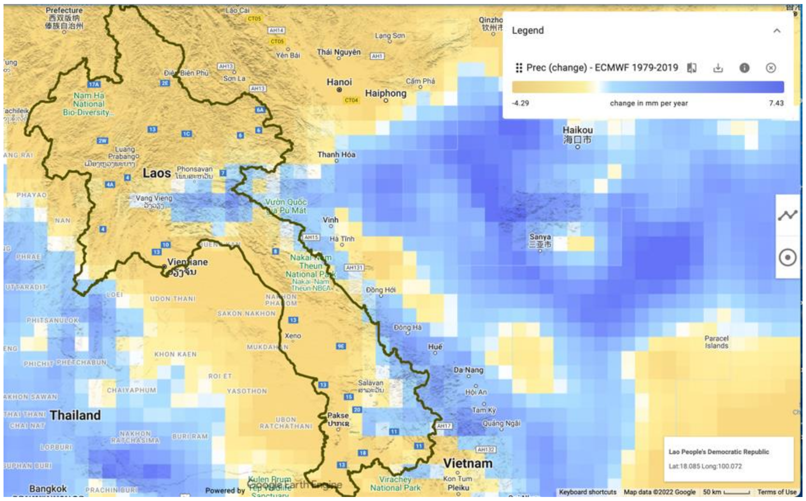


Figure 12: Change in precipitation for Lao PDR for period 1979-2019. Source : Earthmap, using European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis.

Table 6: Rate of change in annual and seasonal precipitation from 1961-1990 to 1991-2020. Source (CRU data on World Bank Data portal) illustrates rates of change in seasonal precipitation for Lao PDR as a whole and the 6 programme provinces. CRU Data was downloaded from the World Bank Climate Change Knowledge Portal[34] for the time series 1961-1990, which serves as a baseline, and compared to time series for the 1990-2020 period. Significant changes occurred in the period December, January and February (DJF) (increases ranging from 8 to 15%), offset by decreases ranging from 2 to 8% in the September, October, November period (SON).

Table 6: Rate of change in annual and seasonal precipitation from 1961-1990 to 1991-2020. Source (CRU data on World Bank Data portal)

	Rate of Change in precipitation (%)				
	Annual	DJF	MAM	JJA	SON
Lao PDR	0.02	14.98	-0.02	-0.26	-2.20
Bokeo	-0.29	8.69	3.75	1.35	-8.88
Sayabouri	0.95	10.00	0.58	4.08	-6.62
Oudomxai	0.55	8.96	4.55	2.16	-8.52
Louang Namtha	-0.15	9.04	5.18	0.85	-8.71
Louang Prabang	1.08	10.28	2.35	3.49	-7.57
Houaphan	1.15	11.99	1.03	4.02	-8.11

[34] World Bank, Climate Change Data portal, Last accessed April 2022.

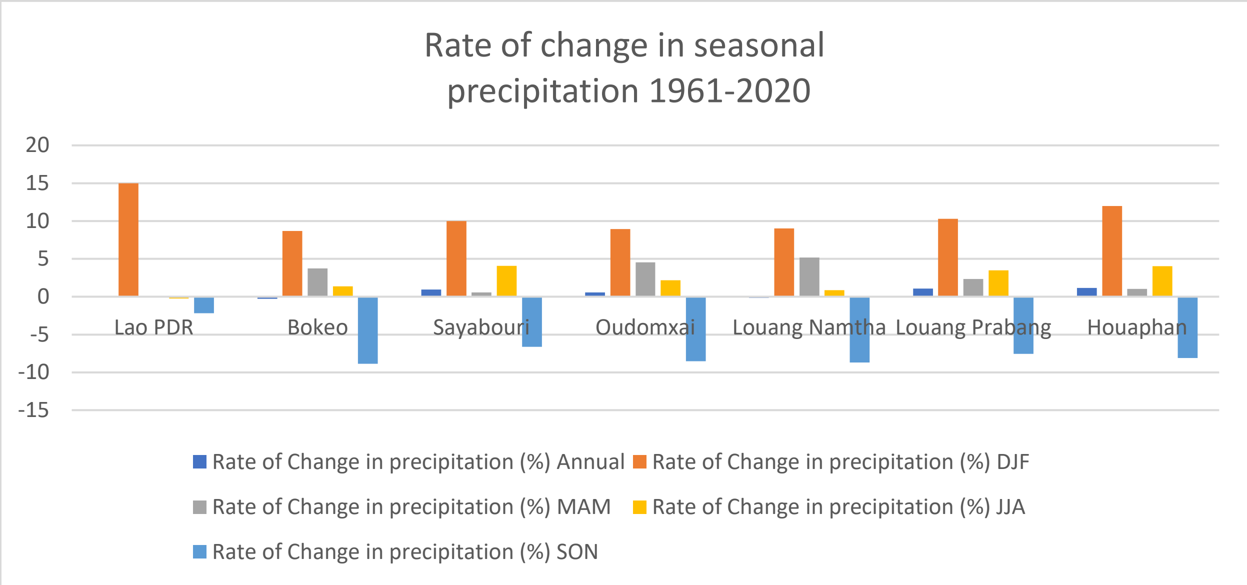


Figure 13: Rate of change in seasonal precipitation (source graphic plotted from CRU Observed data on World Bank Climate Data Knowledge portal downloaded April 2022

Table 6 also indicates that onset of rains have also changed, as shifts have occurred during the major planting season from June – August.[35] This is further corroborated in the 2016 World Food Programme CLEAR analysis[36], which used data from CHIRPS to illustrate changes in seasonality, as illustrated in Figure 14, which shows that Northern Lao PDR has been experiencing both positive and negative changes in seasonality of rainfall (changes in the distribution of rainfall throughout the season). As noted, "decreases in seasonality are associated with decreasing rainfall". This trend is important to note in light of the anticipated potential reversal in terms of rainfall amounts for the Northern region, which may then be associated with further changes in seasonality.

[35] WFP. 2016. CLEAR Report. Retrieved from: https://www.wfp.org/publications/lao-pdr-report
[36] WFP, 2016. CLEAR Report. P. 20

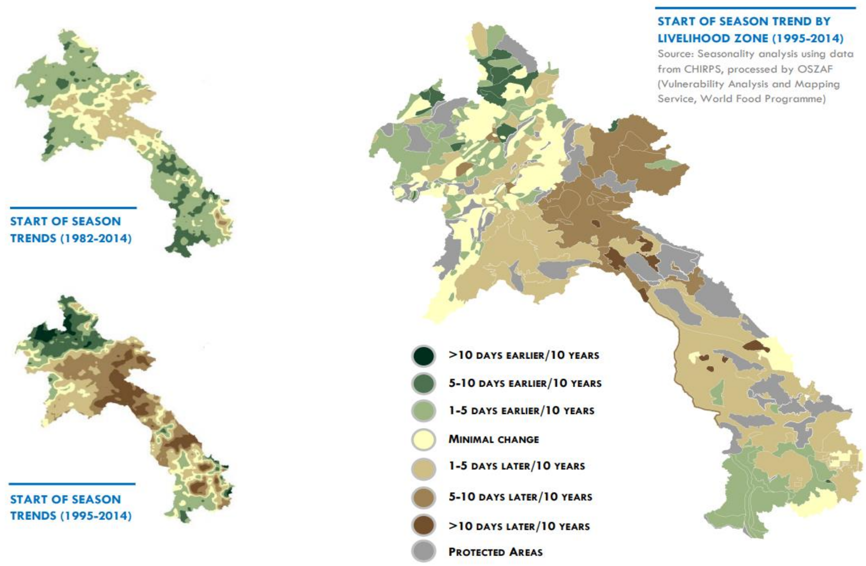


Figure 14: Changes in start of season since 1982. Source WFP CLEAR, 2016.

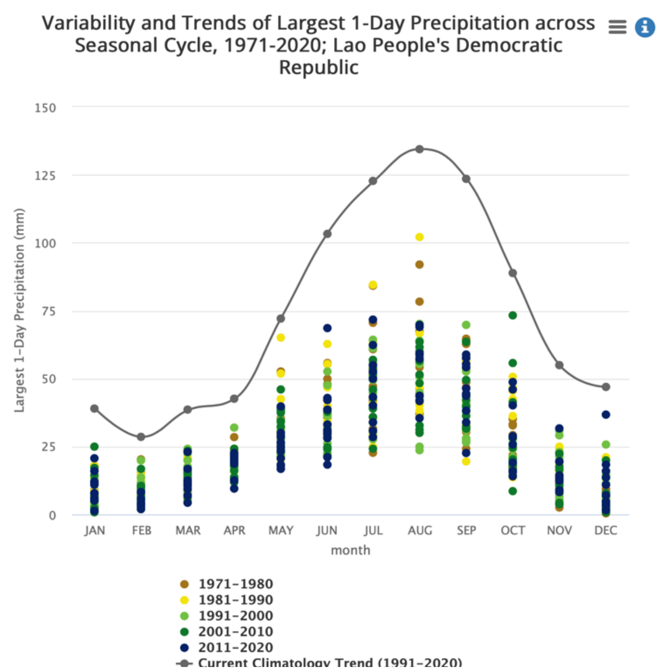
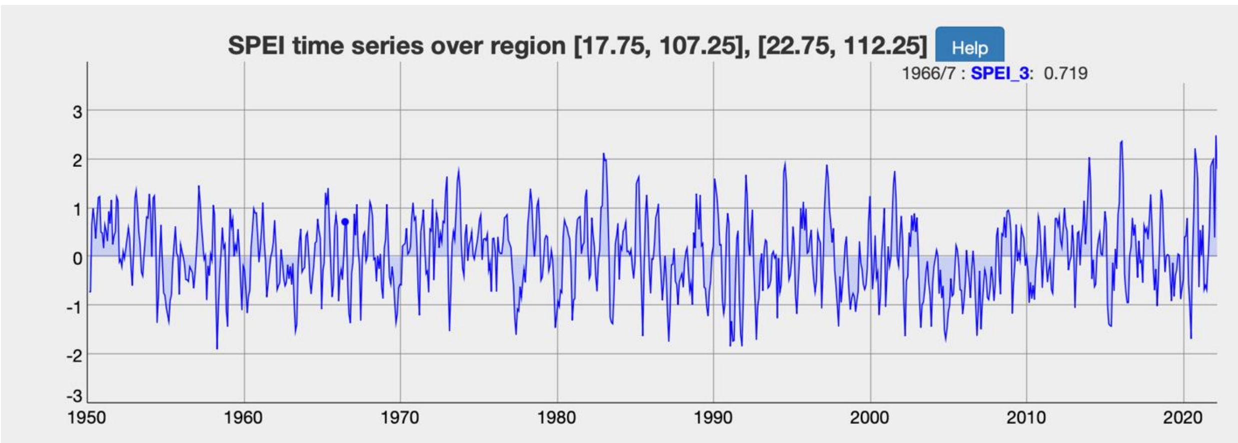


Figure 15: Variability and trends of largest 1-day precipitation across seasons from 1971. Lao PDR, Source: World Bank Climate Change Knowledge Portal

Changes in extremes have also been occurring, with the period 2016-2019 showing significant rainfall deficits for the North of Lao PDR, and excess rainfall in the South[37]. Since 2000, Lao PDR has seen an average of 60 days per year of precipitation totals exceeding 10 mm/day of which at least 10 on average are days of precipitation above 30mm/day[38] (see Figure 15 for trends since 1971).

As for drought, historical data for the country shows low risk of drought with Standard Precipitation Evaporation Index (SPEI) measurements consistently in the positive over the period 1955-2022[39]. This is corroborated by the most recent climate change profile for Lao PDR published by the World bank, which shows "an annual media probability of severe meteorological drought of around 4%"[40]. This is also more significant in the south of Lao PDR[41].



4.2.2 Observed changes in temperature

Temperature trends in Lao PDR have been following global and regional patterns. An average of 0.08 degrees Celsius increase annually has been observed across the country since 1979, meaning an overall increase of 3.2°C in mean annual temperature.[42]

Figure 16: Evolution of Standard Precipitation Evaporation Index over Lao PDR, 1955-2022. Source: SPEI Global Drought Monitor

[37] Climateinformation.org Precipitation anomalies using ECMWF for the period 2016-2019 compared to 1979 baseline.
[38] Climateinformation.org Number of days with extreme rains (>10mm and >30mm) for a single year for the timeframe 2000-2020 using ECMWF ERA5 Land hourly reanalysis set.
[39] Data extracted from SPEI Global Drought Monitor using CRU Observational datasets from January 1955 to 2022
[40] Defined as a SPEI of less than -2. https://climateknowledgeportal.worldbank.org/sites/default/files/2021-06/15505-Lao%20PDR%20Country%20Profile-WEB.pdf p. 13
[41] Data extracted from the SPEI Global Drought Monitor, covering data from 1955 to 2022, using data computed monthly on precipitation and potential evapotranspiration from the Climate Research unit of eastern Anglia University (CRU). https://spei.csic.es/map/maps.html#months=1#month=2#year=2022 last accessed April 2022
[42] Data extracted from earthmap.org, derived from processing ECMWF ERA5 atmospheric reanalysis.

Focusing on the period from 1951-2000, average temperature has increased, on average, between 0.1 to 0.3°C per decade (Figure 17. Average monthly temperature of Lao PDR since 1901. Source, World Bank Climate Data Knowledge Portal, extracted April 2022.). Similar to the findings for the last century, the largest increase in annual temperatures was observed in the Southwest of the country (Figure 18).[43] During the months of March to May, there have been regions in the country where temperatures have reached 30°C; during the cooler months of the dry season (December-January), temperatures have dropped to 15°C and below, particularly in areas with high elevations.[44] Regional disparities have been observed in the annual mean temperatures from 1901 to 2002:[45] Provinces in Northern and Central Lao PDR experienced an increase between 0.1-0.5°C, and 0.5-1.0°C, respectively; meanwhile, the Southern Provinces experienced an increase of maximum temperature in the range of 0.5°C to 4.5°C.

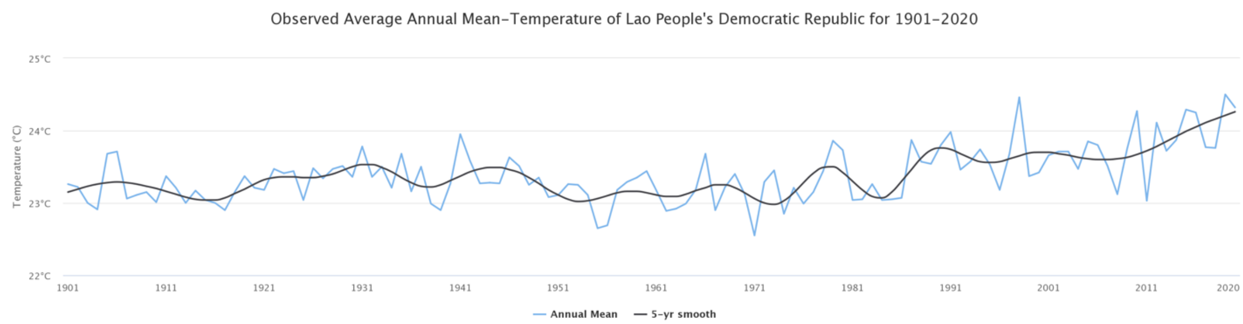


Figure 17. Average monthly temperature of Lao PDR since 1901. Source, World Bank Climate Data Knowledge Portal, extracted April 2022.

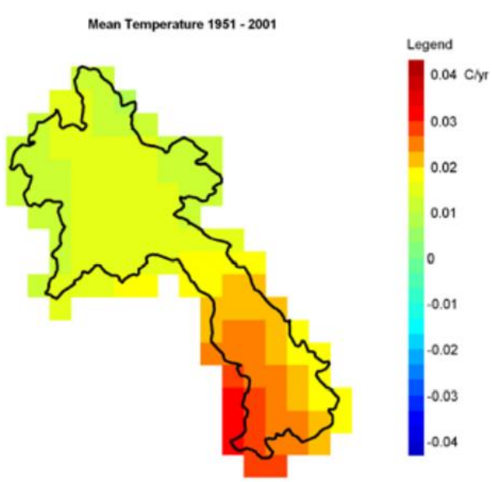


Figure 18. Change in annual temperature during the period from 1951- 2001. Source: NCA 2009, p. 12

[43] World Bank n.d.
[44] World Bank n.d.
[45] Lefroy et al. 2010

There have also been changes in the frequency and intensity of extreme temperatures. For example, since 2000, the number of days with temperatures above 32°C has continually increased, reaching a staggering 70 days in 2019 alone[46] (see Figure 19), while the number of days where the temperature was above 35°C was 20 in 2019. This data should also be seen in association with emerging evidence on the evolving nature of heatwaves, which seem to be lengthening in duration and increasing in frequency worldwide. For SouthEast Asia, the average duration of heatwaves over the past 50 years has been 4 days and more[47], leading to cumulative heat stress.

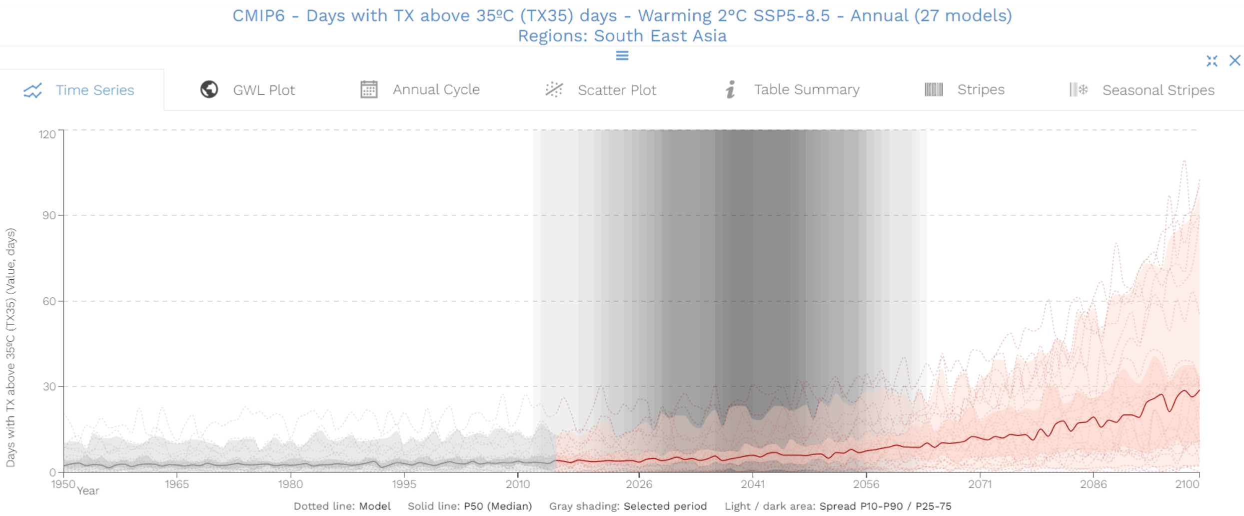


Figure 19 Number of Days with Temperatures >32°C; Source IPCC, 2022, Interactive Map

Table 7: average number of days with extreme temperatures. Source (extracted from earthmap.org using ECMWF ERA5 Land hourly reanalysis dataset

	Days above > 32	Days above 35
2000	25.36	7.98
2001	32.05	12.67
2002	39.57	14.42
2003	38.11	10.72
2004	37.68	11.80
2005	46.09	19.68
2006	40.98	9.87

46 Earthmap.org data extracted April 2022, based on Monthly time series, ECMWF ERA5 Land hourly reanalysis dataset.

47 Perkins-Kirkpatrick, S.E., Lewis, S.C. Increasing trends in regional heatwaves. Nat Commun 11, 3357 (2020). https://doi.org/10.1038/s41467-020-16970-7

2007	38.34	10.97
2008	22.92	7.30
2009	32.81	6.21
2010	54.03	19.66
2011	25.24	6.94
2012	37.55	7.60
2013	42.87	17.17
2014	41.47	9.47
2015	54.26	16.40
2016	48.88	25.28
2017	28.34	7.79
2018	35.67	7.55
2019	69.92	20.50
2020	60.21	21.30

4.2.3 Climate-related natural hazards

Lao PDR is exposed to several climate-related natural hazards, including floods, droughts, landslides, cyclones, wildfires, and extreme heat. In its most recent National Communication, the Government of Lao PDR developed an updated multi-hazard exposure, which is reproduced in

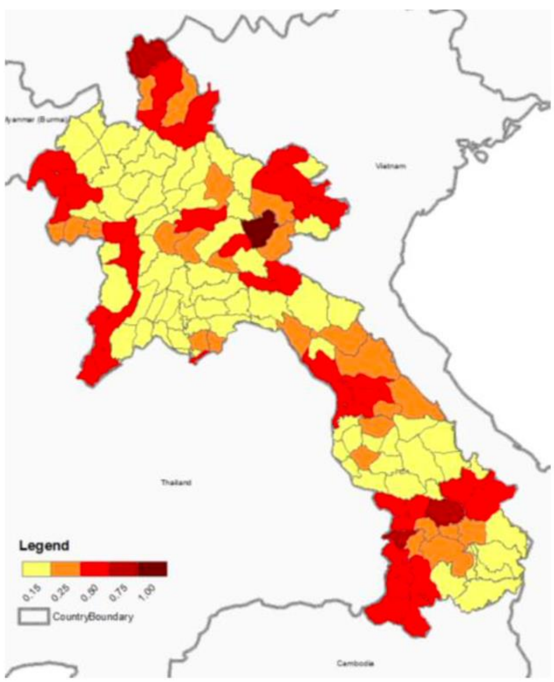


Figure 20: Exposure to multiple hazards. Source Third National Communication, p.22 (forthcoming)

Figure 20. This shows that northern provinces such as as Phongsaly, Bokeo, Xayabouri and Houaphanh are seriously affected.

Nationwide, from 1980 to 2020, ***flooding*** has been the most frequent hazard with an occurrence of nearly 50% of all climate-related hazard in the country (23 events), followed by storms (20%) and droughts (10%) (Figure 21).[48] In that same period, at least 39 natural hazard events occurred, affecting approximately 9 million persons, and resulting in damages and losses exceeding USD $400 million.[49]

As reported in the 2016 WFP CLEAR report, "The number of people affected by climate-related disasters has increased from an average of 60,000 people affected on annual basis in 1993-2002 to over 320,000 on average every year in 2003-2012. To some extent, the increase in number of affected people can be attributed to increases in population in highly exposed areas as well as increasing inequalities in some districts despite rapid development in recent years."[50]

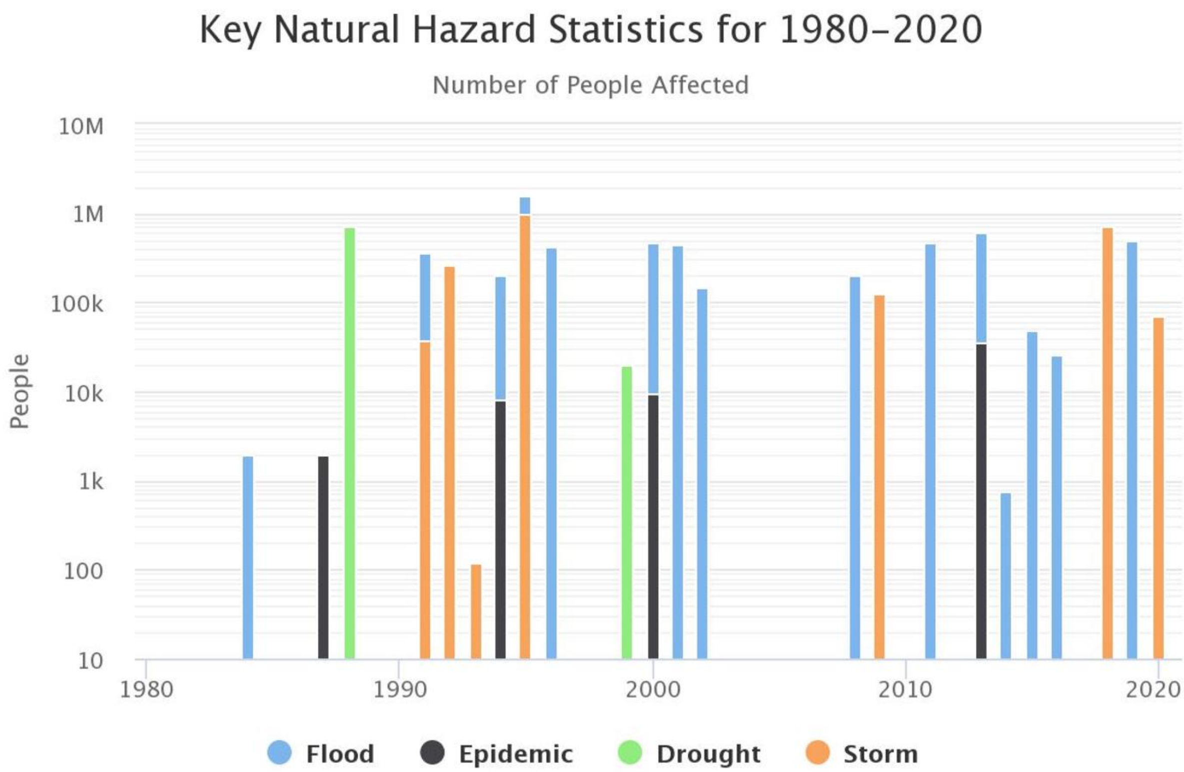


Figure 21: Number of people affected by natural hazards since 1980. Source, World Bank Climate Data Knowledge Portal, with data from UNISDR

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48 Government of Lao PDR 2013
49 EM-DAT in World Bank 2011
50 WFP CLEAR, 2016, p. 21, using Desinventar Database

As stated in Lao's Second National Communication, "*floods normally occur from May to September when monsoon rains accumulate in the upper Mekong River basin, while droughts happen between November and March*".[51] The most vulnerable areas to flooding are in the plain areas along the Mekong River in central and southern Lao PDR, although flash floods tend to occur more in the northern areas[52]. In its Third National Communication, the Government of Lao PDR reports that between 1966 and 2008, the country has seen more than 33 floods of various magnitudes and duration, often linked to cyclones, with total damage and losses from floods representing 2% of the country's GDP (USD $371 million), and affecting over 600,000 people.[53] The Em-DAT database[54] reports 28 occurrences of floods in Lao PDR since 1966, noting that half of those occurred after 2000 (to 2022).

Flood events in Lao PDR are inextricably linked to precipitation patterns, including monsoon rains, but are also tied to El Niño and La Niña and increasing rates of run-off that are observable in most watersheds.

Severe rainfall events are also linked to the appearance of landslides, particularly in the North of the country, due to mountainous terrain. Nonetheless, human activities further exacerbate the risk of landslides by clearing forest and practicing shifting cultivation. In the rainy season, landslides cause damage to key infrastructure and local populations, and it is possible to see the impact on the landscape.


Photos of i) landslides in Northern Lao PDR, and ii) post-landslide infrastructure clearing

Cyclones affect Lao PDR during the rainy season form June until November, especially during the period from August until October. At least five storms or tropical cyclones have affected the country over the last two decades. These storms, as well as the impacts from southwest monsoons,

[51] Government of Lao PDR 2013
[52] Sutton, W.R et al, Striking a Balance: Managing El Nino and La nina in Lao PDR Agriculture. 2019
[53] Government of Lao PDR, Third National Communication, Vulnerability and Adaptation assessment p.10 [*forthcoming*]
[54] Data queried April 2022, EM-DAT, CRED, Université de Louvain

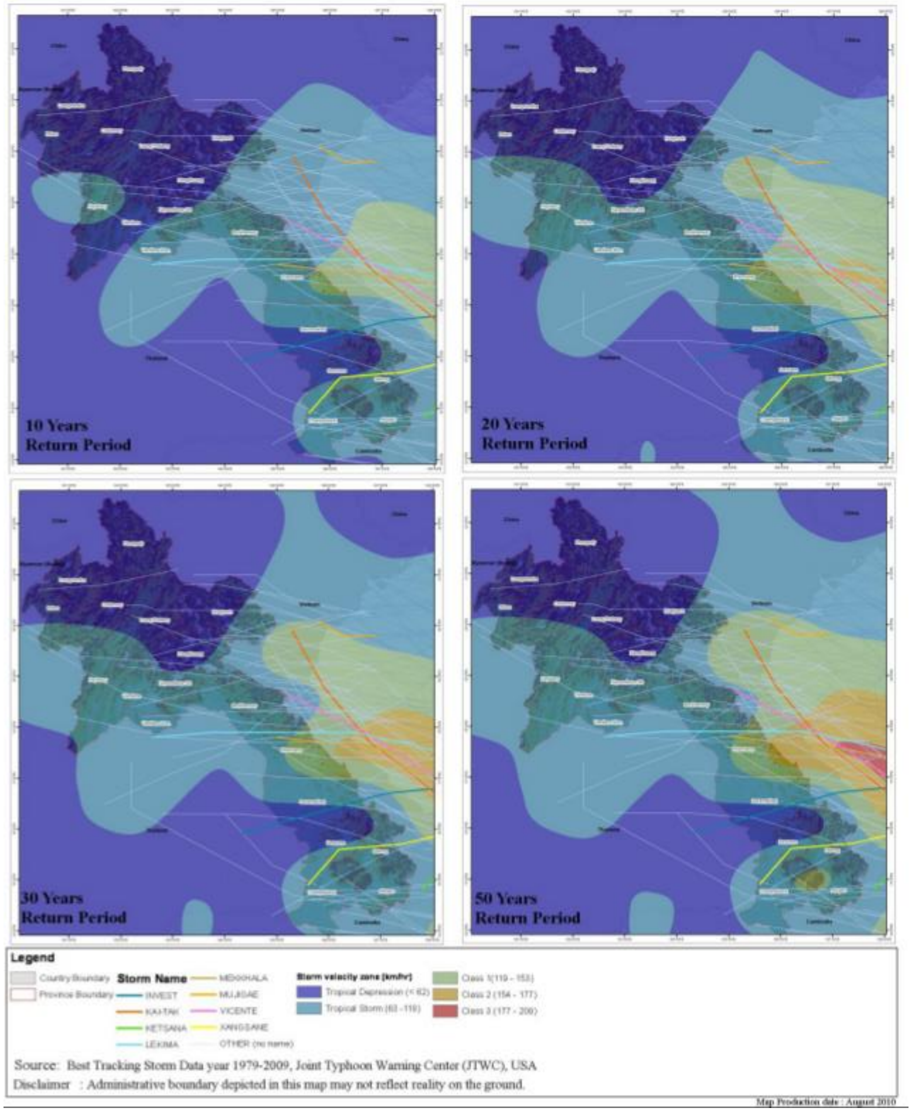

Figure 22: Map of storm distribution in Lao PDR for the period from 1979-2009

have affected over 1.5 million people, and caused damages of over USD 400,000.[55] In 2019, tropical storms and cyclone created widespread floods that affected over 764,000 people.[56]

Lao PDR is also ***drought***- prone, as seen in Figure 23. The Third National Communication reports that drought affects more people and for longer durations of time than floods, with rural communities affected due to reduced crop yields and water supply. From 1967 to 2003, the Third National Communication lists 9 droughts (6 droughts reported in the EM-DAT database from 1966 to 2022).[57]

[55] World Bank 2011

[57] Third National Communication, Forthcoming and EM-DAT database at Université de Louvain queried April 2022.

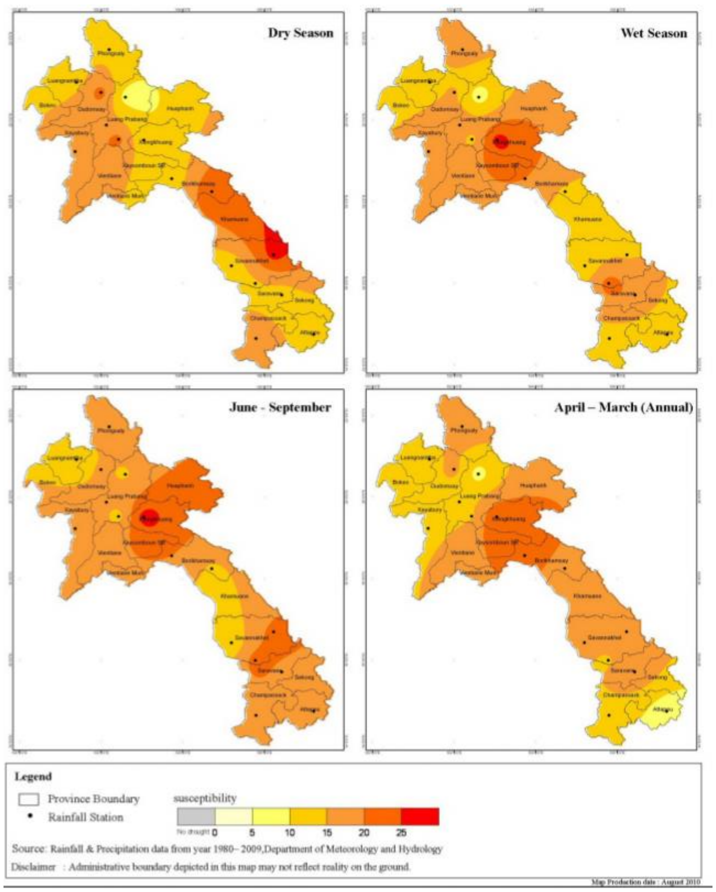

Figure 23. Map of moderate to extreme drought susceptibility in the dry season and wet season in Lao PDR. Source: National Disaster Management Committee 2010, p. 88

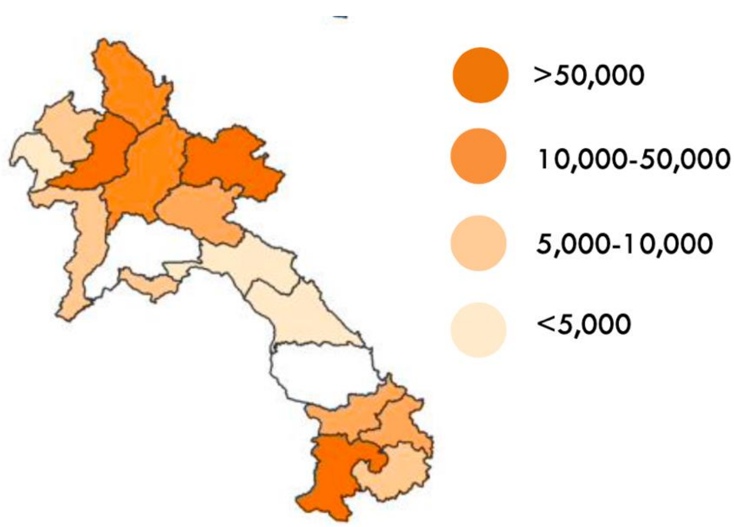

Figure 24: evolution in the number of people affected by drought, 1993-2012. Source: WFP CLEAR, 2016, p.22

Wildfires primarily affect the country during the dry season from November to March. Although many wildfires are linked with anthropogenic activities and the use of fire for clearing agricultural areas, the risk of fires (both of natural and anthropogenic origin) increases with increasingly dry conditions. While Lao PDR is highly at risk of wildfires, the northern region experienced the most intense forest fires from 2003 until 2010 (see Figure 25).

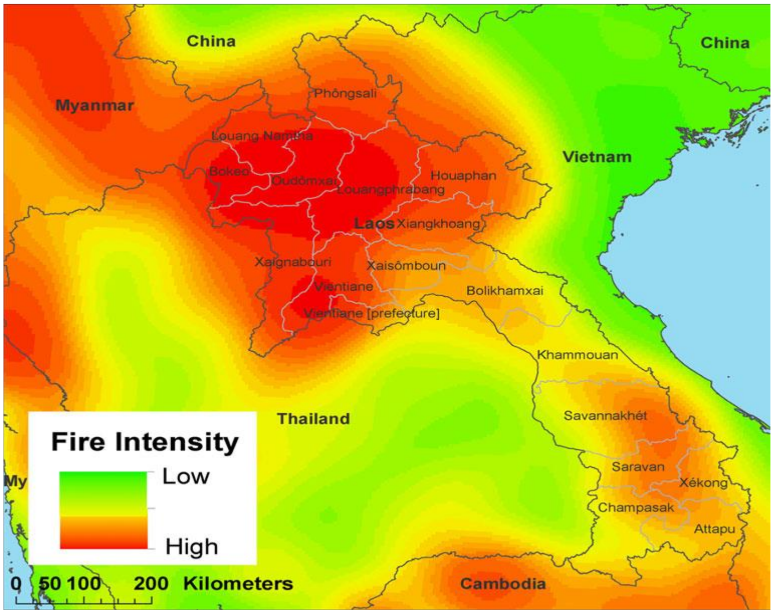

Figure 25. Map of fire intensity in Lao PDR 2003-2010. Source: Müller et al. 2013

4.3 Future projections

In this section we shall present only the projections relevant to the entire country or Northern Lao PDR as a whole, while province specific findings are explained in Chapter 5. For information on methodology, models and projections used, and sources of data, please refer to Section 2.

4.3.1 Projected temperature under RCP 4.5 and 8.5 scenarios

Data compiled for the third national communication shows that under RCP 4.5 scenario, Lao PDR can expect an increase in temperature of on average 1.35°C by 2041, with interregional variability as well as seasonal variability[58]. This is consistent with most models for the South East Asia Region, which show an average increase of 1.5 °C in the near term, 2°C in the medium term and upwards of 3°C by 2060, while under a RCP 8.5 scenario, the 3oC increase is achieved sooner

[58] Goernment of Lao PDR, Third National Communication,

(medium-term), as seen in Figure 26 and Figure 27. Figure 28 shows projections for Lap PDR according to the different models, and different RCP trajectories.

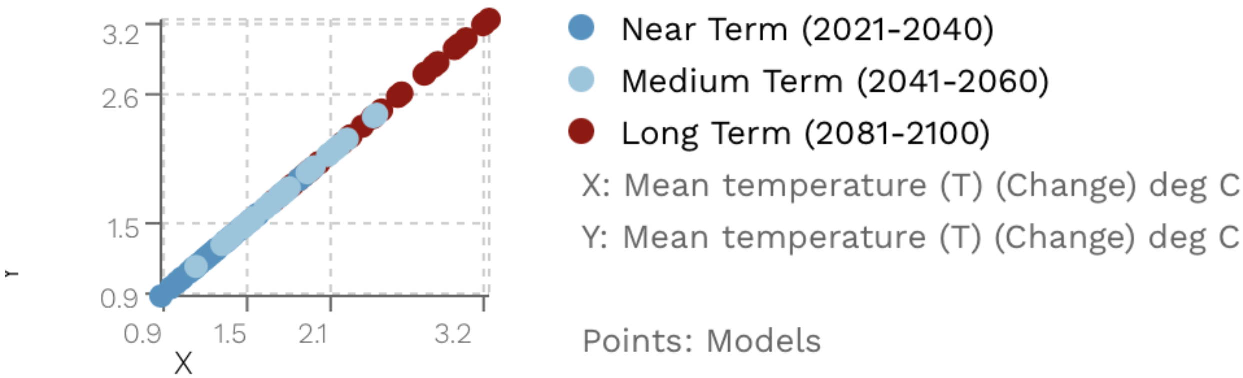

Figure 26: Projected temperature increases under SSP 4.5 for South East Asia .Source: ipcc interactive atlas

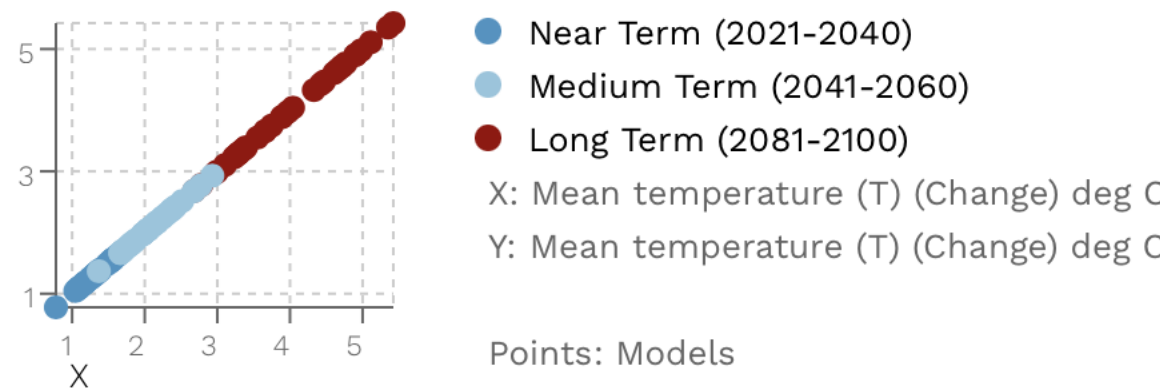

Figure 27: Projected temperature increases under SSP 8.5 for South East Asia. Source: IPCC interactive atlas

The range of simulated changes in climate for the 2021-2040 period for the 9 downscaled GCMs are presented for SSP245, 585 for each province in Figures 22 and 21 below. While SSPs are not the same as the RCP, they show increases in simulated temperatures under both SSP245 and SSP 585, with only marginally higher increases under SSP585 (0.9-1.5°C). There are however differences in the simulated changes in rainfall between SSP245 (+5% to -15%) and SSP585 (+7% to -7%). Most of the models simulated negative changes in rainfall under SSP245 (medium scenario) whereas the same models mostly simulate no change under SSP585 (extreme scenario)[59].

[59] 9 GCM climate models (BCC-CSM2-MR, CNRM-CM6-1, CNRM-ESM2-1, CanESM5, GFDL-ESM4, IPSL-CM6A-LR, MIROC-ES2L, MIROC6, MRI-ESM2-0) from the CNMIP6 archive.[59] The models follow Worldclim methodology, data

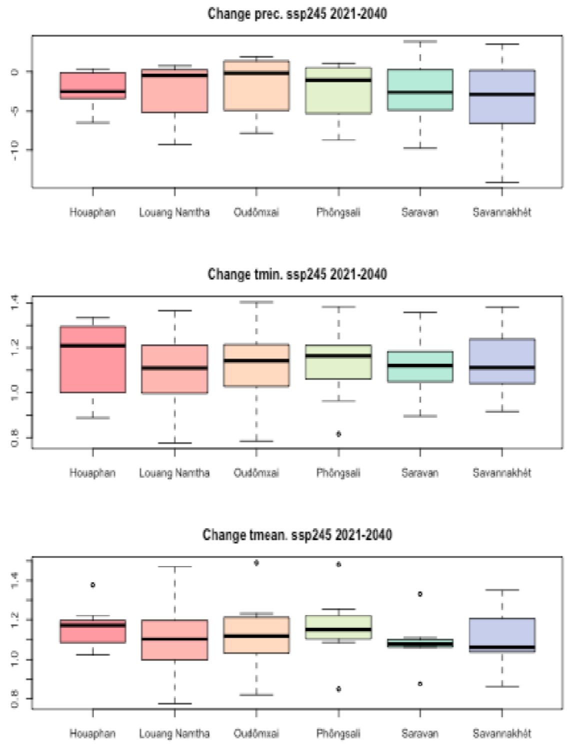

Figure 28 SSP 245 2021 - 2040

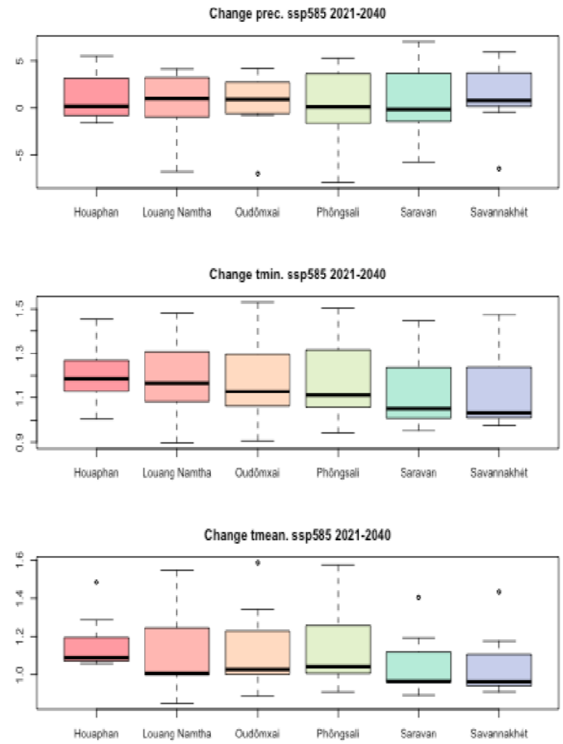

Figure 29 SSP 585 2021 - 2040

For Lao PDR, this translates into different realities according to region and under RCP 8.5 scenario, Eastern Lao PDR is projected to experience the highest temperatures. Changes in maximum temperatures, compared to the baseline, will increase within the range of 1.2 to 1.6 °C, mostly in Northern Lao PDR.

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and were conducted for two time periods (2021 - 2040 and 2041 – 2060, and two shared socioeconomic pathways SSPs: SSP245 – 'Middle of the Road' and SSP585 – 'Fossil Fueled Development'[59]).

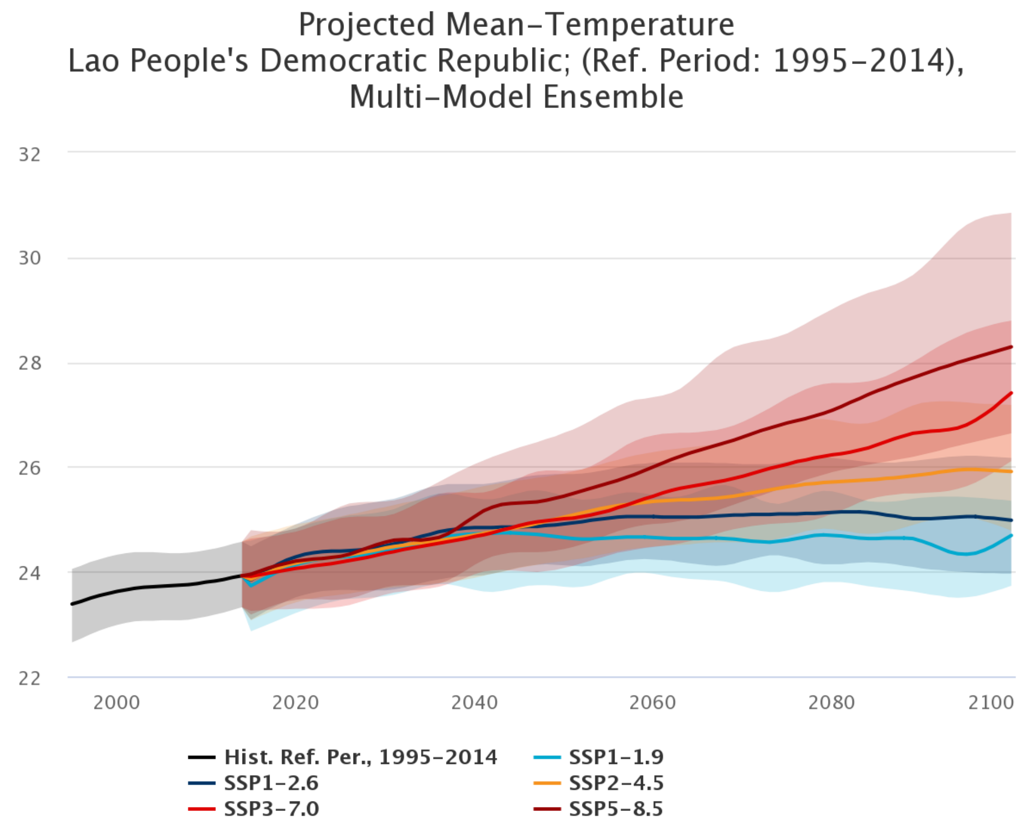

Figure 30: projected mean temperature change for lao PDR by 2011 according to different climate scenarios. Source (World Bank Climate Data portal using multi-model ensemble)

This translates into significantly higher maximum temperatures for all of Laos. By the 2040-2059 period, under the RCP 4.5 scenario, maximum daily temperature in the period March April May (MAM) are expected to reach 38.61°C on average, with some parts of the country (eg. Khammouane, reaching 41°C)[60]. The rate of change then slows down, with only marginal increases expected for the periods 2060-2100 under a 4.5 scenario. Under the RCP8.5 scenario, mean temperatures would increase by more than 2 degrees by 2060, 2.6 degrees by 2080, and 4 degrees by 2100. The number of days exceeding 35oC will follow similar trajectories, as seen in Figure 31.

[60] Data extracted from World Bank Climate Change Knowledge Portal, using multi-model ensemble mean values.

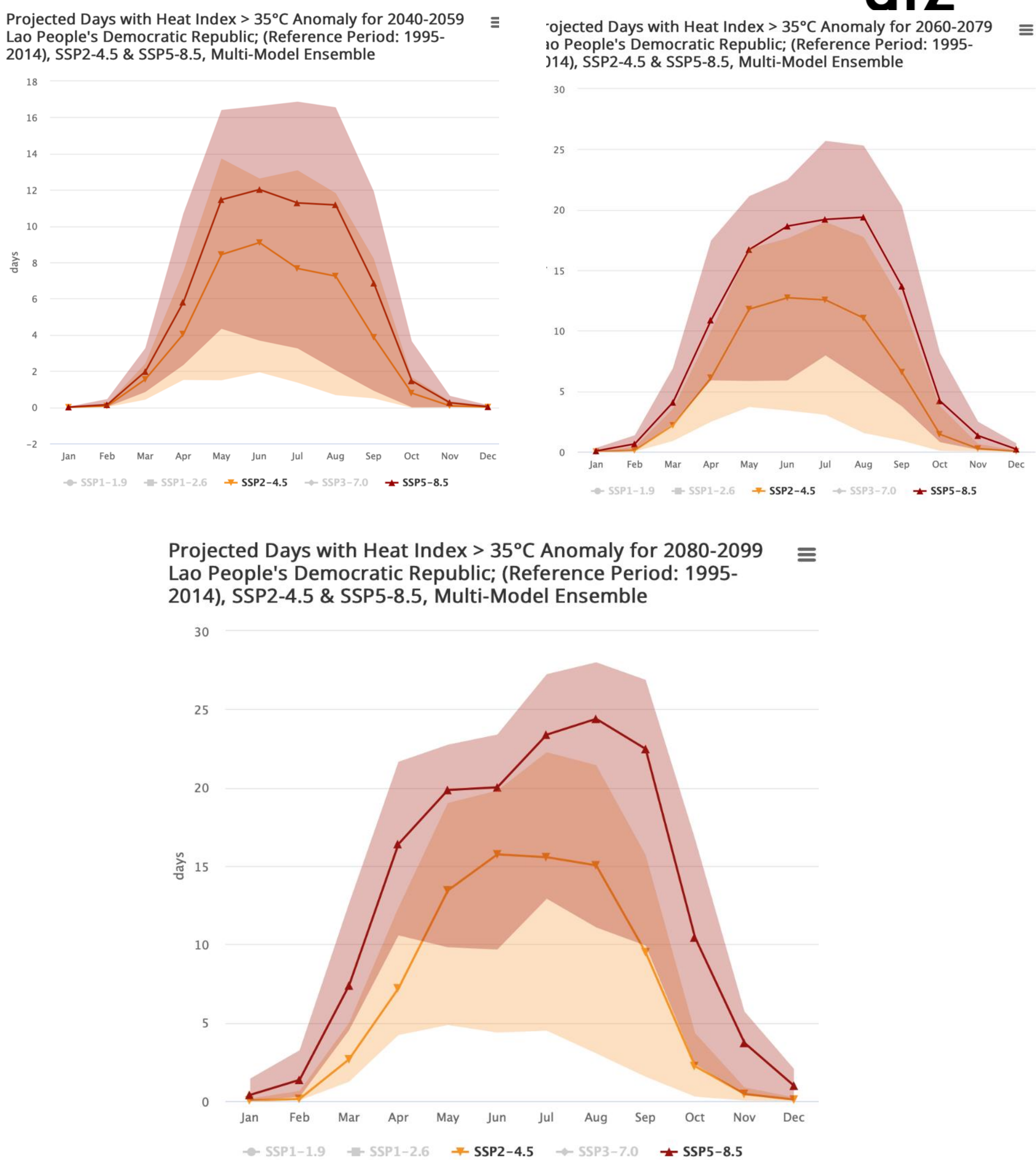

Figure 31: projected days with extreme heat under RCP 4.5 and 8.5 at three different horizons. Source (WorldBank Climate Data Portal, extracted april 2022

4.3.2 Projected Precipitation under RCP 4.5 and 8.5 Scenarios

In terms of **precipitation**, Lao PDR is expected to experience an increase in mean annual rainfall, with the majority of the increase occurring in the rainy season. Using ensemble model data from the World Bank Climate Change Knowledge portal, from 2020-2039, both RCP 4.5 and 8.5 project minor changes with slight decreases in average monthly precipitation in Northern Lao PDR and Central Lao PDR (Figure 32).[61] However, after 2040 annual precipitation is projected to increase in all of the country under both RCP 4.5 and 8.5. RCP 4.5 sees the largest increases in precipitation in the South of the country, while RCP 8.5 sees increases by 6-10mm/ month in majority of the country.

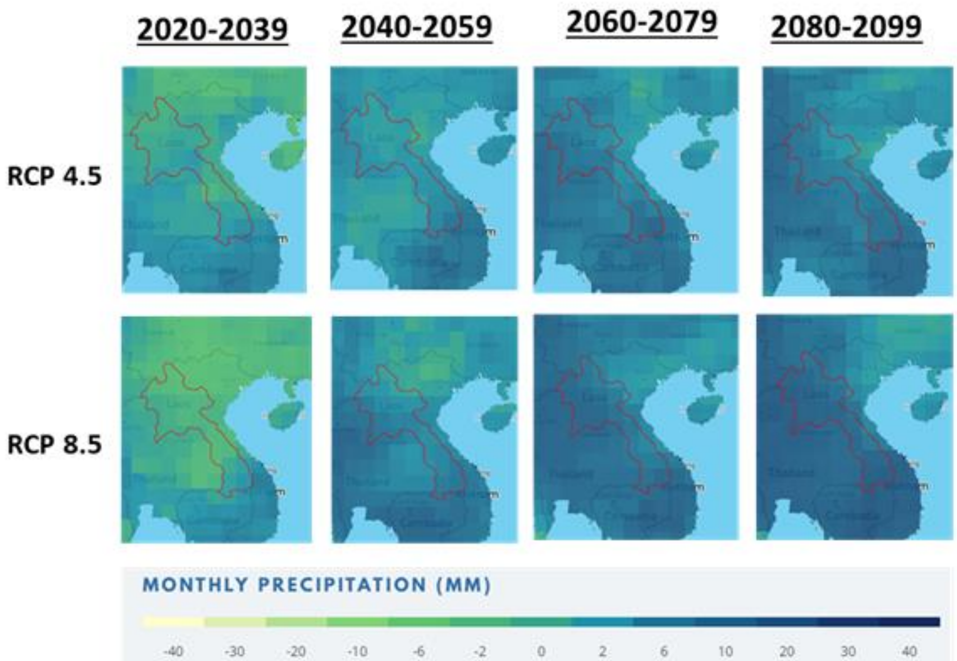

Figure 32. Projected change in average monthly precipitation in Lao PDR based on ensemble model (based on 1986-2005 data)

Source: Compiled using Figures from World Bank Climate Knowledge Portal, n.d.

According to preliminary data from the forthcoming Third National Communication to the UNFCCC, precipitation in the rainy season is projected to increase by up to 6% in Lao PDR by 2030 under the RCP 4.5 scenario (using baseline data from 1975-2005; see Figure 33 below).[62] Northern Lao PDR will experience different trends, with parts of Sayabouri and Houaphan experiencing among the largest increases in the country with an increase in seasonal precipitation by up to 6%, and areas in Luang Prabang among the lowest in the country with an increase of

[61] World Bank n.d.

[62] Climate models in the fortchcoming Third National Communication report included six climate models: Access, BNU-ESM, CCSM4, INCM4, IPSL-SM5ALR, and IPSL-SM5A-MR. The scale of each model was equivalent to 0.25° x 0.25° or 25 km and the projection used two periods; short-term 2021 to 2050 and long-term 2070 to 2099. The based year of historic model is 1976-2005. (Those climate projection and historic models are from NASA NEXGDDP). Figures included in the draft are limited to 2030.

around 2%. Under RCP 8.5 the differences are much more pronounced, with potential increases in seasonal precipitation in the range of 10-50% in Lao PDR (Figure 33 and Figure 34).

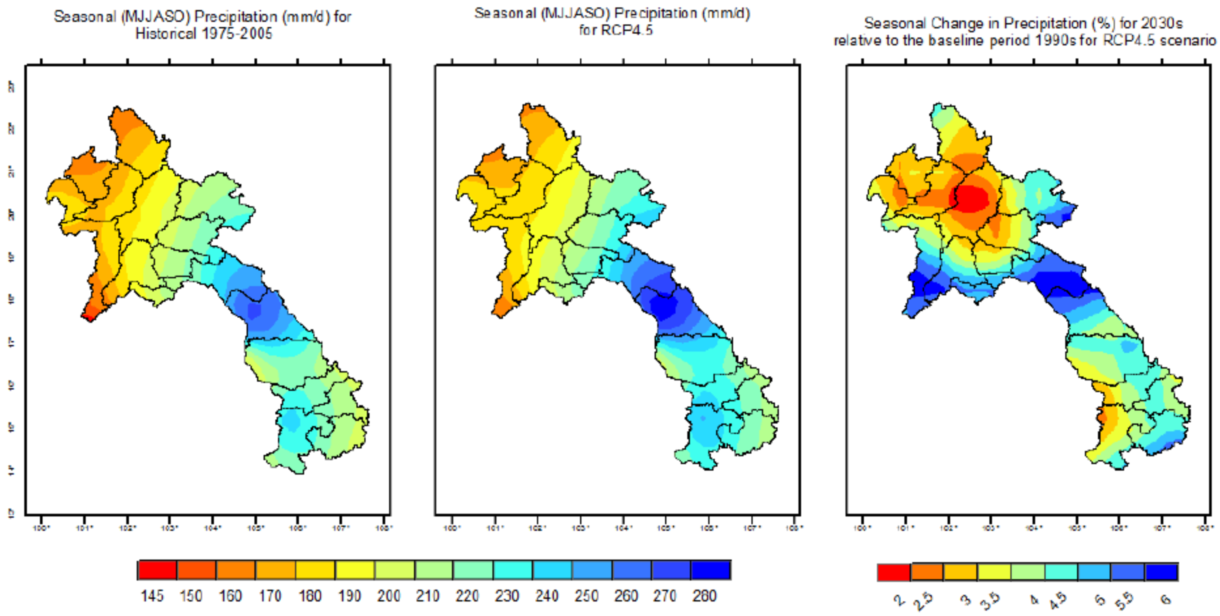

Figure 33. Seasonal (MJJASO) changes in precipitation (%) for 2030s relative to the baseline (1990s) for RCP4.5 scenario

Source: Chanhsomphou and Maniphousay 2020 [*forthcoming*], *p. 31*

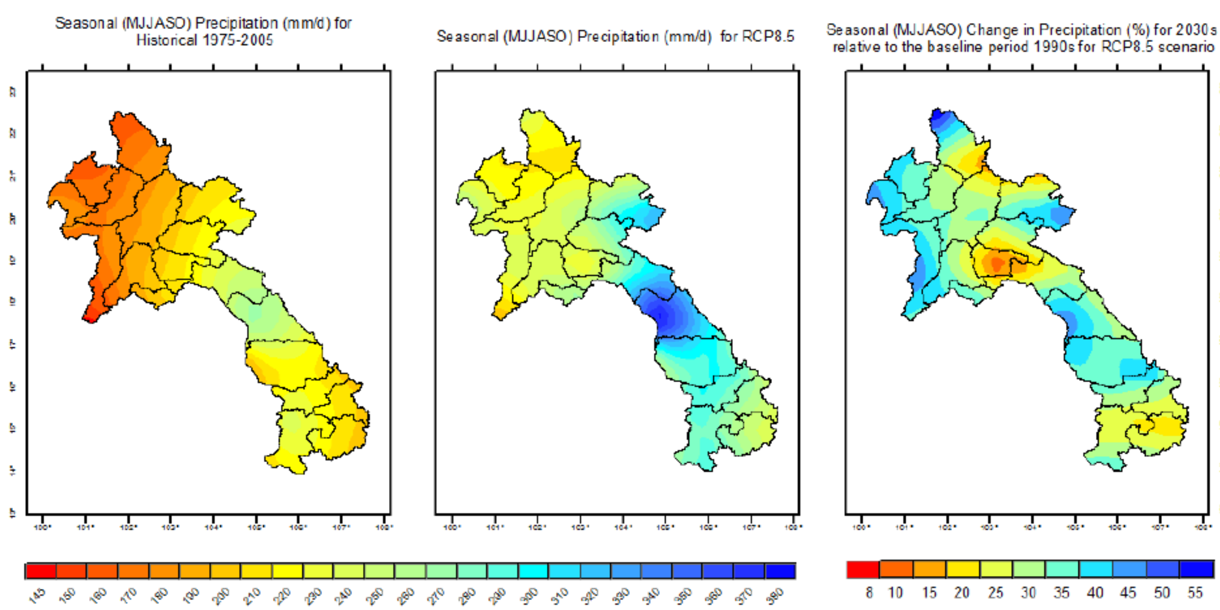

Figure 34. Seasonal (MJJASO) changes in precipitation (%) for 2030s relative to the baseline (1990s) for RCP 8.5 scenario

Source: Chanhsomphou and Maniphousay 2020 [forthcoming], p. 3

In addition to these changes in quantity and distribution of rain, Lao PDR also expects a change in the number of consecutive dry days which is expected to increase in April, May and June and slightly decrease in SON under both the RCP 4.5 and 8.5 scenarios by 2060, but which shows somewhat sharper trends by 2099.[63] By that time, dry spells may last up to, on average, 13 days during key planting seasons.

Interestingly, the combination of precipitation and temperature changes lead to changes in aridity for Lao PD, with the Northeast past of the country experiencing the most significant change by 2070 even under a "moderate" RCP 4.5 scenario, as seen in

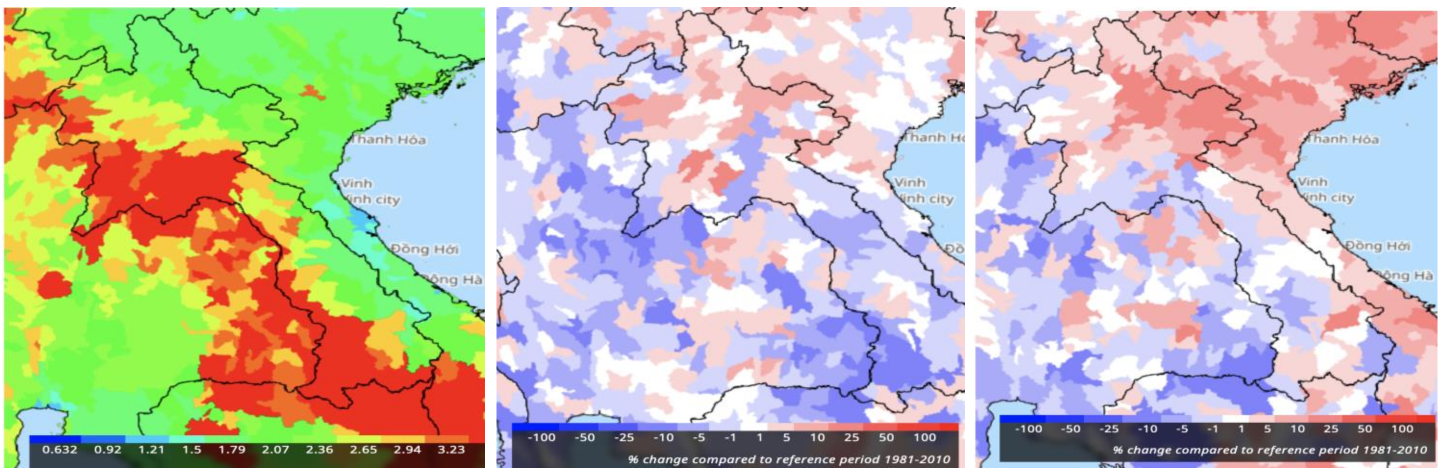

Figure 35: expected change in aridity under RCP 4.5 and RCP 8.5 at 2080. Source (generate from climateinformation.org using CMIP5 Global model)

4.3.3 Climate-related natural hazards

Changes in the distribution, frequency and intensity of climate hazards are also to be expected under all climate futures. The key determinant factor appears to be run-off and modeling of run-off for the Mekong basin and for Lao PDR indicate that exponential increases are expected under any climate scenario, up to 21% by 2030[64] and The same article projects maximum monthly by 35-41% by 2100[65], while minimum monthly flows would drop by 17-24% by the end of the century. [66] These trends are expected to further exacerbate the risk of flooding and droughts. [67]

[63] Data extracted using multi-model ensemble CMIP6 on the World Bank Climate Knowledge Data portal

[64] FAO, 2011, Managing climate change risks for food security in Lao PDR, pp.10-11

[65] Inagaki et al., 2011 in EcoLao 2012
[66] Inagaki et al., 2011 in EcoLao 2012
[67] Inagaki et al., 2011 in EcoLao 2012

These variations will have an impact on intra-annual sediment yield with an estimated increase from 81.8 to 242.5% between 2011 and 2040 and 87.8% to 207.3% between 2041 and 2070. The change will be more important for the wet season[68]. According to the world Bank, "What would historically have been a 1 in 100-year flow, could become a 1 in 50-year or 1 in 25-year event in most of South, Southeast, and East Asia. There is good agreement among models on this trend and the increased potential for major disaster level events requires adaptation attention. In conjunction, the model ensemble projects an increase of up to 23% under the highest emissions pathway in the amount of rainfall accumulated during extreme rainfall events." [69]

Changes in distribution in drought are also expected, with the southern provinces expected to see a significant increase in drought months.[70] The annual probability of heatwave (as with the number of hot days, see section 4.2.3 above) is also projected to increase, as seem in Figure 36.

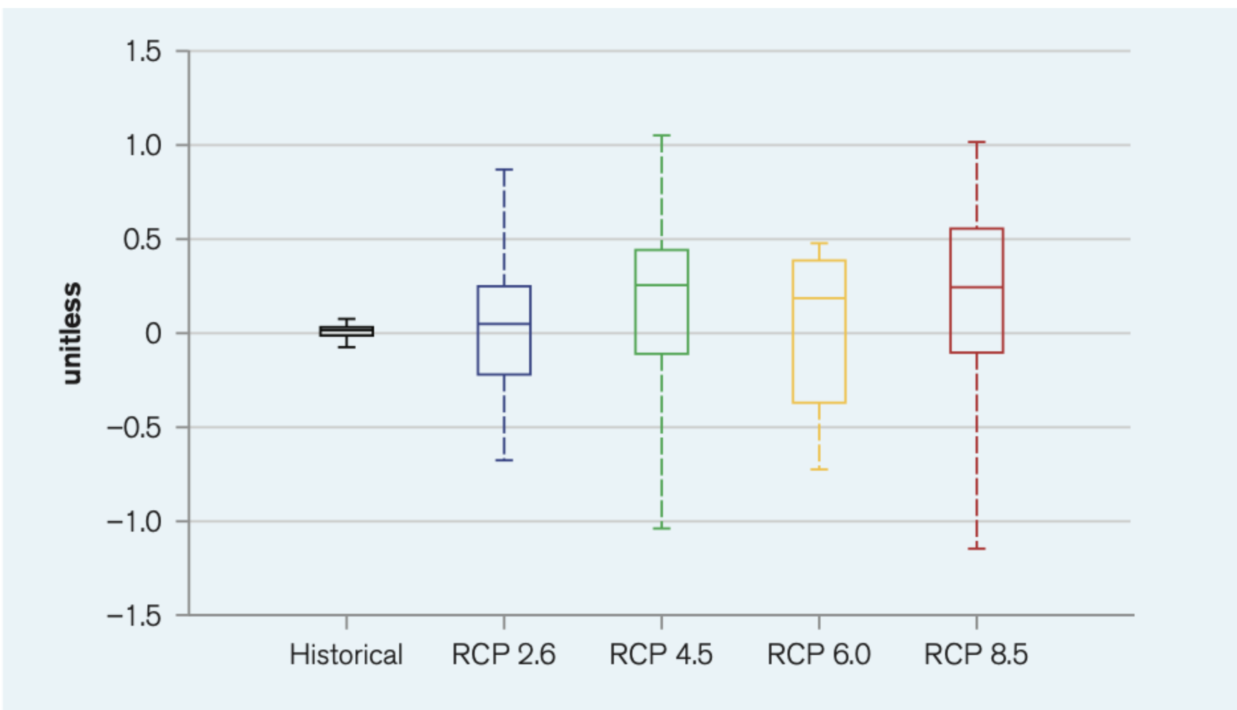

Figure 36: Annual probability of experiencing a severe drought in 2080 under 4 emissions pathways (source World Bank Lap PDR Climate Risk profile 2019, p.18)

[68] Shresta B., Babel M. S., Maskey S., Griensven Van A., Uhlenbrook S., Green A., Akkharath I., Impact of climate change on sediment yield in the Mekong River basin : a case study of the Nam Ou basin, Lao PDR, Hydrology and Earth System Sciences, 2013.

[69] World Bank, Climate Change profile for lao PDR, 2019, p. 18.
[70] WFP, CLEAR 2016,

The following Table 8 shows the risk ranking for these hazards, where the project region is particularly at risk of floods, landslides, cyclones, wildfires, and drought.[71]

Table 8. Level of risk for main climate-related hazards (see Annex for overview of ranking criteria)

	River flood	Landslide	Cyclone	Wildfire	Extreme Heat	Water scarcity
National average	**High**	**High**	**High**	**High**	**Medium**	**Low**
Bokeo	High	Medium	High	High	Medium	Low
Houaphan	Very low	High	High	High	Medium	Low
Luang Namtha	High	High	High	High	Medium	Very low
Luang Prabang	Low	High	High	High	Medium	Low
Oudomxay	High	High	High	High	Medium	Very low
Sayabouri	Low	High	High	High	Medium	Low

Source: GFDRR n.d.

With the aforementioned projected changes in precipitation and temperature, it is projected that "*dry seasons will get longer, there will be more intense rainfall events, and more frequent and severe droughts and floods*. With an increase in precipitation and flooding in the monsoon season, there could be accelerated soil erosion, sedimentation, watershed degradation and landslides.[72] Landslides and soil erosion are often driven by clearing forest land in steep slopes to practice shifting cultivation, which will exacerbate the impact of climate change with increasing precipitation in the monsoon season.[73] This implies the need to protect high-risk areas and maintain these under forest cover and improve land use planning.[74]

Increasingly dry conditions and increasing temperatures in the dry season may also exacerbate the risk of forest fires, which are often started by anthropogenic activities but are expected to become more intense and frequent with climate change.[75]

4.4 Climate risk and vulnerability

With a ND-GAIN index of 40.5 in 2021[76], Lao PDR ranked 137 among all countries for vulnerability to climate change. While there has been some improvement since the 1990s (ranking 157), much remains to be done. Sectors that are the most affected include agriculture and natural resources and water, representing the key impact pathways for the country.
Figure 37 depicts the district level climate change vulnerability map developed for the country´s forthcoming Third National Communication to the UNFCCC. It builds on the AR4

[71] GFDRR n.d., Annex 1 includes a table describing the risk ranking criteria.
[72] World Bank 2011
[73] World Bank 2020
[74] Merger et al. 2019; World Bank 2020
[75] EcoLao 2012
[76] https://gain-new.crc.nd.edu/country/laos

definition of vulnerability, where vulnerability is comprised of exposure to hazards, sensitivity and adaptive capacity. Northern Lao PDR is considered highly and very highly vulnerable to climate change.

Climate change poses a great challenge for Lao PDR, where it is projected to result in temperature increases, and exacerbate seasonal extremes – including longer dry seasons and an increased occurrence of droughts, as well as more intense rainy seasons with severe and frequent rainfall that could increase the risk of flooding. Increasingly dry conditions outside of the monsoon season are also expected to increase the frequency and intensity of forest fires.

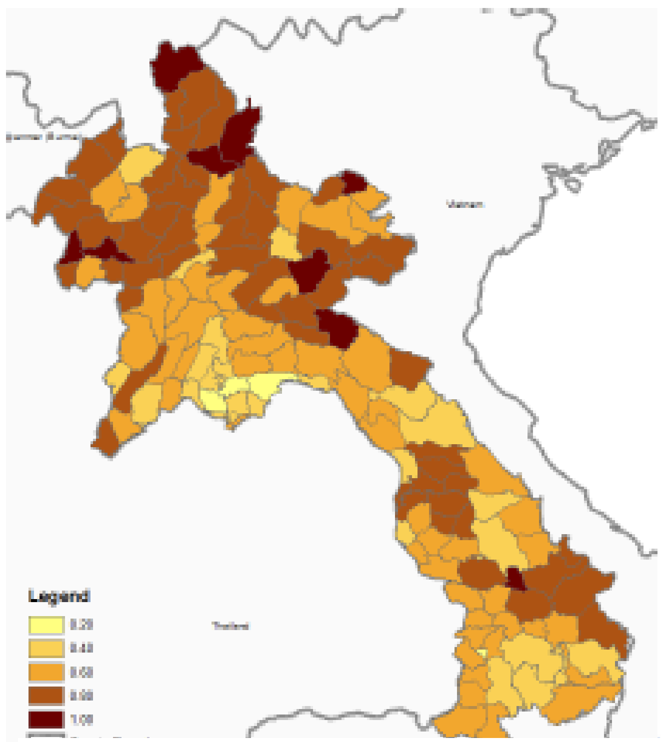

Figure 37: District level climate change vulnerability ranking, reproduced from Third National Communication (forthcoming)

4.4.1 Risks to agriculture and food production

As seen in Chapter 3. Analysis of Impact Pathways, the impacts of climate change are mainly felt on natural resources (water, biomass and land), which in turn lead to impacts on food production and human communities. The following describes the anticipated impacts of climate change on natural resources at the national level, with an accent on the Northern region.

In a seminal study, Rozenzweig et.al presented the results from a comparison of multiple global gridded crop models (GGGMs) across 5 global climate models and four RCP scenarios (IPCC AR4). They find that there is general model agreement on negative impacts of climate change on yields in all regions, with further evidence suggesting that tropical croplands are generally likely to see more negative impacts especially at higher levels of temperature change associated with higher RCPs[77].

In the IPCC Fifth assessment report, already, there was high confidence that biota composition and ecosystem processes had been affected by past changes in climate, that many plant and animal species had seen – and would continue to see – range, size and location changes as well as shifts in seasonal activity, due to the appearance of new climate conditions particularly in the tropical areas[78]. Findings in the IPCC 6th assessment report illustrate that the life cycle of major crops have been shortened, but that local adaptations are possible by selecting early maturing cultivars or shifting planting dates[79]. Constraints to most crops are expected to occur through heat stress, aridity, changes in water demand and supply (evaporation and water balance), and the modification/emergence of pests and diseases.

In Lao PDR, higher temperatures, greater frequency of heatwaves and delayed onset of rains (see Chapter 4.4 above) are likely to affect key crops such as ride, maize and cassava. Rainfed rice and maize start their planting periods in May/June (depending on location: plains versus mountains) and are harvested in September (maize in northern areas) or in November/December (rice). Irrigated rice is planted in December and harvested until May, whereas irrigated maize is grown in southern and plain areas and is planted in November and harvested in March[80]. Expected changes in potential evapotranspiration are similar for both RCP 4.5 and 8.5 scenarios, with most models simulating increases in PET in all months, with the highest increases during the dry season in the first half of the year (particularly during April and May). The changes are similar from 2041-2060 or from 2061-2080, although the expected magnitude of change in the long-term is higher[81].

Estimated impacts of climate change on rice and maize yields are also reported in the Third National Communication, with reductions in rice yields expected under RCP4.5 by 2050 compared to the 2005-2016 baseline for rice, but increases expected after. It should be noted that the TnC does not report a correlation between Temperature increase and rice yield, confirming the evidence that in Northern Lao PDR, precipitation changes are the key determining factor in yield reductions[82]. There remains variability in the crop modeling and results reported from one source to another, and additional research is warranted.

Changes in suitability for key crops are projected as shown in Figure 38. For upland rice (Houaphan, Louang Namtha, Oudômxai and Phôngsali), changes in suitability are clearly

[77] Rosezweig, C. et al, Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison, 2013. https://doi.org/10.1073/pnas.1222463110

[78] IPCC, AR5 and also IPCC, 2019, Climate change and Land Special Report.
[79] IPCC, AR6, Chapter 5 (Food Security)
[80] Tadross, M. Trends and simulated future changes in climate and crop suitability in Lao PDR, 2019. Reproduced with permission from the author.

[81] Tadross, M. Trends and simulated future changes in climate and crop suitability in Lao PDR, 2019. Reproduced with permission from the author.. Potential evapotranspiration (PET) was calculated for each month and GCM using the R package 'envirem'[81] utilising the method of Hargreaves[81].
[82] Government of Lao PDR, Third National Communication, pp. 43-45

negative in for both the near future and mid-century with similar magnitude of change for RCP 4.5 and 8.5. Simulated changes in suitability for maize are mixed and different to those for rice; suitability for maize mostly increases under the reduced rainfalls for SSP245 in the 2021-2040 period, whilst it more clearly reduces in the later period and under SSP585 with higher rainfall. Reductions in suitability are greater in Louang Namtha and Oudômxai[83].

Cassava suitability are reasonably consistent across SSPs and time periods, with mostly increases in suitability in Houaphan and Phôngsali and little or no change elsewhere. There is, however, a tendency for increases in suitability in the northern provinces [84].

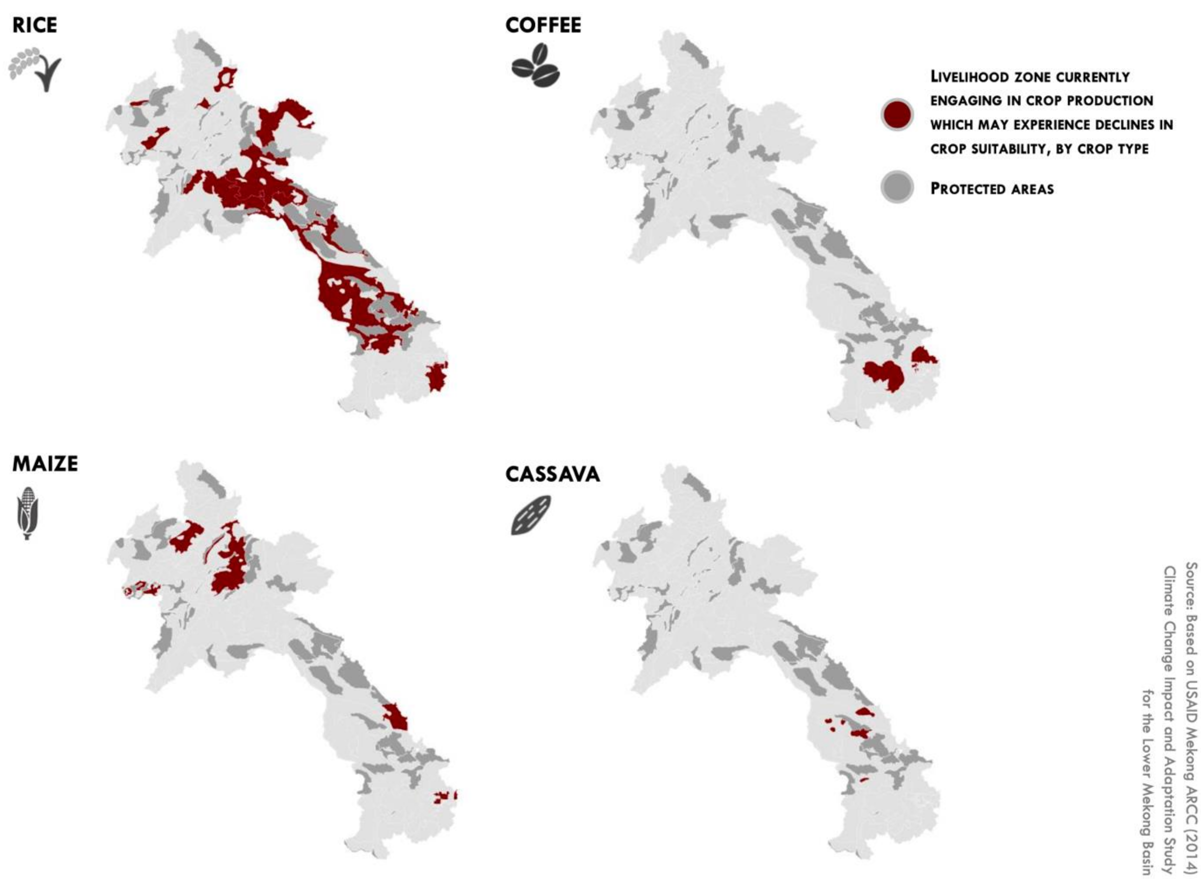

Figure 38: future changes in crop suitability . Source (WFP, CLEAR 2016)

Most households in Northern Lao PDR are dependent on the agro-forestry ecosystems, with 61% of the working population employed in the sector in 2019 (63% of female employment).[85]

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83 Id. And also WFP, CLEAR, 2016.

84 Tadross, M. Trends and simulated future changes in climate and crop suitability in Lao PDR, 2019. Reproduced with permission from the author

85 World Bank Data Bank. n.d. Employment in agriculture (% of total employment) (modelled ILO estimate) - Lao PDR. Available online: https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=LA.

Northern Lao PDR is particularly exposed as many households are dependent on low productive, upland rainfed agriculture for their subsistence and livelihoods. In the project area, rain-fed (lowland and upland) paddy rice, maize and vegetables are among the key agricultural crops grown.[86] Changes in temperature, precipitation patterns and the occurrence or intensity of climate-related hazards are expected to have detrimental impacts on agro-forestry ecosystems and smallholder farmers resulting in: changes in planting/ growing seasons, productivity, outbreaks of pests and disease, crop damage and losses, among other impacts.[87]

Households face exposure due to climate change impacts on forest ecosystems (e.g. increased frequency and intensity of forest fires).[88] The Third National Communication to the UNFCCC ranked Northern Lao PDR among the most vulnerable areas in the country. A combination of being the poorest regions in the country and land degradation due to traditional rotational forest/rice systems,[89] are causing the increase in exposure. The mountainous terrain is highly sensitive to climate change due to its sloped terrain, which is naturally prone to erosion events and landslides (especially deforested or degraded areas). Simultaneously, high rates of deforestation and forest degradation exacerbate the northern regions' exposure to climate change. Six provinces in Northern Lao PDR (Bokeo, Luang Namtha, Luang Prabang, Oudomxay, Sayabouri, and Houaphan) experienced > 40% of the country´s deforestation and forest degradation rate (in area) from 2005 to 2015.[90] Human-driven land degradation exacerbates climate change-induced risk and natural hazards (drought, flooding, forest-fires); reducing key ecosystem services that could enhance resiliency and adaptive capacity of local ecosystems, and the persons who depend on them.

Regarding forest degradation – which encompasses reductions in forest stocking, changes in species composition and size structure, loss of wildlife and plant habitats, and declines in wildlife and plant populations – is as concerning as deforestation.[91] The main drivers of deforestation and forest degradation are agricultural expansion, shifting agriculture, unsustainable harvesting of wood and non-timber forest products, and infrastructure development.

Water resources are also affected by deforestation and degradation, as both limit water recharge and storage. Limited water recharge and storage degrade water quality and quantity for both local and downstream communities.[92] With less water availability, plants and animals that help ensure soil and forest viability degrade, increasing risk and vulnerability due to flooding, droughts, and forest fires. Dryer topsoils are unable to retain water and without plant cover, have no protection from the impact of rainwater itself, stripping protective topsoil, resulting in mass erosions and landslides.[93] Erosions increase sedimentation and riverbank rise, reducing water quality and increasing risk of flooding downstream, where sediments are deposited.[94] Healthy forests are critical, as they help reduce flood peaks due to vegetative cover that slows flooding,

[86] Agricultural Census Office 2012 in FP117 Feasibility Study.
[87] World Bank. 2011. Climate Risk and Adaptation Country Profile: Lao PDR.
[88] World Bank. 2020. Lao PDR Forest Note: Toward Sustainable Forest Landscapes for Green Growth, Jobs and Resilience.
[89] World Bank. 2020. Lao PDR Forest Note.
[90] Pimhidzai et al. 2014 in UNDP 2015 in FP117 Feasibility Study.
[91] Thomas, I. L. 2015. Drivers of Deforestation in the Greater Mekong Subregion - Lao PDR Country Report
[92] World Bank. 2020. Lao PDR Forest Note: Toward Sustainable Forest Landscapes for Green Growth, Jobs and Resilience.
[93] Thomas, I. L. 2015. Drivers of Deforestation in the Greater Mekong Subregion - Lao PDR Country Report
[94] World Bank. 2020. Lao PDR Forest Note: Toward Sustainable Forest Landscapes for Green Growth, Jobs and Resilience; Thomas, I. L. 2015. Drivers of Deforestation in the Greater Mekong Subregion - Lao PDR Country Report.

increases soil infiltration and water detention, reduces erosion, sedimentation, and droughts; increasing water recharge, reducing soil evaporation, and improving water retention.

An estimated 25% of rural households in the region are food poor.[95] A major limitation for ensuring food security is the region's mountainous terrain, and limited valley space for growing rice paddy.[96] Local households cultivate upland rice for subsistence; however, yields are low, cultivation requires challenging physical labour, and unsustainable practices can further exacerbate climate change vulnerability (e.g. creating conditions for landslides, mass erosion events, sedimentation, and riverbank cutting downstream etc.). At the same time, climate change poses a risk for future yields of upland rice in some provinces, such as Houaphan. Moreover, most farmers in the region are dependent on rainfed agriculture, and changes in precipitation patterns could have devastating impacts on food security and agricultural livelihoods in Northern Lao PDR; especially where key crops such as maize are posed to be negatively impacted by climate change in the short-term.   In a 2017 study of the impacts of climate change on water yields and rice suitability, Trisurat et.al found that "Effects of drier climate overall in combination with medium emissions were substantial and would reduce annual water yield by approximately 24% from the baseline runoff…The largest reduction of suitable areas for rice cultivation was predicted for Thailand, followed by Lao PDR … Lao PDR and Cambodia are expected to face food security shortage problems and will likely need to import rice for larger populations by 2030"[97].

Lao PDR´s updated NDC notes that "changes in temperatures and precipitation will trigger variations in hydrology and deteriorations of flood conditions, perturbations for biodiversity, ecosystems and ecosystems services."[98] The increase in temperatures may increase the frequency of forest fires, and pests and diseases that contribute to forest degradation.[99] Flooding may lead to substantial erosion, watershed degradation and massive landslides. It further highlights the risk of changes in climatic conditions that could affect the growing conditions and distribution of flora and fauna.[100]

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95 Pimhidzai et al. 2014
96 GIZ FP117 Feasibility Study
97 Trisurat, Y. et al, Basin Wide Impacts of Climate change on Ecosystem Services in the Lower Mekong Basin, Ecological Research, 2017.
98 *Ibid.*
99 *Ibid.*
100 Government of Lao PDR [forthcoming]. Third National Communication to the UNFCCC. Vientiane, Lao PDR

5. Provincial level profiles

The following pages contain summaries of province and district-level climate risks and vulnerability analyses, which were derived on the basis of the methodology and data sources explained in Section 2, Methodology.

Using our methodology, each province's total Risk Index score was calculated by adding all the indicator scores. Given that there is no standardised Risk test, we collected data and then generate a scaled value, which was then translated into a score. We then tallied these scores to produce a Risk Index score. Three different Risk Indexes were created for each district and province: i) baseline risk score with no data from the climate scenarios included, ii) a risk index with RCP 4.5 projection scores tallied, and iii) a risk index with RCP 8.5 projection scores tallied, both latter scores also delineated for the three time points of 2040, 2070 and 2090.

Our analysis of the data included conducting emission scenarios RCP 4.5 and 8.5 projections using climateinformation.org's "Site-specific report" for three time points 2030, 2050, and 2080 as per the terms-of-reference. Both RCP 4.5 and 8.5 were added to baseline vulnerability scores to provide insight to how vulnerability for each of the six provinces would alter under each RCP scenario and at different time periods; please refer to section 2 for further detail on methodology, models and sources of data. See Annex 1 for a table summarizing the key changes for Bokeo for three main parameters of temperature, rainfall and aridity (all three of which are of particular relevance to forests and agriculture).

5.1 Bokeo province

Bokeo province is the most northwestern province of Lao PDR, bordering Thailand to the south and Myanmar to the north. With a forested, mountainous topography, Bokeo is a gateway province with access to the Mekong (in Tonpheung, Meung, Houay Xay and Paktha districts) and to the markets of Myanmar and Thailand (through Luang Namtha). It is also home to the Bokeo Nature Reserve, a protected area containing mixed-deciduous forest of 136,000 ha. Key cash crops crops are tea, maize, and rubber[101], but many communities rely on a variety of livelihood options depending on accessibility, including sesame, livestock and non-timber forest products such as mushrooms, broomgrass and cardamom[102].

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101 https://www.nsecbiz.com/provincial-profile/bokeo-province/

102 See for example WFP, CLEAR 2016 and Food And Nutrition Security Atlas of Lao PDR, 2013.

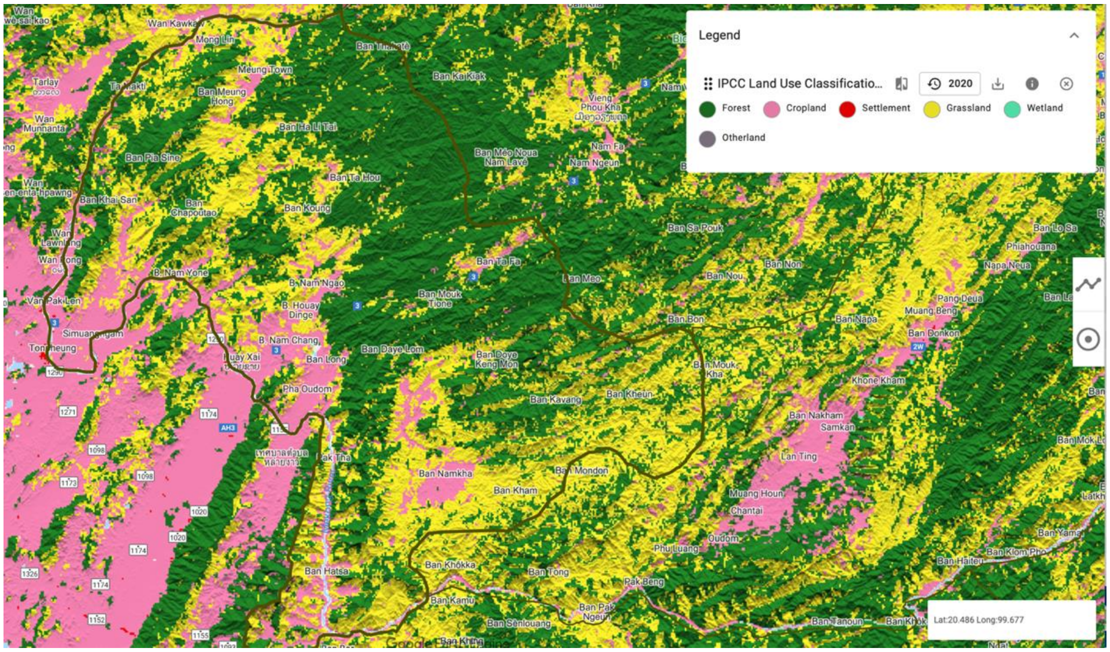

Figure 39: Land use classification map of Bokeo province. Source: extracted from Earthmap.org

Historically experiencing warm temperatures with seasonal rainfall (see Figure 40**Error! Reference source not found.**), our research shows that Bokeo has gotten dryer, especially in the last 30 years[103] (**Error! Reference source not found.**. This finding is supported by earthmap.org which showed that Bokeo's mean annual surface temperatures have increased by 0.01°C to 0.03°C (Figure 6) since 1979. By contrast, Bokeo's mean annual rainfall, which has oscillated around 1500 mm since 1901, has in the past decade plummeted to 1150 mms as of 2022 (**Error! Reference source not found.**). Bokeo's population is reliant on agriculture irrigated by rainfall for livelihood and food. Increasing surface temperatures and a drastic decrease in annual rainfall is delaying crop growing season[104], causing a knock-on effect that is driving high malnutrition/stunting rates and food insecurity.[105] In addition to the drastic changes it has already experienced, the projected climate future under RCP 4.5 and 8.5 shows that temperature trends would increase by as much as 3°C and precipitation up to 25% by 2080.[106] While more rainfall would seem to solve most of Bokeo's food insecurity, increased aridity in both RCP 4.5 and 8.5 would exacerbate baseline vulnerability, explained further below.

5.1.1 Historic and Current Climate Context

[103] Okapi Environmental Consulting, Inc. 2022. Vulnerability Assessment (VA) Tool.
[104] WFP. 2016. *CLEAR Report*, pg 18. Retrieved from https://www.wfp.org/publications/lao-pdr-report
[105] Okapi Environmental Consulting. 2022. VA Tool.
[106] *Ibid.*

Data from World Bank's Climate Change Knowledge Platform (CCKP), going back to the 1901[107], shows that Bokeo's mean annual temperatures is 27°C in January, increasing to a 33°C in April, decreasing to 29°C in August, and then dropping to 26°C in December. Precipitation follows an inverse pattern, with precipitation around 11.13 mms in January, increasing to 90 mms in April, increasing to190 mms in Jun, and peaking in August at 300 mms before dropping to 200 mms in September, and back to 15.24 mms in December. Climate change has altered these historic patterns, as shown by earthmap.org, Bokeo has experienced an increase of 1.73°C in mean annual surface temperatures (**Error! Reference source not found.**) 1975 to 2020[108]. S upporting earthmap.org's data is World Bank's CCKP, which showed that from 1982/83 to 2022, Bokeo's annual surface temperatures have increased by 1 °C (Figure 42).[109] Of all the provinces that the CRVA assessed for the project, Bokeo had the greatest increase in annual surface temperatures.

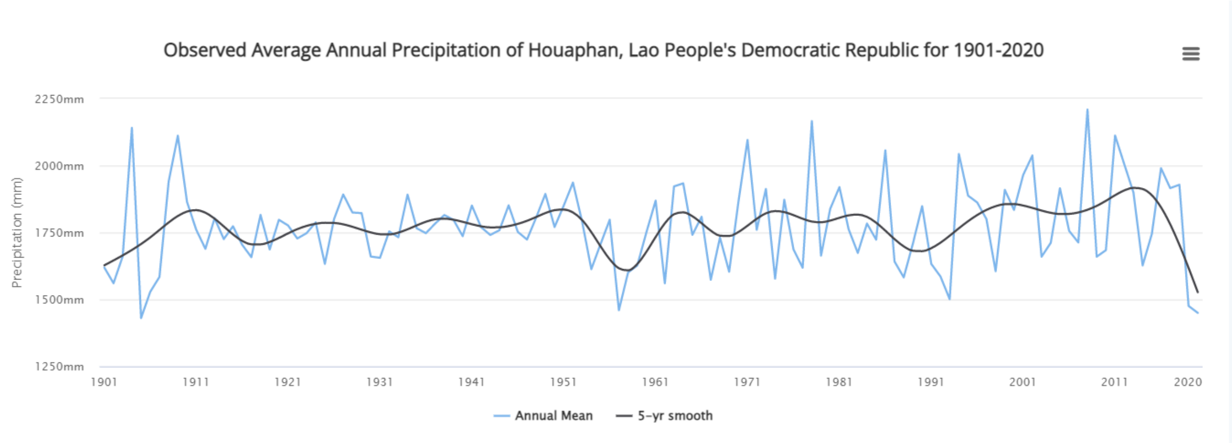

Figure 40: Observed average precipitation, Houaphan, 1901-2020. exteracted from World Bank Climate Change Knowledge Data Portal

[107] World Bank Climate portal, extracted April 2022. Retrieved from https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical

[108] Analysis of historic temperature and precipitation trends used earthmap.org's 'mean temperature change' indicator on an interactive global map. From earthmap.org information on the indicator, "The 'Mean Temperature' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map represents the change (by year) of the average Mean Temperature per year for the whole period (thus the total change would be the multiplication of this number by the total number of years).A change of 0.1 degrees per year would thus represent a 4 degrees total change between the start and the end of the period.The pixel size is 0.25 deg (approx. 28km at the equator). Period of observations: 1979 to near-present (4 month lag time for processing). Monthly aggregates have been calculated based on the ERA5 hourly values of each parameter; Unit = °C."

[109] World Bank. *Lao PDR: Climate Profile*. Retrieved from: https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical

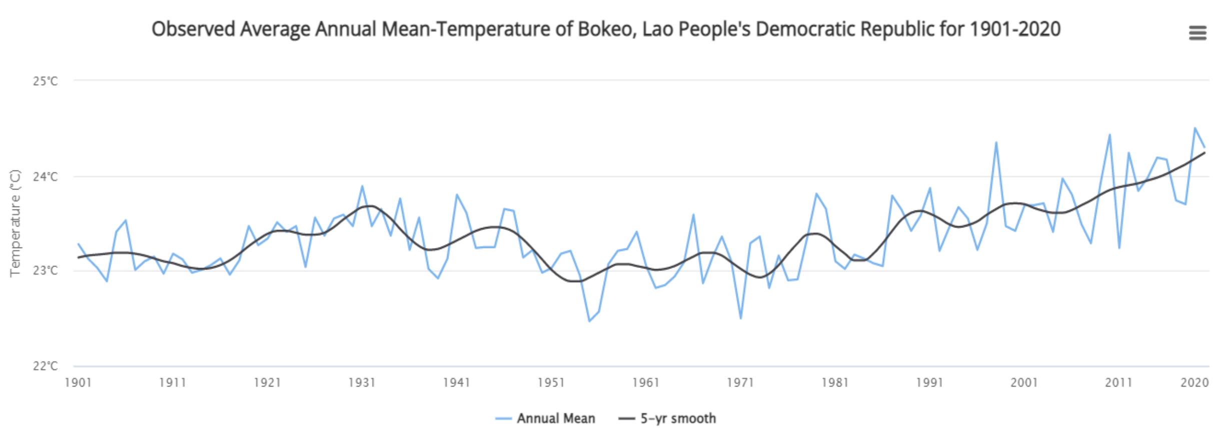

Figure 42: Observed average annual mean temperature, Bokeo, 1901-2020. Source: extracted from earthmap.org

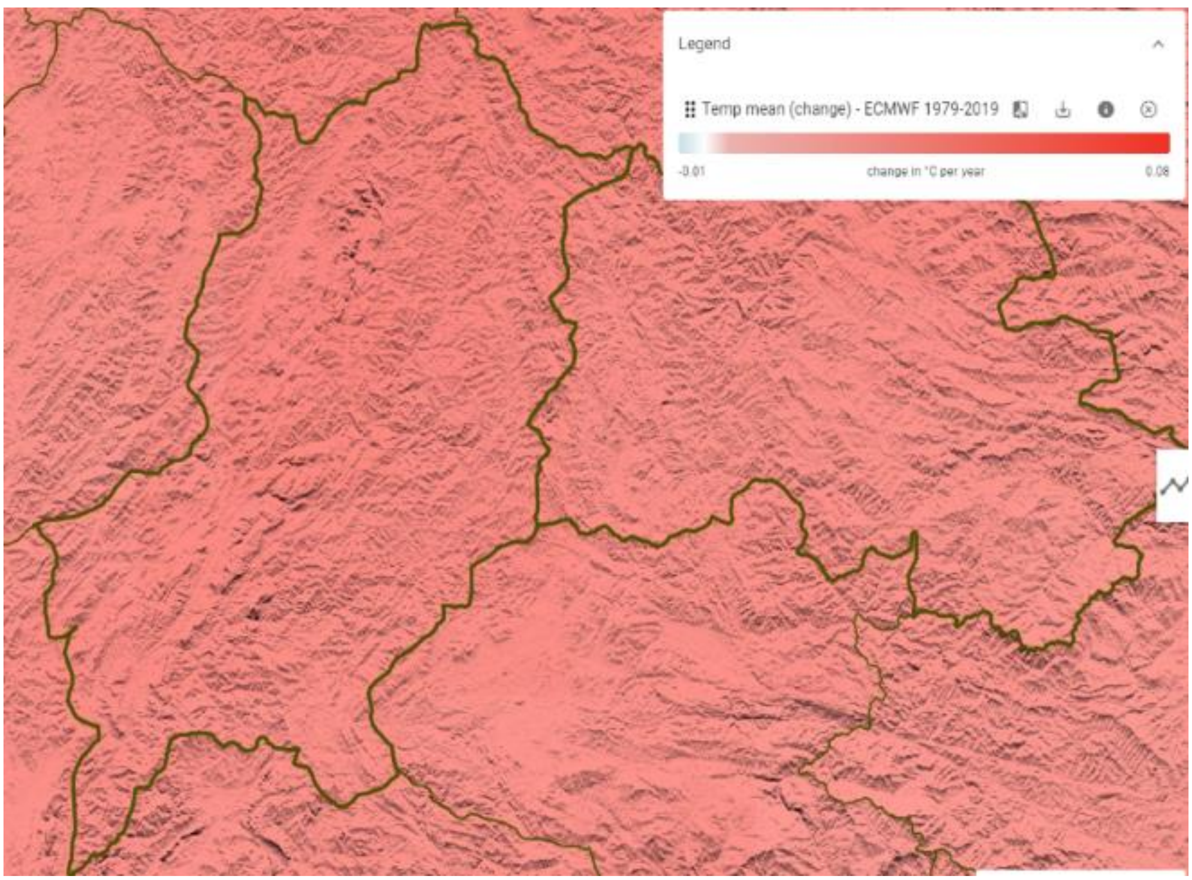

Figure 41:Change in mean average temperature 1901-2020, source: earthmap.org

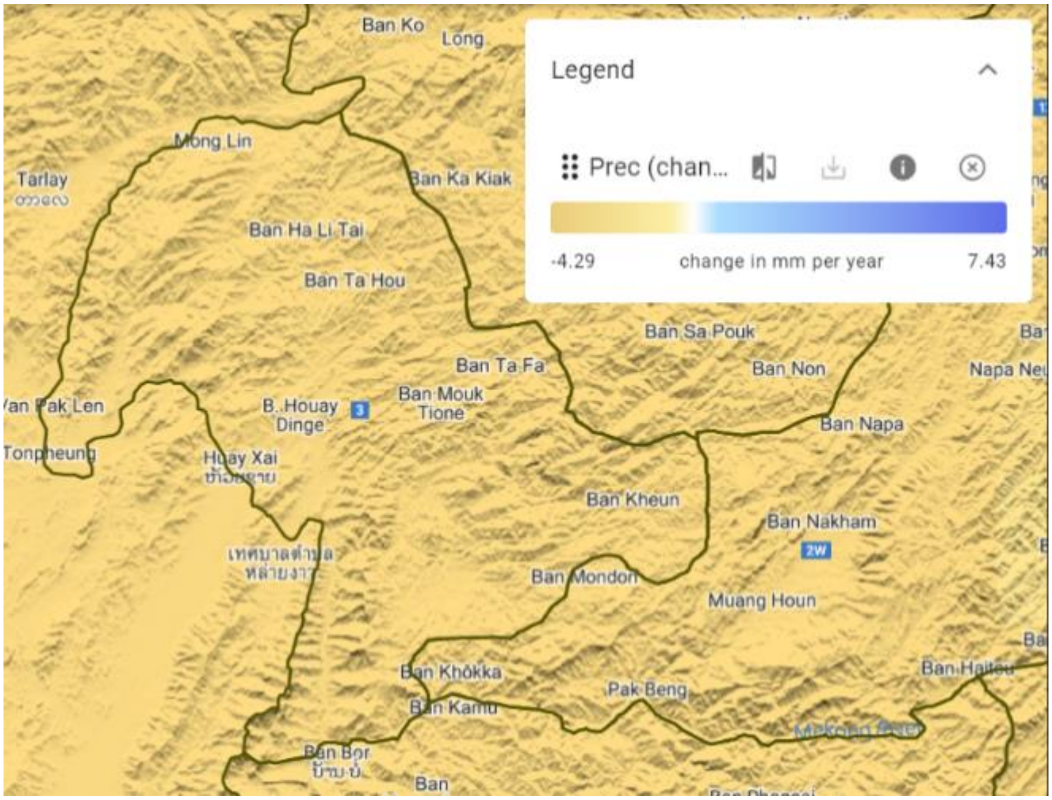

Figure 43: Change in average temperature, Bokeo, 1901-2020 (source: earthmap.org)

Regarding precipitation, data from the CRU extracted through earthmap.org shows that from 1979 to present, Bokeo has experienced a reduction of an average of 2.29 mm per year or 98.47 mms in total in rainfall.[110] Mentioned earlier, World Bank's CCKP shows a greater decrease in precipitation as the historic norm since 1901 of 1450 mms has dropped to 1050 mms as of 2022. While Bokeo has lost rainfall in the short-term, it also experienced the greatest number of extreme precipitation events (rainfall greater than 10 mm) of all the assessed provinces, with an average of 21 days a year since 2000 having rainfall more than 10 mm. Not only is the amount of rainfall yearly and in a day changing, but so too is the pattern of precipitation.

While less rainfall is occurring during the rain season, precipitation is occurring earlier in the year as well, causing a more uniform distribution of rainfall throughout the year.[111] For Bokeo, which grows bananas and other cash crops, such as maize, sugarcane, and tea, change in rainfall and increased temperature has the potential to decrease the productivity of its agricultural and

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[110] From earthmap.org "The 'Total Precipitation' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map represents the change (by year) of the average total precipitation per year for the whole period (thus the total change would be the multiplication of this number by the total number of years). A change of 2 millimeters per year would thus represent a 80 mm total change between the start and the end of the period."

[111] WFP. 2016. *Lao PDR: CLEAR* report. Retrieved from: https://cdn.wfp.org/wfp.org/publications/LAO_CLEAR-%20English%20version-FINAL%201-9-2016-standard.pdf?_ga=2.178019557.1912144398.1648411551-583810545.1636743625

even the suitability of certain crops.[112] This variability in rainfall and temperature drives Bokeo's exposure.

Data collected for this CRVA shows that Bokeo has seen an average 0.03 annual increase in mean annual temperature since 1990, and nearly an 8% increase in precipitation over the past 30 years. These trends feed into the risks of river flooding and landslides by increasing run-off, surface flooding in urban and rural areas due to lack of drainage, and both spontaneous and human-induced forest fires.

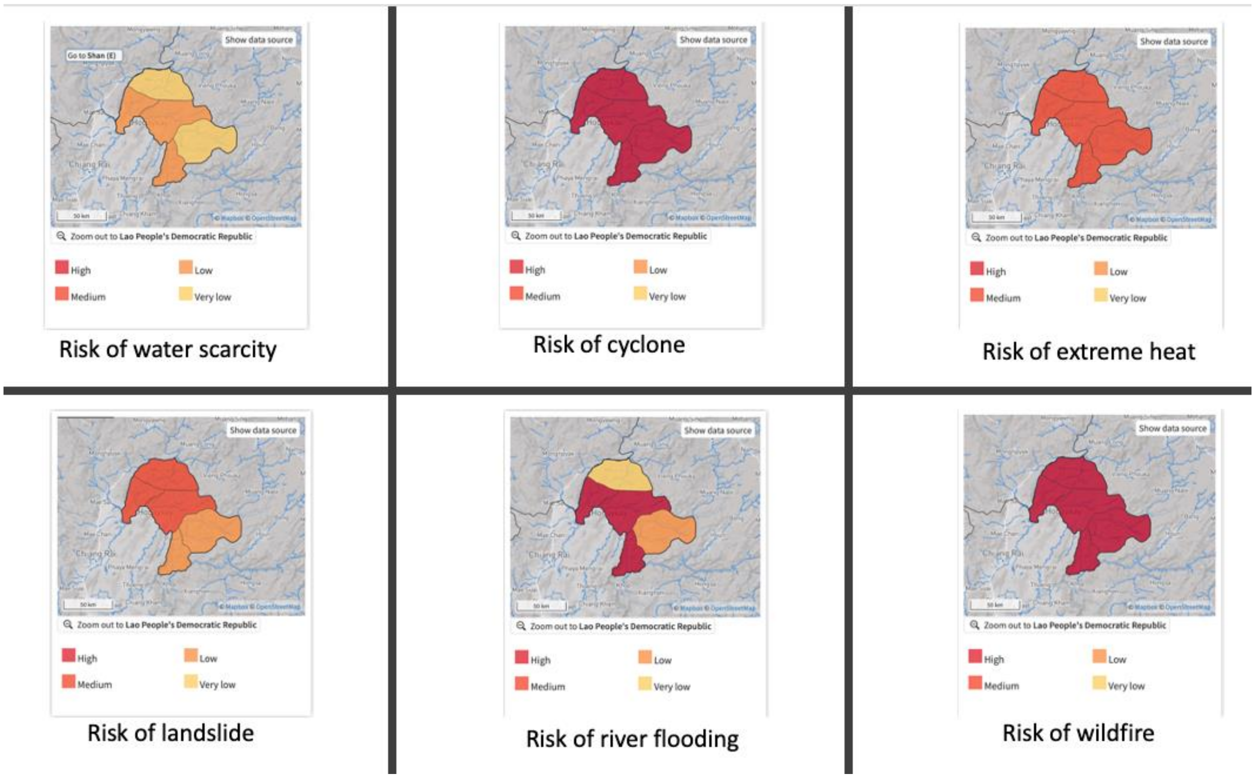

Figure 44: Risks of climate hazards for Bokeo province, source (Think Hazard, extracted april 2022)

While Bokeo has been exposed to hazard such as landslides, droughts, storms, and floods, it remains the least affected of the six provinces studied in this CRVA (see Figure 44. Even the Third National Communication's Vulnerability Index, which includes precipitation and temperature as hazards, had Bokeo ranked highest for exposure.[113] Supporting these findings are the WFP CLEAR Report, which showed Bokeo having 'High-Climate Sensitivity[114].'' This high

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[112] *Ibid*.

[113] Lao PDR. Third National Communication, pg 22. *To be published*.

[114] WFP. 2016. *Lao PDR: CLEAR* report. The CLEAR report explains climate sesnitivyt as "The limited access to irrigation means that households are generally quite sensitive to the effects of rainfall variability: delays in the onset of the rainy season can have severe effects on planting and other agricultural activities and can have negative effects on crop yields, leading to substantial food and income losses. Households engaging in activities that do not depend directly on rainfall patterns—such as mining, harvesting of non-timber forest products, and tourism—are less climate-sensitive and are therefore less affected by climate variability.

exposure level is why Bokeo has an estimated 20,000 people facing food insecurity daily in 2022 and in the past 30 years seen 44,763 people displaced by drought and flood, a quarter of Bokeo's total population.[115]

5.1.2 Projected trends

As summarized in Table 9,[116] Bokeo's mean annual surface temperatures would increase by 1°C (RCP 4.5) and 1.75 (RCP 8,.5), and precipitation would increase by 9.1% (RCP 4.5) and 14% (RCP 8.5). While temperature increases appear to have reached their maximum by 2030, precipitations continually increase under both scenarios, reaching a potential 29% increase in precipitation by 2080.

Table 9:Projected changes in Temperature, precipitation and aridity - multiple scenarios and time points (Bokeo)

Province	District	Parameter	2030	2050	2080	
Bokeo	*Meng*	Temperature	+ 1°C	+ 1°C	+ 1°C	RCP 4.5
		Precipitation	+ 6%	+ 9%	+ 10%	RCP 4.5
		Aridity	+ 2%	+ 3%	+ 13%	RCP 4.5
		Temperature	+ 1°C	+ 1°C	+ 2°C	RCP 8.5
		Precipitation	+ 7%	+ 11%	+ 21%	RCP 8.5
		Aridity	+ 6%	+ 27%	+ 26%	RCP 8.5
	Huay Xai	Temperature	+ 1°C	+ 1°C	+ 1°C	RCP 4.5
		Precipitation	+ 5%	+ 9%	+ 10%	RCP 4.5
		Aridity	0%	+ 1%	- 6%	RCP 4.5
		Temperature	+ 1°C	+ 1°C	+ 3°C	RCP 8.5
		Precipitation	+ 6%	+ 10%	+ 19%	RCP 8.5
		Aridity	+ 13%	- 9%	+ 3%	RCP 8.5
	Pha Oudom	Temperature	+ 1°C	+ 1°C	+ 1°C	RCP 4.5
		Precipitation	+ 6%	+ 11%	+ 13%	RCP 4.5
		Aridity	0%	+ 1%	- 6%	RCP 4.5
		Temperature	1°C	+ 2°C	+ 3°C	RCP 8.5
		Precipitation	+ 6%	+ 14%	+ 29%	RCP 8.5

[115] Lao Statistics Bureau. 2015. Lao 2015 Population Census. Retrieved from: https://lao.unfpa.org/en/publications/results-population-and-housing-census-2015-english-version
Okapi Environmental Consulting, Inc. 2022. VA Tool.
[116] Please refer to section 2 for sources of data and extraction methods.

		Aridity	+ 13%	- 9%	+ 3%	**RCP 8.5**
	Paktha	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 6%	+ 11%	+ 13%	**RCP 4.5**
		Aridity	+ 4%	+ 4%	+ 4%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 6%	+ 14%	+ 29%	**RCP 8.5**
		Aridity	+ 11%	+ 9%	- 4%	**RCP 8.5**

Under RCP 4.5, Bokeo's provinces of Huayxai and Pha Oudom would benefit from the increased rainfall, as their scores decreased. Under RCP 8.5, however, Bokeo's risk score is the lowest, despite its districts having some of the highest risk scores. Influencing this is that in RCP 8.5, Bokeo's annual surface temperatures would increase by 2^{o}C by 2050, increasing 3^{o}C by 2080, causing Bokeo's aridity to increase by 7.42% (RCP 8.5). The increase in surface temperatures would increase the number of days per year that Bokeo has surface temperatures greater than 32^{o}C. This could reduce crop productivity, increasing food insecurity, as well as heat stroke and heat stress. With a population highly reliant on rainfed agriculture for livelihoods, this would present a burden on communities, who would have to expend limited financial resources for medical treatment or in the case of morbidity, a loss of a productive member.

5.1.3 Climate Risk and Vulnerability Analysis

Bokeo's baseline Risk Index score was quite high (80, the highest baseline score of all the 6 provinces) indicating that the province is seeing the brunt of impact already. From our analysis, as illustrated in Table 10, it appears that under a RCP 4.5 scenario, risk could decrease in Bokeo but that the trend would reverse under a RCP 8.5 scenario.

Table 10: Summary of risk scores, Bokeo

		RCP 4.5				RCP 8.5					
	Baseline	Total at 2030	Total at 2050	Total at 2080	Median	Total at 2030		Total at 2050		Total at 2080	Median
Bokeo	**80**	**75**	**72**	**70**	**72**	**86**	**0**	**85**	**0**	**89**	**86**
Mueng (20.74/100.47)	34	32	28	30	30	44	0	47	0	49	47

Huay Xai (20.26/100.42)	67	57	53	51	53	85	0	78	0	85	85
Pha Oudom (20.21/100.54)	60	54	51	49	51	74	0	77	0	78	77
Paktha (20.10/100.59)	47	45	42	41	42	79	0	86	0	83	83

What Bokeo's Risk Index scores mean is that of all the provinces assessed in the baseline assessment, Bokeo was vulnerable to the greatest risk. Bokeo's vulnerability to risk was driven primarily by its exposure to temperature and precipitation hazards. High sensitivity to food insecurity, and limited adaptive capacity due to its population being highly-reliant on agriculture for livelihoods translate into Bokeo having limited opportunities to beneficially adapt to climate change risks. (Please refer to Annex 1 for data tables)

The results highlight that despite not being the most densely populated or having the greatest population, Huay Xai, Paktha, and Pha Oudom are more at risk. The only reason why Mueng is not as high as Huay Xai, Paktha, and/or Pha Oudom was because its exposure had a lower index than all three other districts, given its extensive forest cover and mountainous terrain. Huay Xai, while similar to Mueng in exposure, is the densest and its population size drives up its vulnerability.

The driver for Huay Xai, Paktha, and Pha Oudom's overall climate risk is the low access to safe, clean drinking water. Given that these communities rely on rainfall for crop irrigation and that precipitation has decreased for the past 10 years, food insecurity is high and should be addressed in the short term. In the long term, the greater precipitation expected under both RCP 4.5 and 8.5 may not be the panacea, and with greater runoff and discharge, there is worry that flooding can be just as destructive as consecutive years of drought. This makes the lack of infrastructure to handle water resources the more dangerous, as there may be no means to control excessive precipitation.

Bokeo's exposure is the lowest of all the targeted provinces. Given the extensive forest cover (discussed further below), the mountainous terrain found in most districts, and as it is historically the least flooded province, Bokeo's projected 'wet' future may not translate into a more productive future.

Huay Xai was by far the densest district with 41 persons per sq. km, followed by Pha Oudom and Paktha at 22 and 23 persons per sq. km., and Mueng was the least at a surprising 9 persons per sq. km. Given how dense Huay Xai is, it is unsurprising that the number of people affected by drought and flood in the past 30 years was highest at 11,322 people for non-Lao ethnic group and 12,870 people for Laotian ethnic group. Interestingly, even though Huay Xai is the most densely populated, it is also the second hilliest district, as 70% of its areas has an incline greater than 10%, second only to Mueng which has 80% of its territory with an incline greater than 10%. Pha Oudom and Paktha were the flattest, having on 5% of their territory with an incline greater than 10%. Despite Huay Xai being the most dense and having the greatest percentage of its land built on (20%), it has the greatest forest cover (78%), least forest degradation (7%), and its land degradation is the same as Pha Oudom and Paktha at 33%.

In the midst of researching this indicator, there hasn't been explanation for these surprising results, so it may be a result of policy or planning choices that led Huay Xai not to lose that much forest despite its development. It may also be that the hilly/mountainous nature of the terrain plays a role, as Mueng had the second lowest rate of forest degradation (56%) and was the only district that showed a negative figure on land degradation trends (-9%). Perhaps, hilly/mountainous terrain reduces the amount of development possible, having the effect of limiting the disturbance of forested areas. This is conjecture as time-constraints did not allow exploration of this hypothesis, however, it should be considered for further study.

This is consistent with the findings of the third national communication[117] which also finds that Bokeo, along with the adjoining districts in the Northwest, does not appear among the most "sensitive" districts (using AR4 definitions). This may be due to the size of river basins in the area: the third national communication notes that small and medium sized river basins present lower vulnerability (again using AR4 definitions), despite already moderately high run-off potential[118].

For the four districts in Bokeo, vulnerability indicators (both in terms of coping and adaptive capacity) are encouraging, however much remains to be done to maximize adaptation potential. For example, only 56% of the population in the province have access to climate information and early warning systems, and access to communication media that would enable them to take anticipatory action or to adapt to variability.

Bokeo's districts, of all the districts studied, had the greatest rates of food insecurity and second lowest values for access to safe drinking, sanitation facilities. Surprisingly, despite high levels of food insecurity, while stunting/malnutrition affected 36 – 40% of all children populations in all districts, this was not the highest value for all the districts studied. In fact, Bokeo's districts had the second lowest stunting percentage. Much more dire is the exceptionally low rates of accessibility to safe drinking water and sanitation facilities, as no district in Bokeo showed rates of access higher than 10%.

[117] Government of Lao PDR, Third National Communication, Vulnerability and Adaptation Assessment Report. Page 23.
[118] Earthmap.org, extrgacted April 2022 using HYSOGs 250m, global gridded hydrologic soil groups.

Paktha, on the other hand, showed the lowest level of accessibility to roadways, with only 72% of its population able to access paved/unpaved roads while all others were equal to or greater than 90%.

5.2. Houaphan province

Houaphan province is the eastern-most province of Lao PDR, bordering Vietnam on its northern, southern, and eastern border. Climatically, Houaphan is a warm climate as data from World Bank's CKMP shows that Houapahn's mean annual surface temperature has been 22.71°C and has a rain season beginning in June that peaks in August.[119] Since the 1971, mean annual surface temperature have risen by 1°C since 1971, while its precipitation in the last decade has dramatically decreased from 1760 mm to 1500 mm (**Error! Reference source not found.**, REF _Ref100472493 \h * MERGEFORMAT **Error! Reference source not found.**). Supporting this data is data from earthmap.org showing mean annual surface temperatures increasing by 0.01°C to 0.03°C per year since 1979 (**Error! Reference source not found.**) and decreasing precipitation during the same period (**Error! Reference source not found.**). Given Houaphan's agrarian population, reliant on rainfed cash crops and highland rice paddies[120] for livelihood and food security, this is a source of exposure to temperature and precipitation hazards that Houaphan's population is highly sensitive too[121]. Even more worrisome is that only 39% of Houaphan's population has access to climate information and early warning information[122], reducing Houaphan's ability to cope and adapt to current and projected climate futures. Considering that the CRVA Tool found that Houaphan will have the greatest precipitation and temperature increases (of the six project-targeted provinces that were assessed) under 4.5, and the third most in RCP 8.5[123], Houaphan faces some of the greatest risk under either climate future.

5.2.1 Historic and Current Climate Context

Data from the World Bank Climate Change Knowledge Portal going back to the 1930's shows that Houaphan's mean annual temperatures is 16.59°C in January, rising to a 23.44°C in April, before dropping to 25.21°C in August, and then dropping to 17.38°C in December (**Error! Reference source not found.**,). Precipitation follows an inverse pattern, with precipitation around 14.66 mms in January, increasing to 110.26 mms in April, to 282.88 mms in Jun, and peaking in August at 367.3 mms before dropping to 244.85 mms in September, and back to 17.91 mms in December. April, to 282.88 mms in Jun, and peaking in August at 367.3 mms before dropping to 244.85 mms in September, and back to 17.91 mms in December.

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[119] World Bank, 2022, Lao Climate Profile, Retrieved from: https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical
[120] WFP. 2016. CLEAR Report.
[121] Okapi Environmental Consulting, Inc. 2022. CRVA Tool
[122] GIZ. 2021. GIZ carried out a field exercise to gather data on the state of early warning systems and climate change information for the population's of the project-targeted provinces. ADD MORE ABOUT THIS
[123] Okapi Environmental Consulting, Inc. 2022. CRVA Tool.

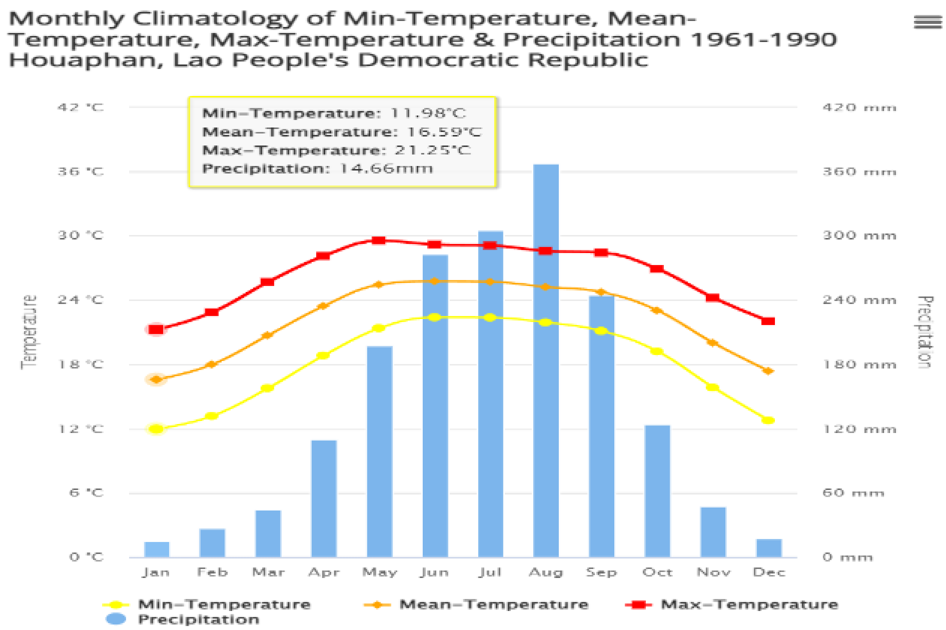

Figure 45 Houpahn's Mean Temperature, Max-Temperature, and Precipitation 1931 – 1960; Source: World Bank, Lao Climate Profile

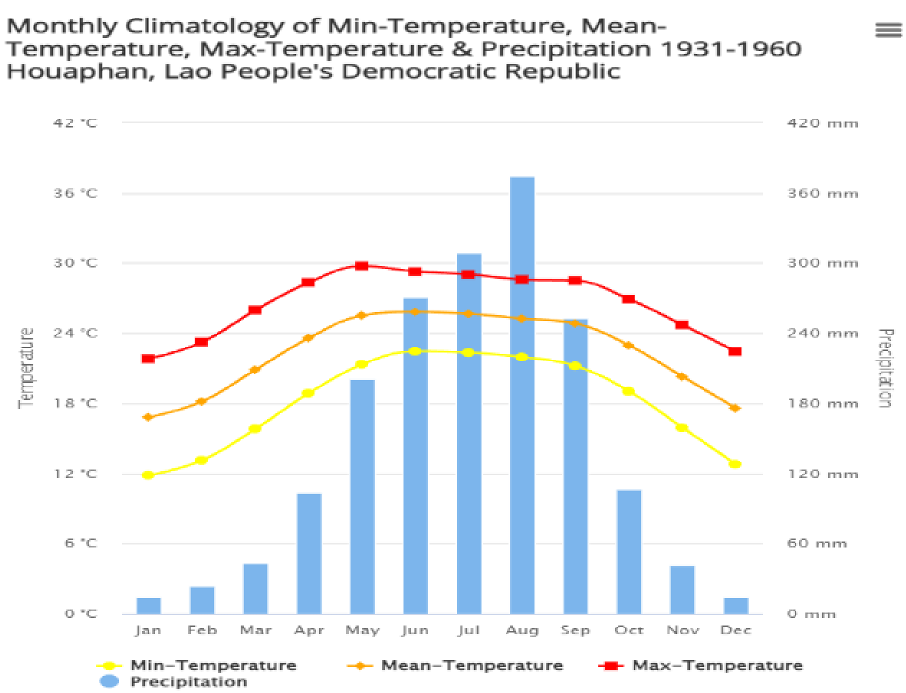

Figure 46 Bokeo's Mean Temperature, Max-Temperature, and Precipitation 1961 - 1990; Source: World Bank, Lao Climate Profile

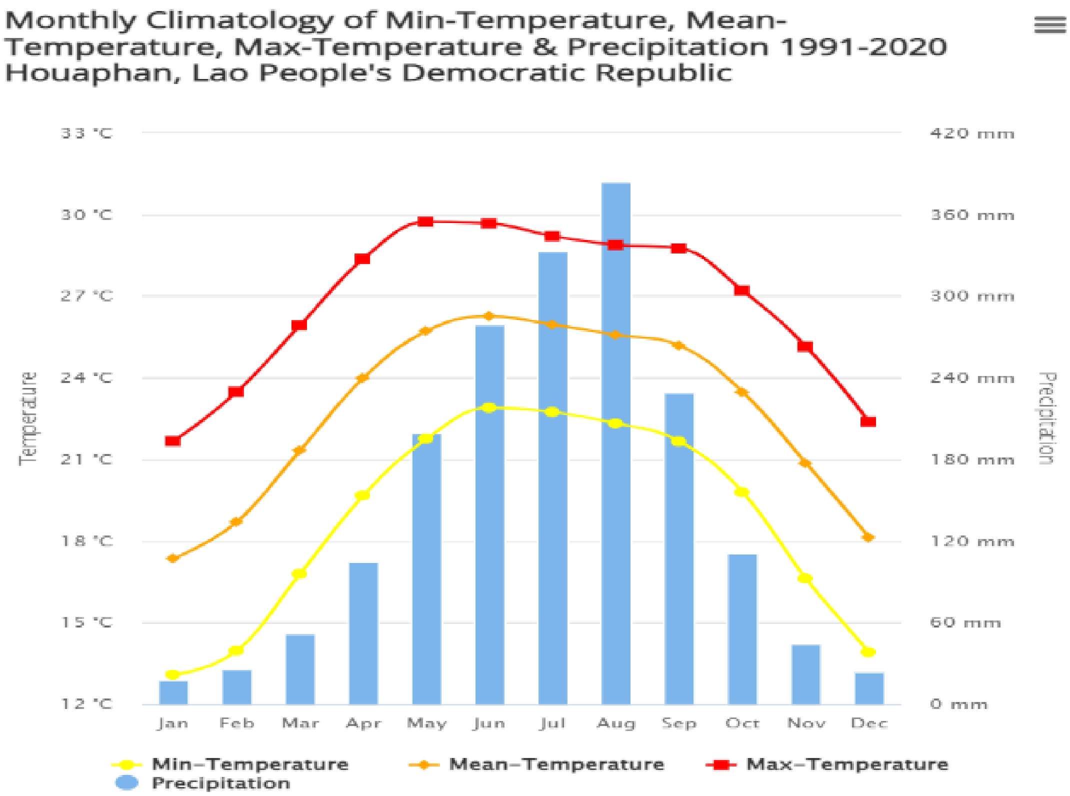

Figure 47 Bokeo's Mean-Temperature, Max-Temperature, and Precipitation 1991 - 2020; Source: World Bank, Lao Climate Profile

Houaphan's historic precipitation and temperature trends have changed. According to earthmap.org, Bokeo has experienced an increase of 1.5°C in mean annual surface temperatures (Figure 16 and 17) from 1971 to 2020[124]. This is corroborated by data from World Bank that shows mean annual surfaces temperatures increasing since 1971 (**Error! Reference source not found.**).[125] When focusing on seasonal shifts in temperature, the shift is around 0.3°C per annual mean temperature for each month, as seen in Figures Figure 45Figure 46Figure 47. From 1979 to present,

[124] Analysis of historic temperature and precipitation trends used earthmap.org's 'mean temperature change' indicator on an interactive global map. From earthmap.org information on the indicator, "The 'Mean Temperature' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map represents the change (by year) of the average Mean Temperature per year for the whole period (thus the total change would be the multiplication of this number by the total number of years).A change of 0.1 degrees per year would thus represent a 4 degrees total change between the start and the end of the period.The pixel size is 0.25 deg (approx. 28km at the equator). Period of observations: 1979 to near-present (4 month lag time for processing). Monthly aggregates have been calculated based on the ERA5 hourly values of each parameter; Unit = °C."

[125] World Bank. *Lao PDR: Climate Profile*. Retrieved from: https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical

Houaphan has experienced a reduction in annual precipitation but increased precipitation in June to August. Houaphan has experienced a reduction of an average of 1 mm per year or 40 mms in total in rainfall, while its seasonal rainfall has increased by .17 mms[126] - meaning that while less falls in a year, rainfall patterns are shifting towards a more even distribution throughout the year. While precipitation has averaged roughly 1750 mms since 1901 (), it has dropped precipitously in the past eight years, by as much as 250 mms by 2021 (Figure 48).

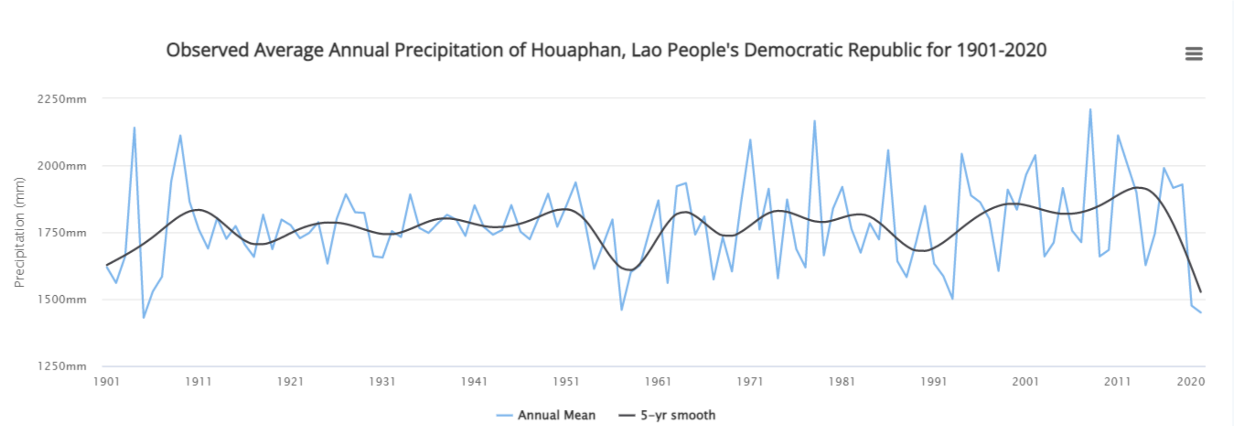

Figure 48 Change in Houaphan's Mean Annual Precipitation, 1901 - 2020; Source: World Bank, 2022

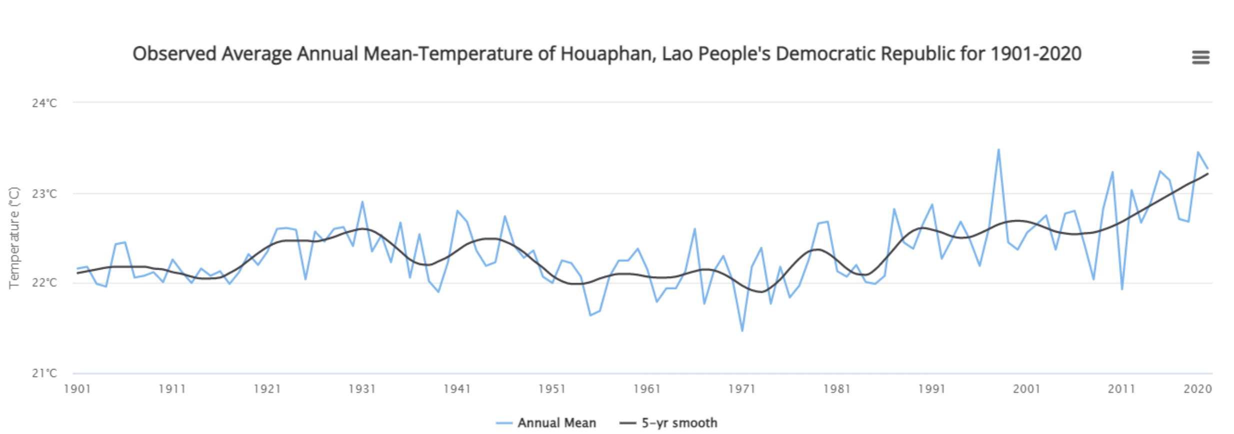

Figure 49 Change in Houaphan's Mean Annual Temperature, 1901 - 2020; Source: World Bank, 2022

Not only has the precipitation patterns altered, but also when the season starts as WFP noted that the rain season in Houaphan over the course of the past decade has shifted 5 to 10 days later than

[126] From earthmap.org "The 'Total Precipitation' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map represents the change (by year) of the average total precipitation per year for the whole period (thus the total change would be the multiplication of this number by the total number of years). A change of 2 millimeters per year would thus represent a 80 mm total change between the start and the end of the period."

its historic norm.[127] Despite the increase in temperature and decrease in annual precipitation, data gathered from GIZ, Sendai DeSinventar, and EMDAT, showed that Houaphan has been exposed to 10 droughts, 10 floods, 1 storm, 1 landslide, and 1 wildfire event in the past 30 years.[128] In comparison to the six targeted provinces, Houaphan had the lowest exposure given having the least number of extreme events. Despite having the lowest exposure to the extreme event hazards, Houaphan has had 44,936 people displaced by drought and flood over the past 30 years or 16% of its population. This is primarily due to its low adaptive and coping capacity reflected in only 39% of its population having access to climate change information and early warning systems.

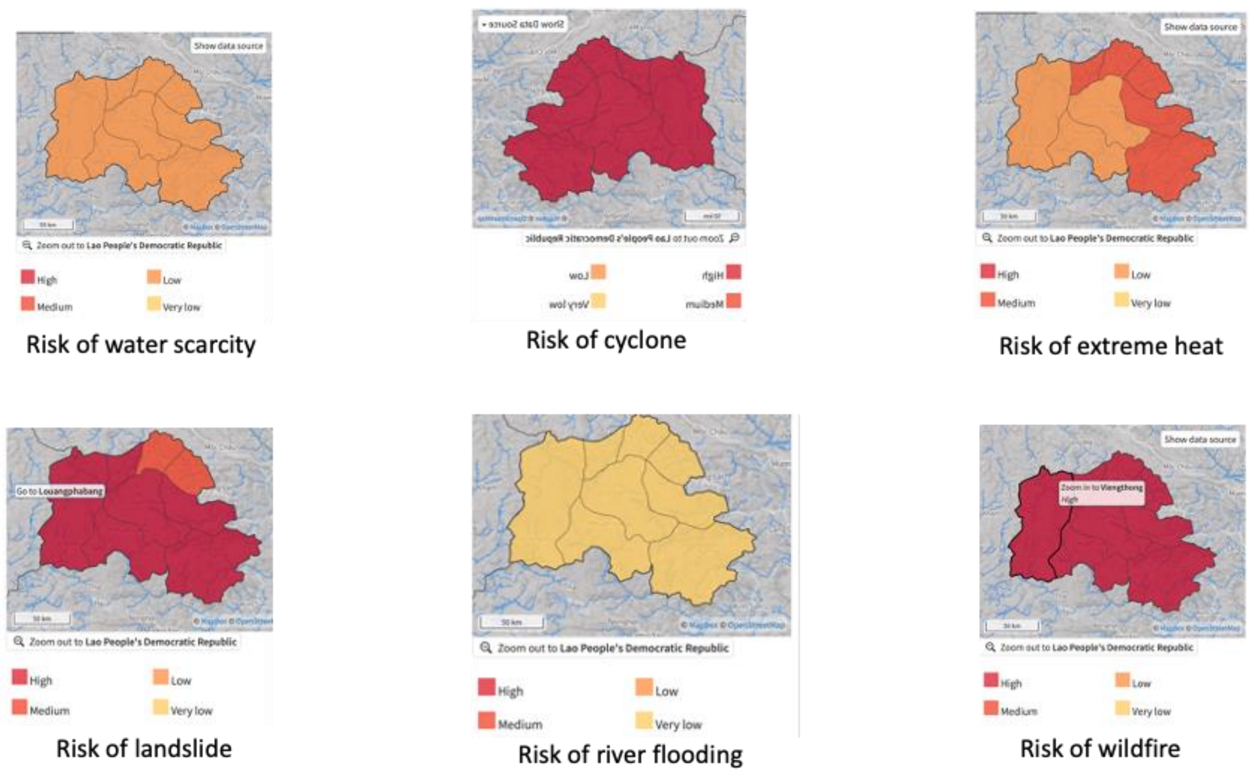

Figure 50: Level of risk of multiple climate hazards, Houaphan

Even more worrying is Houaphan's sensitivity with an estimated 56% of its population 5 years or younger suffering from stunting[129]. Driving stunting and malnutrition is declining crop

[127] WFP. 2016. *Lao PDR: CLEAR* report. Retrieved from: https://cdn.wfp.org/wfp.org/publications/LAO_CLEAR-%20English%20version-FINAL%201-9-2016-standard.pdf?_ga=2.178019557.1912144398.1648411551-583810545.1636743625

[128] Okapi. 2022. CRVA Tool

[129] Using data from the 2015 Lao Census, each province's population was multiplied by 0.21, which is the percent of the national population age 5 and younger. After calculating the population age 5 or younger, then that number was multiplied by percentage of stunting and malnutrition provided a 2018 UNICEF Indicators Report. Stunting and malnutrition are defined by the WFP definition that "Stunting is the impaired growth and development that children experience from poor nutrition, repeated infection,

production, as found by a joint FAO/WFP 2019 Food Security Assessment[130], for example by 70% between 2018 and 2019, and lack of diversity in crops, as Houaphan primarily grows rice, cassava, and corn, which while high in carbohydrates lack essential minerals and vitamins for development.

4.2.2 Projected Trends

When projecting potential climate change impacts under RCP 4.5 and 8.5 from 2020 – 2070, Houaphan's mean annual surface temperatures would increase by 1.45°C (RCP 4.5) and 2.11°C (RCP 8.5). Precipitation is projected to increase by 14.06% (RCP 4.5) and 22% (RCP 8.5), as seen in Table 11: Change in Temperature, aridity and precipitation for Luang Namtha.

Table 11: Change in Temperature, aridity and precipitation for Luang Namtha

Xon	Temperature	+ 1°C	+ 2°C	+ 2°C	**RCP 4.5**
	Precipitation	+ 7%	+ 14%	+ 14%	**RCP 4.5**
	Aridity	0%	+ 4%	+ 9%	**RCP 4.5**
	Temperature	+ 1°C	+ 2°C	+ 4°C	**RCP 8.5**
	Precipitation	+ 9%	+ 14%	+ 26%	**RCP 8.5**
	Aridity	+ 1%	+ 8%	+ 29%	**RCP 8.5**
Xamnue	Temperature	+ 1°C	+ 1°C	+ 2°C	**RCP 4.5**
	Precipitation	+ 9%	+ 16%	+ 21%	**RCP 4.5**
	Aridity	+ 3%	+ 4%	+ 21%	**RCP 4.5**
	Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
	Precipitation	+ 11%	+ 24%	+ 41%	**RCP 8.5**
	Aridity	- 1%	+ 9%	+ 17%	**RCP 8.5**
Hiam	Temperature	+ 1°C	+ 2°C	+ 2°C	**RCP 4.5**
	Precipitation	+ 7%	+ 14%	+ 14%	**RCP 4.5**
	Aridity	- 14%	- 7%	+ 9%	**RCP 4.5**
	Temperature	+ 1°C	+ 2°C	+ 4°C	**RCP 8.5**

and inadequate psychosocial stimulation," retrieved from: https://www.who.int/news/item/19-11-2015-stunting-in-a-nutshell. Higher rates of malnutrition and stunting correspond to higher rates of child mortality. Given that district level data was not available, it is assumed that provincial level rates are reflected in their constituent districts.

130 FAO. 2020. Special Report - 2019 FAO/WFP Crop and Food Security Assessment Mission to the Lao People's Democratic Republic. Rome. https://doi.org/10.4060/ca8392en

	Precipitation	+ 9%	+ 14%	+ 26%	**RCP 8.5**
	Aridity	+ 11%	- 10%	- 8%	**RCP 8.5**
Hua Muang	Temperature	+ 1°C	+ 1°C	+ 2°C	**RCP 4.5**
	Precipitation	+ 11%	+ 14%	+ 19%	**RCP 4.5**
	Aridity	+ 3	0%	+ 14%	**RCP 4.5**
	Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 4.5**
	Precipitation	+ 11%	+ 23%	+ 35%	**RCP 8.5**
	Aridity	- 7%	+ 3%	+ 2%	**RCP 8.5**
Viengxai	Temperature	+ 1°C	+ 1°C	+ 2°C	**RCP 4.5**
	Precipitation	+ 9%	+ 16%	+ 21%	**RCP 4.5**
	Aridity	+ 2%	+ 7%	+ 24%	**RCP 4.5**
	Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
	Precipitation	+ 11%	+ 24%	+ 41%	**RCP 8.5**
	Aridity	- 1%	+ 10%	+ 18%	**RCP 8.5**
Xamtai	Temperature	+ 1°C	+ 1°C	+ 2°C	**RCP 4.5**
	Precipitation	+ 10%	+ 16%	+ 21%	**RCP 4.5**
	Aridity	+ 3%	+ 6%	+ 22%	**RCP 4.5**
	Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
	Precipitation	+ 9%	+ 25%	+ 43%	**RCP 8.5**
	Aridity	- 2%	+ 9%	+ 16%	**RCP 8.5**

In comparison to all other targeted provinces, this makes Houaphan the most affected province. Considering the population's almost complete dependence on agriculture for livelihood and food, the population is most exposed to precipitation and temperature hazards. As precipitation increases, the temperature increases also increase drought periods[131], which was reflected in Houaphan's aridity increasing by 6.06% (RCP 4.5) and 5.78% (RCP 8.5). Given adequate access to information and planning, it is possible that Houaphan could adapt to these projections, however, Houaphan is severely lacking. Data collected for this exercise found that only 39% of Houaphan's population has access to climate change information and early warning systems. Combined with Houaphan's 56% of its population 5 years of age or younger being stunted and facing malnutrition, this means that any climatic future which decreases Houphan's crop

[131] WFP. 2016. CLEAR Report, pg 22

productivity will most likely lead to increased rates of malnutrition and stunting. Even worse is Houaphan's access to safe drinking water and sanitation, which was only 7% of its total provincial population[132]. While 74% of Houaphan's population has year-round access to road networks[133], this means that a third of its population does not. This means that a third of the population lacks the ability to move if needed from exposures.

When considering the individual districts, no one district stood out as particularly affected. For example, Muang Xon and Muang Hiam (both formerly part of Viengthong district) are projected to increase by 1.67°C and 2.34°C under RCP 4.5 and 8.5. However, these values are not truly outlying as all other districts are projected to increase by 1.34°C (RCP 4.5) and 2°C (RCP 8.5). For precipitation, however, both districts gain the least precipitation, with Xamtai, Viengxai, and Xamnue all gaining more with 15.33% and 25.67% under RCP 4.5 and 8.5 respectively.

5.2.3 Climate Risk and Vulnerability Assessment

Using our methodology, Houaphan's total Risk score was 51 in baseline vulnerability, increasing to a Median risk score of 60 under a RCP 4.5 scenario, and a score of 75 under a RCP 8.5 scenario. Contrarily to Bokeo, Houaphan's risk score steadily increases over the years (see Table 12: Risk Scores, Houaphan

Table 12: Risk Scores, Houaphan

		RCP 4.5				RCP 8.5			
	Baseline	Total at 2030	Total at 2050	Total at 2080	Median	Total at 2030	total at 2050	total at 2080	median
Houaphan	**51**	**60**	**58**	**65**	**60**	**68**	**79**	**75**	**75**

132 Used data from the Lao 2015 Census, Annex 1, summed categories 'Piped water,' 'Well/borhehold protected,' 'bottled or canned water,' and 'Tank;' from Table P8.1 and then multiplied the result by the average persons per household from Table P8.1 in Annex 1. The result from this calculation was then divided by total pop for province - from Table P1.1 and disaggregated for gender, ethnicity.

District numbers were generated by first calculating by using the household population numbers and finding the percentage of the provinicial population living in households (for example Bokeo has 81630 people living in households out of a total popualtion of 179243 or 46%) . After generating the percentage, multiplied the district population by that estimate and then disaggregate the numbers. While some disrepancies exist between the sum of the district percentages and the provincial percentages, the fact that the estimates approximate the Census numbers lends viability to this method.

Since only persons in households are considered, it should be noted that any population that isn't a part of a household is not captured in this calculation - which isn't large, but needs to be noted.

133 Lao BoS. 2015. Lao 2015 Census, Annex 1, Table P5.1

*Viengthong - Muang Xon (20.46/103.34)	33	30	40	37	37	47	53	58	53
Xamnue/Sam Nuea (20.41/104.05)	46	57	56	68	57	48	58	56	56
*Vienthong - Maung Hiem/Muang Hiam (20.08/103.36)	24	16	27	27	27	35	33	36	35
Hua Muang (19.26/102.29)	48	60	54	66	60	64	73	68	68
Viengxai (20.41/104.22)	40	43	44	56	44	44	54	52	52
Xamtai (20/104.63)	56	67	66	77	67	65	79	77	77

Even under moderate increases in GHG emissions, Houaphan will be adversely affected as it lacks the adaptive capacity to beneficially adapt to climate hazards and its sensitivity, in the form of stunting/malnutrition, access to clean water and sanitation, and road networks limits its population's capacity.

Interestingly, mitigating Houaphan's risk is forest cover and incline. In districts with most of its area with a slop incline greater than 10%, not only is forest cover more extensive, but the exposure to climatic hazards is lower. This suggests that the more hilly, mountainous, and/or steep the terrain is, the less propensity for flooding, for deforestation, and limited development. This trend showed up, as lower percentages of terrain with a slope greater than 10% had higher rates of forest and land degradation.[134] Conversely, districts with less construction and development, also had less accessibility to roadways and access to safe drinking water/sanitation. This suggests that to lower Houaphan's risk, areas of more development need to have more forest conservation and reforestation integrated, and less developed areas need greater access to

[134] Annex X, Table X

roads and safe drinking water, without comprising their buffer to climate hazards in the form of forest cover.

5.3 Luang Namtha

Luang Namtha province borders Bokeo province on the east, Thailand to the north, and Oudomxay to the south and west. Mean annual temperature is 21.96 °C with a progressive rain season that peaks between June and August. Much like Bokeo and the other northern regions, Luang Namtha's rainfall is becoming more uniform with earlier shifts in the rain season and less rainfall during its peak, with increasing rainfall in other months. Despite the continuing shift in rainfall patterns, this hasn't decreased the amount of rainfall Luang Namtha has received. Despite having high exposure to hazards such as floods and storms, Luang Namtha's adaptive capacity reduces its sensitivity, reducing its risk. RCP 4.5 and 8.5 modeling shows that Luang Namtha will not increase in mean annual surface temperatures by more than 1.67°C and precipitation by 20%. Increasing precipitation is expected to increase flooding for Luang Namtha, however this seems to be mitigated by Luang Namtha's comparatively greater adaptive capacity and lower sensitivity to exposures that lower its vulnerability, lowering its risk.

5.3.1 Historic and Current Climate Context

World Bank data going back to the 1930's shows that Luang Namtha's mean annual surface temperatures range from 18.72°C in January, rising to 25.22°C in April, before gradually decreasing to 19.03°C in December (Figures 28-30). Precipitation follows an inverse pattern, with precipitation around 1 mms in January, increasing to 90 mms in April, increasing to 190 mms in Jun, and peaking in August at 300 mms before dropping to 200 mms in September, and back to 1 mms in December (Figure 51, Figure 52, Figure 53).

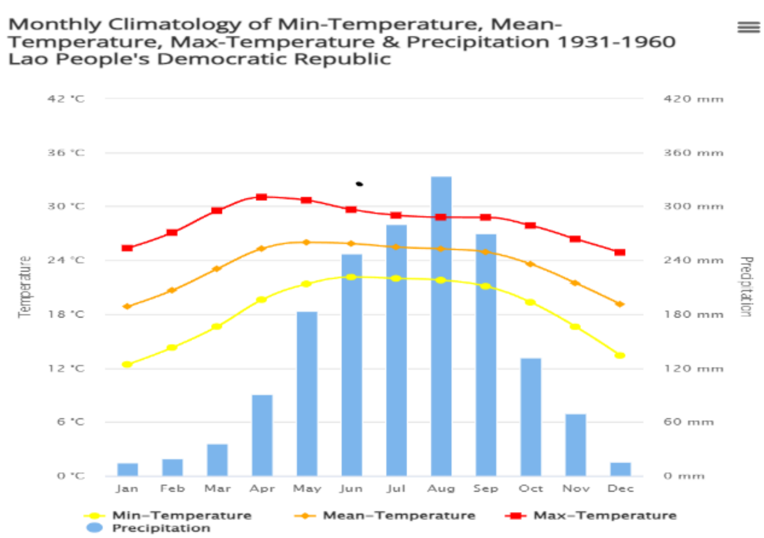

Figure 51 Luang Namtha's Mean Temperature, Max-Temperature, and Precipitation 1931

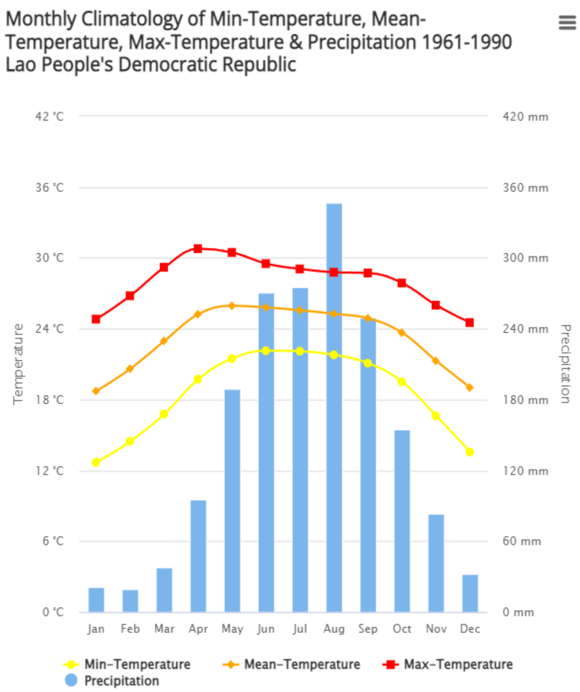

Figure 53 Luang Namtha's Mean-Temperature, Max-Temperature, and Precipitation 1961 - 1990; Source: World Bank, Lao Climate Profile

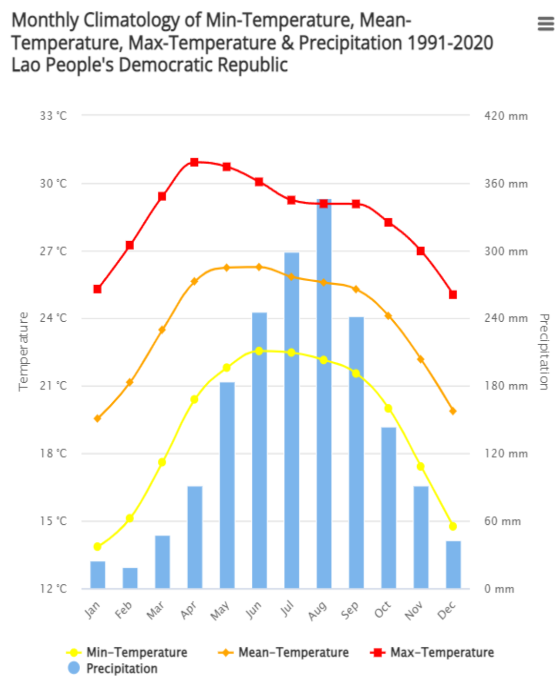

Figure 52 Luang Namtha's Mean Temperature, Max-Temperature, and Precipitation 1991 - 2020; Source: World Bank, Lao Climate Profile

Luang Namtha's historic precipitation and temperature trends are changing. According to earthmap.org, Luang Namtha has experienced an increase of 1.3°C in mean annual surface temperatures (Figure 55) from 1975 to 2020[135]. Data shows a dip in annual surface temperatures in 1981 of 0.5°C before climbing 1°C in the past 40 years.[136] From 1979 to present, Luang Namtha has experienced a reduction of an average of 2.41 mm per year or 104.06 mms in total (Figure 4) in rainfall.[137] While precipitation has averaged roughly 1750 mms since 1901, it has

[135] Analysis of historic temperature and precipitation trends used earthmap.org's 'mean temperature change' indicator on an interactive global map. From earthmap.org information on the indicator, "The 'Mean Temperature' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map represents the change (by year) of the average Mean Temperature per year for the whole period (thus the total change would be the multiplication of this number by the total number of years).A change of 0.1 degrees per year would thus represent a 4 degrees total change between the start and the end of the period.The pixel size is 0.25 deg (approx. 28km at the equator). Period of observations: 1979 to near-present (4 month lag time for processing). Monthly aggregates have been calculated based on the ERA5 hourly values of each parameter; Unit = °C."
[136] World Bank. *Lao PDR: Climate Profile*. Retrieved from: https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical
[137] From earthmap.org "The 'Total Precipitation' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map

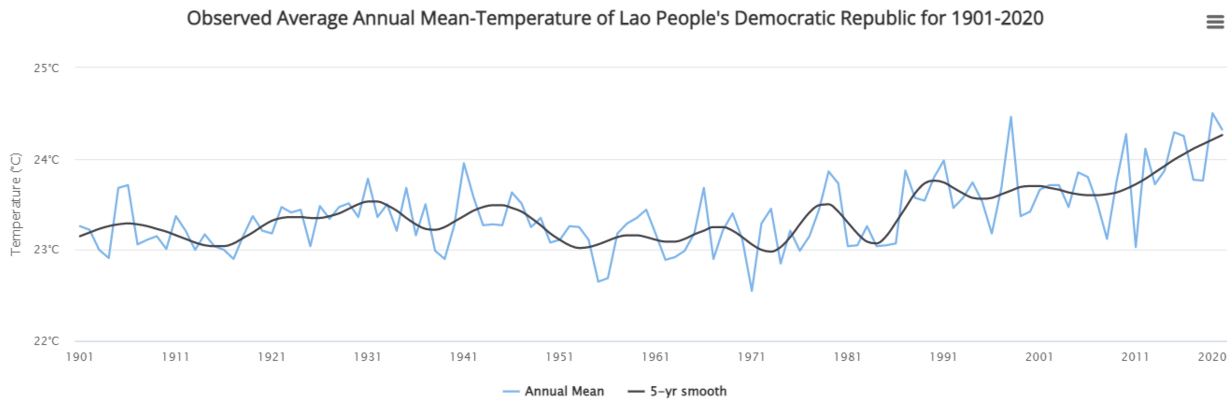

Figure 54:Change in Mean annual temperature since 1901

nosedived in the past eight years, dropping to 1500 mms in 2021 (Figure 6). Along with decreasing rainfall and increasing surface temperatures, Luang Namtha's rain season has steadily shifted 5 – 10 days earlier since 2006. Luang Namtha's rain season from June to August receives less rainfall, though rainfall now has started to occur earlier in the year causing a shift towards a uniform distribution of rainfall throughout the year.[138]

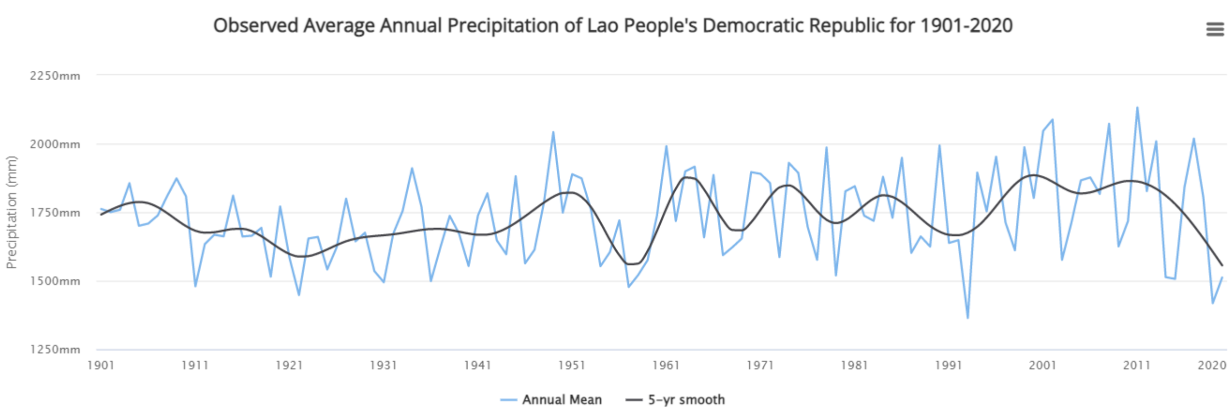

Figure 55 Change in Luang Namtha Mean Annual Precipitation, 1901 - 2020; Source: World Bank, 2022

represents the change (by year) of the average total precipitation per year for the whole period (thus the total change would be the multiplication of this number by the total number of years). A change of 2 millimeters per year would thus represent a 80 mm total change between the start and the end of the period."

[138] WFP. 2016. *Lao PDR: CLEAR* report. Retrieved from: https://cdn.wfp.org/wfp.org/publications/LAO_CLEAR-%20English%20version-FINAL%201-9-2016-standard.pdf?_ga=2.178019557.1912144398.1648411551-583810545.1636743625

Shifting precipitation and increasing surface temperatures explains why Luang Namtha is the most affected province for its exposure to flood, storm, and wildfire hazards. In the past 30 years, Luang Namtha has had 18 floods, 7 storms, and 9 wildfires[139]. Due to these hazards, 58,128 or 33% of Luang Namtha's population has been displaced in the past 30 years[140]. Despite this exposure, the overall exposure to hazards is low and that is due to Luang Namtha's adaptive capacity and low sensitivity.

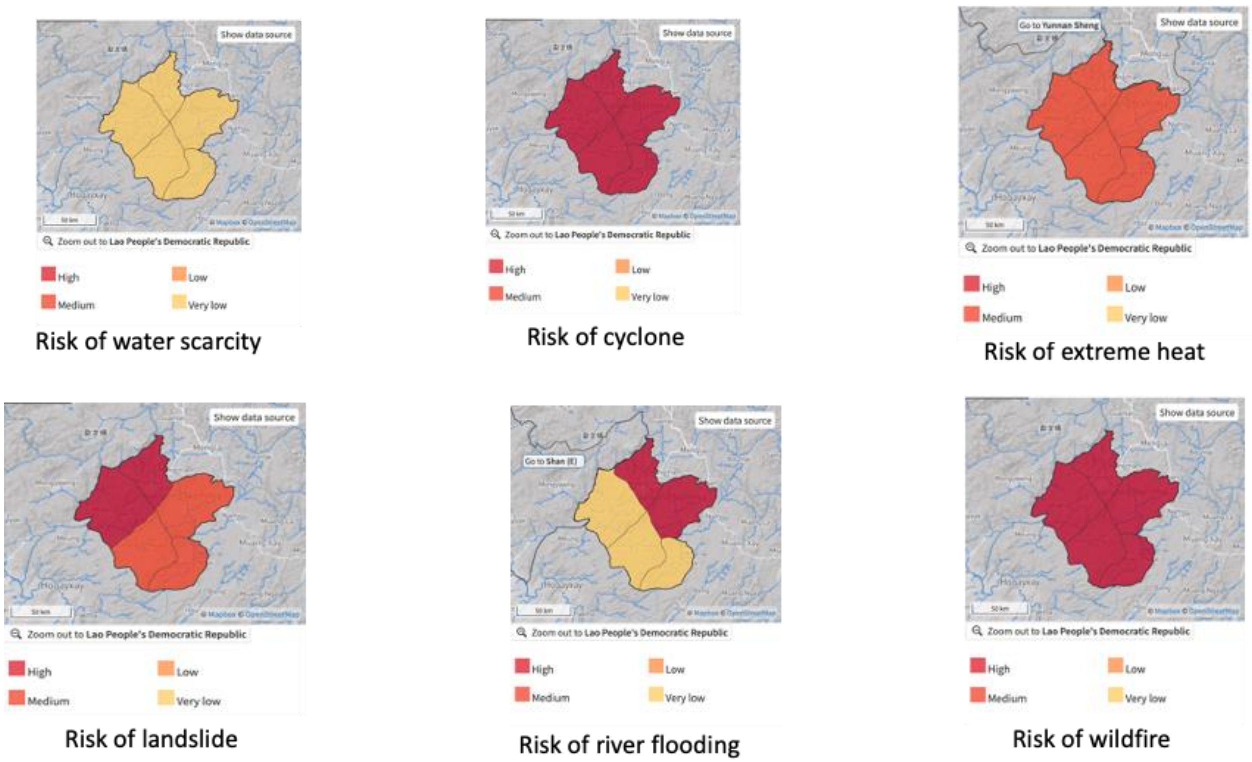

Figure 56: Risk of multiple climate hazards, Luang Namtha

Luang Namtha's population is entirely dependent on agriculture for livelihood and food security. Despite the drop in rainfall and increasing surface temperatures, data collected for this CRVA highlights that Luang Namtha has one of the lowest rates of stunting (34%), food insecurity (0.01% of total provincial population)[141], access to safe drinking water and sanitation (58%), and 54% of its area is under forest cover. Despite the reduction in precipitation and increasing surface temperatures, the CRVA tool also found that Luang Namtha's aridity also reduced. The reduction in aridity may have to do with Luang Namtha land being only 16% developed and 54% of its area under forest cover[142].

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139 EMDAT; DesInventar Sendai; GIZ
140 2015 Lao Census; DesInventar Sendai.
141 Okapi Environmental Consulting, Inc. 2022. CRVA Tool
142 GIZ. 2019. , nSite selection tool for development of Project 1 CN.

5.3.2 Projected Trends

When projecting potential climate change impacts under RCP 4.5 and 8.5 from 2020 – 2070, Luang Namtha's mean annual surface temperatures would increase by 1°C (RCP 4.5) and 1.67 (RCP 8.5). Precipitation projections show that Luang Namtha would receive 11.59% (RCP 4.5), making it the least affect of the project targeted provinces. Under an RCP 8.5 projection, precipitation would increase by 19.5%[143]. The increase in precipitation may compensate for the increase in aridity projected for Luang Namtha at 3.34% (RCP 4.5) and 7.42% (RCP 8.5). Despite the increase in rainfall, Luang Namtha is the third most affected province for aridity, with a 9.34% increase in aridity in RCP 4.5 and 11% in RCP 8.5. While the increase in rainfall will most likely result in increasing flooding, the increase in aridity may also contribute to increasing wildfires for Luang Namtha. Table 13: Expected changes at various time scales and scenarios, Luang Namthacontains a summary of projected changes across different scenarios and time frames.

Table 13: Expected changes at various time scales and scenarios, Luang Namtha

Province	District	Parameter	2030	2050	2080	
Luang Namtha	*Long*	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 7%	+ 12%	+ 15%	**RCP 4.5**
		Aridity	+ 3%	+ 14%	+ 9%	**RCP 4.5**
		Temperature	+ 1°C	+ 1°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 8%	+ 12%	+ 34%	**RCP 8.5**
		Aridity	- 1%	+ 13%	+ 7%	**RCP 8.5**
	Louangnamtha	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 7%	+ 13%	+ 15%	**RCP 4.5**
		Aridity	+ 10%	- 1%	+ 8%	**RCP 4.5**
		Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 8.5**
		Precipitation	+ 10%	+ 15%	+ 35%	**RCP 8.5**
		Aridity	- 3%	+ 4%	+ 14%	**RCP 8.5**
	Viengphoukha	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 7%	+ 13%	+ 15%	**RCP 4.5**
		Aridity	+ 1%	+ 3%	+ 12%	**RCP 4.5**
		Temperature	+ 1°C	+ 1°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 10%	+ 15%	+ 35%	**RCP 8.5**

[143] Please refer to Annex 1 for data tables

		Aridity	+ 6%	+ 28%	+ 28%	**RCP 8.5**
	Muang Nalae/Nale	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 7%	+ 13%	+ 15%	**RCP 4.5**
		Aridity	+ 11%	+ 17%	+ 16%	**RCP 4.5**
		Temperature	+ 1°C	+ 1°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 10%	+ 15%	+ 35%	**RCP 8.5**
		Aridity	+ 11%	+ 8%	+ 17%	**RCP 8.5**

As mentioned, Luang Namtha is the most affected province for all project-targeted provinces for flooding and wildfires. Despite the reduction in rainfall, the more even distribution of rainfall may explain why Luang Namtha's evapotranspiration rate has decreased significantly, in particular Namtha's evapotranspiration rate, which decreased by 115% (See table below).

5.3.3 Climate Risk and Vulnerability Assessment

Using our methodology, Luang Namtha's score was 57 in baseline assessment, increasing to a Median 60 with 4.5 projections, and 80 with RCP 8.5 projections. Despite the higher provincial score, the individual districts did not increase that much, with only Meuang Nale increasing to 64 and only under an RCP 8.5 scenario. This shows that Luang Namtha's adaptive capacity and low sensitivity reduces its risk.

		RCP 4.5				RCP 8.5			
	Baseline	Total at 2030	Total at 2050	Total at 2080	mediam	Total at 2030	total at 2050	total at 2080	median
Luang Namtha	**57**	**61**	**60**	**57**	**60**	**80**	**77**	**87**	**80**
Long (20.96/100.82)	26	29	29	26	29	28	28	37	28
Louangnamtha (20.97/101.4)	33	37	32	31	32	47	44	49	47

Viengphoukha (20.68/101.06)	12	16	15	15	15	36	35	43	36
Muang Nalae or Nale (20.53/101.44)	33	36	35	32	35	64	56	67	64

Just as all other project-targeted provinces have populations highly dependent on agriculture, it should be expected that Luang Namtha's risk should be much higher. However, it seems that the low levels of land degradation, high forest cover, 83% of its population having access to climate change information and early warning systems[144], and 83% of its population having year-round access to roads, substantially reduce Luang Namtha's risk. Other factors at play may be that Luang Namtha's is one of the main maize growing areas of Lao PDR, and maize is expected to benefit from increases in temperature and precipitation under the RCP4.5 scenario by mid-century.[145] Efforts to keep Luang Namtha's forested areas conserved or expanded should be considered, as well as efforts to control for increasing precipitation.

5.4 Luang Prabang

Luang Prabang province is the central province of the northern provinces of Lao PDR – with only a small corner touching Vietnam and the rest bordering most of the northern provinces. Mean annual temperature is 20.25 °C with a progressive rain season that peaks between June and August. Much like Bokeo and the other northern regions, Luang Prabang's rainfall is becoming more uniform with earlier shifts in the rain season and less rainfall during its peak, with increasing rainfall in other months. In fact, Luang Prabang saw the third-most drop in evapotranspiration rates in the past 20 years at a decline of 10%; only Houaphan and Sayaboury province had greater drops in evapotranspiration rates. Despite the continuing shift in rainfall patterns, Luang Prabang's projected climate future is wet. RCP 4.5 and 8.5 modeling shows that Luang Prabang will not increase in mean annual surface temperatures by more than 1.93°C and precipitation by 16.47%. However, the increase in precipitation is also projected to be offset by increasing aridity, as Luang Prabang is projected to be the worst hit province by projected aridity, at 8% in RCP 4.5 and 19.4% in RCP 8.5. While Luang Prabang is neither the most or least vulnerable of the project-targeted providences, the projected aridity with increase

[144] 2015 Lao Census; GIZ 2022
[145] Tadross, M. Climate trends and crop suitability for Lao PDR, 2019

precipitation will exacerbate current trends.

5.4.1 Historic Climate

Data going back to the 1930's shows that Luang Prabang's seasonal mean temperatures range 17.44°C in January, rising to a 24.02°C in April, minimally decreasing until September, before dropping down to 17. 54°C by December. Precipitation follows an inverse pattern, with precipitation around 13.11 mms in January, increasing to 108.53, before peaking in August at 318.96 mms, before dropping precipitously down to 7.45 mms by December.

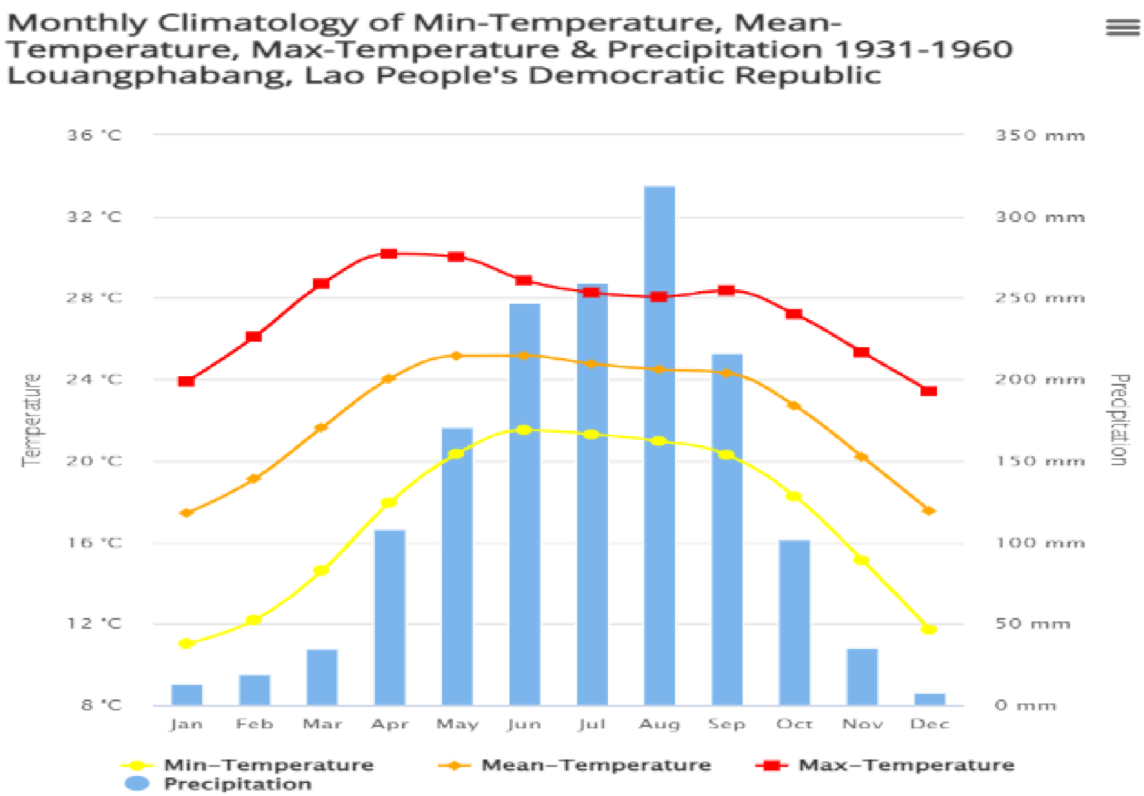
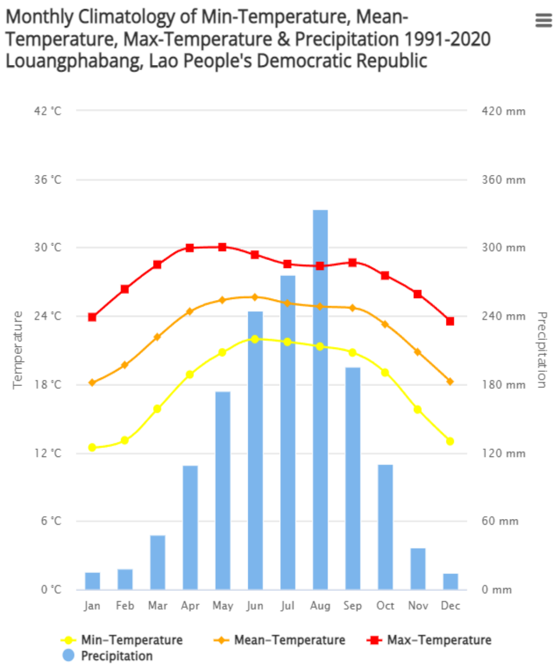


Figure 57 Luang Prabang's Mean Temperature, Max-Temperature, and Precipitation 1931 – 1960; Source: World Bank, Lao Climate Profile



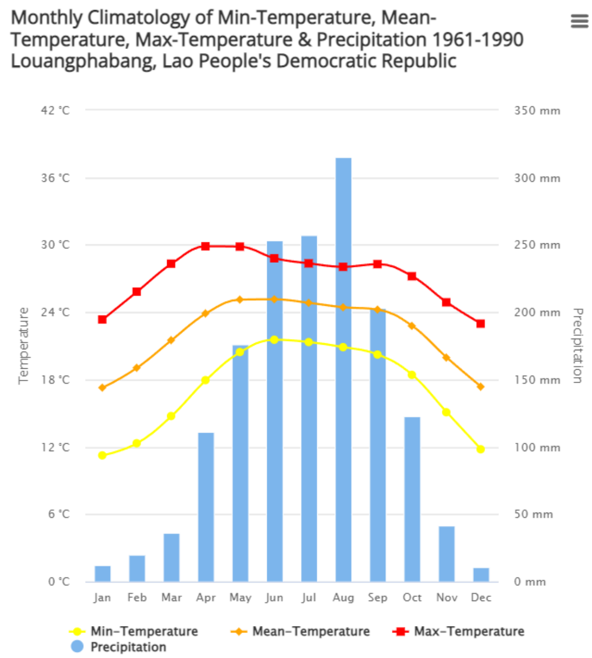


Figure 58 Luang Prabang's Mean-Temperature, Max-Temperature, and Precipitation 1961 - 1990; Source: World Bank, Lao Climate Profile

Figure 59 Luang Namtha's Mean Temperature, Max-Temperature, and Precipitation 1991 - 2020; Source: World Bank, Lao Climate Profile

5.4.2 Current Climate Context

Luang Prabang's historic precipitation and temperature trends are changing. According to earthmap.org, Luang Prabang has experienced an increase of 1.3°C in mean annual surface temperatures from 1975 to 2020[146]. This is corroborated by data from World Bank that shows climbing annual surface temperatures from 1981 onward of 1°C in the past 40 years.[147] From 1979 to present, Luang Prabang has experienced a reduction of an average of 1mm per year or 40 mms in total in rainfall.[148] While precipitation has averaged roughly 1500 mms since 1901, it has taken a nosedive in the past eight years, dropping to 1250 mms in 2021. This trend was also

[146] Analysis of historic temperature and precipitation trends used earthmap.org's 'mean temperature change' indicator on an interactive global map. From earthmap.org information on the indicator, "The 'Mean Temperature' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map represents the change (by year) of the average Mean Temperature per year for the whole period (thus the total change would be the multiplication of this number by the total number of years).A change of 0.1 degrees per year would thus represent a 4 degrees total change between the start and the end of the period.The pixel size is 0.25 deg (approx. 28km at the equator). Period of observations: 1979 to near-present (4 month lag time for processing). Monthly aggregates have been calculated based on the ERA5 hourly values of each parameter; Unit = °C."

[147] World Bank. *Lao PDR: Climate Profile*. Retrieved from: https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical

[148] From earthmap.org "The 'Total Precipitation' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map represents the change (by year) of the average total precipitation per year for the whole period (thus the total change would be the multiplication of this number by the total number of years). A change of 2 millimeters per year would thus represent a 80 mm total change between the start and the end of the period."

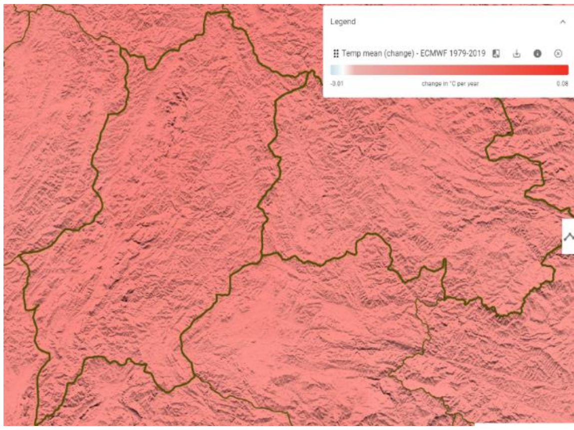


Figure 61 Luang Prabang Change in Mean Annual Precipitation 1979 to Present; Source: Earthmap.org

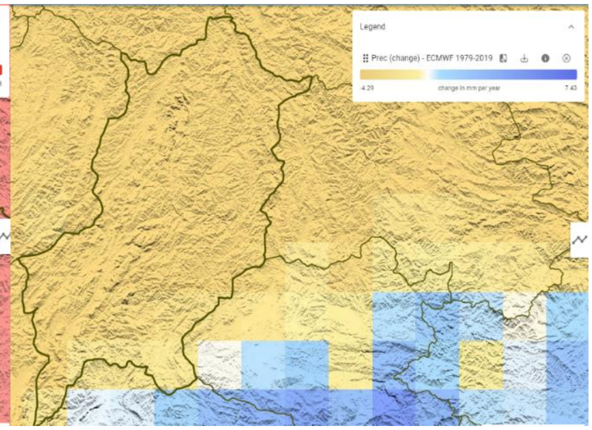


Figure 60 Luang Prabang Mean Annual Surface Temperature Change, 1975 to Present; Source:

captured in earthmap.org baseline data, which has an interactive map that will generate a data layer with various precipitation levels and only generated a layer at 10 mms.

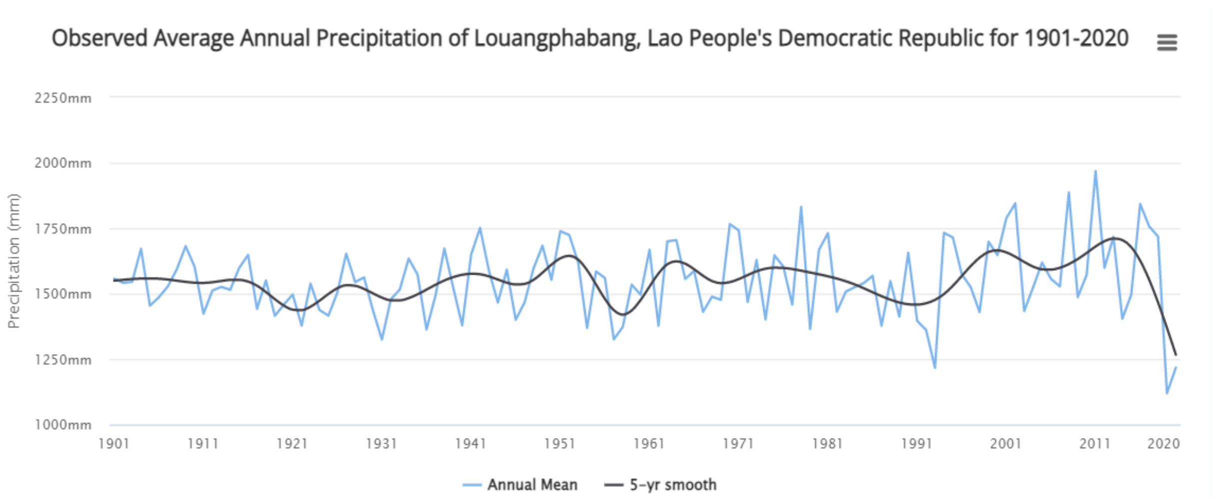


Figure 62 Change in Luang Prabang Mean Annual Precipitation, 1901 - 2020; Source: World Bank, 2022

Along with decreasing rainfall and increasing surface temperatures, Luang Prabang's rain season have steadily shifted 5 – 10 days earlier since 2006. Luang Prabang's rain season from June to August receives less rainfall, though rainfall now has started to occur earlier in the year causing a shift towards a uniform distribution of rainfall throughout the year.[149]

Despite being the most affected by floods and landslide, Luang Prabang had the least displaced people for droughts and floods. This doesn't mean that Luang Prabang had no people affected, indeed 12,553 people have been displaced in the past 30 years by flood and drought in Luang Prabang, but compared to all other provinces studied, it was the least affected. This may be

[149] WFP. 2016. *Lao PDR: CLEAR* report. Retrieved from: https://cdn.wfp.org/wfp.org/publications/LAO_CLEAR-%20English%20version-FINAL%201-9-2016-standard.pdf?_ga=2.178019557.1912144398.1648411551-583810545.1636743625

explained by the fact that only Xieng Nguen and Muang Nan are the only districts with less than 100% of their land with an incline over 10%; all other districts had 100% of their land with inclines over 10%. Having all land being mountainous appears to provide a buffer to potential flooding, by channeling water away from communities to lower elevations. Perhaps Luang Prabang's mountainous communities explains why it had the second least developed land at 8% (Bokeo and Houaphan tied for first at 7%), fifth most forest cover (47%), least amount of forest degradation (9%), and tied with Luang Namtha for second least-amount of land degradation (16%). With minimal land degradation and being mostly mountainous, it appears that Luang Prabang's exposure to hazards are minimized (see Figure 63).

Figure 64 Change in Bokeo's Mean Annual Surface Temperatures, 1901 - 2020; Source, World Bank, 2022

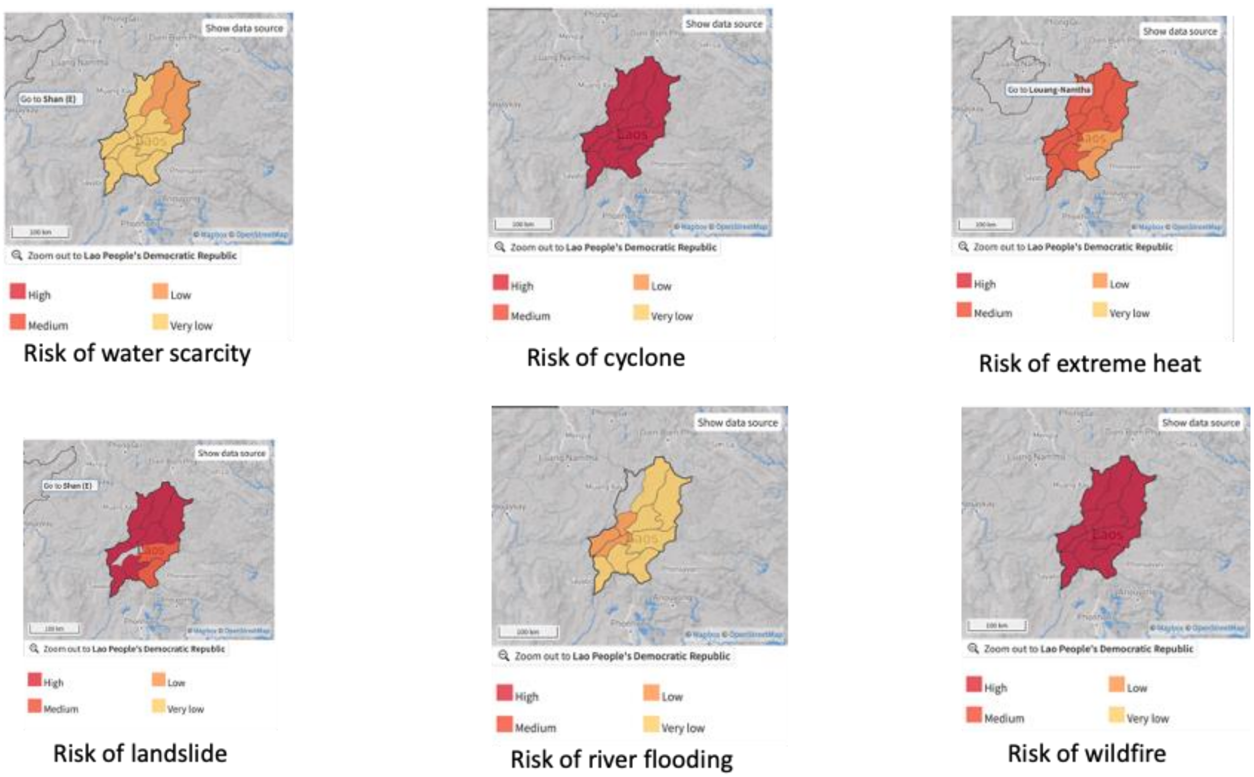
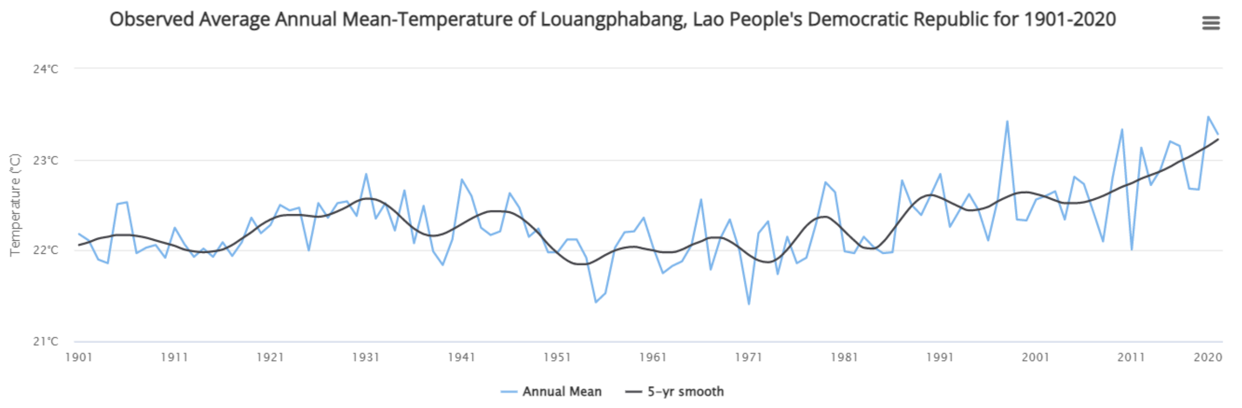


Figure 63: Risk of various climate hazards, Luang Prabang

5.4.3 Projected Trends and Hazards



When projecting potential climate change impacts under RCP 4.5 and 8.5 from 2020 – 2070, Luang Prabang's mean annual surface temperatures would increase by 1.07°C (RCP 4.5) and 1.93°C (RCP 8.5). Precipitation projections show that Luang Prabang would receive 11.07% (RCP 4.5) and 16.47% (RCP 8.5) more rainfall. Primarily due to the excess rainfall, Luang Prabang is the second most affected province under RCP 8.5, but the least affected under the RPC 4.5 model, in comparison to all the other project targeted provinces; however, the increase in precipitation may compensate for the increase in aridity of 3.34% (RCP 4.5) and 7.42% (RCP 8.5). Despite the increase in rainfall, Luang Namtha is projected to gain the most aridity at 8% in RCP 4.5 and 19.4% in RCP 8.5. With increases in rainfall and aridity, Luang Prabang will most likely suffer more flooding and landslides, of which Luang Prabang was third for having the most flooding, behind Luang Namtha and Xaiabouri, while being the only province to record more than one landslide in the past 30 years.

The table below shows the data for the climatic projections and hazards facing Luang Prabang. Despite the annual reduction in rainfall, the more even distribution of rainfall may explain why Luang Prabang's evapotranspiration rate has decreased significantly by 10% (See Table 14).

Table 14: Projected change for temperature, precipitation and aridity under various scenarios and timeframes, Luang Prabang

Province	District	Parameter	2030	2050	2080	
Luang Prabang	*Muang Nan*	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 5%	+ 10%	+ 9%	**RCP 4.5**
		Aridity	+ 13%	+ 10%	+ 16%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 6%	+ 10%	+ 13%	**RCP 8.5**
		Aridity	+ 7%	+ 25%	+ 16%	**RCP 8.5**
	Xieng Nguen	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 9%	+ 12%	+ 16%	**RCP 4.5**
		Aridity	+ 6%	- 5%	+ 20%	**RCP 4.5**

		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 4.5**
		Precipitation	+ 8%	+ 17%	+ 27%	**RCP 8.5**
		Aridity	+ 17%	+ 21%	+ 27%	**RCP 8.5**
	Phonxai	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 9%	+ 12%	+ 16%	**RCP 4.5**
		Aridity	+ 6%	- 6%	+ 21%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 8%	+ 17%	+ 27%	**RCP 8.5**
		Aridity	+ 17%	+ 12%	+ 29%	**RCP 8.5**
	Viengkham	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 11%	+ 14%	+ 19%	**RCP 4.5**
		Aridity	+ 3%	0%	+ 14%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 11%	+ 23%	+ 35%	**RCP 8.5**
		Aridity	- 7%	+ 3%	+ 2%	**RCP 8.5**
	Phonthong	Temperature	+ 1°C	+ 1°C	+ 2°C	**RCP 4.5**
		Precipitation	+ 6%	+ 12%	+ 15%	**RCP 4.5**
		Aridity	+ 1%	+ 5%	+ 17%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 7%	+ 17%	+ 30%	**RCP 8.5**
		Aridity	+ 5%	+ 14%	+ 39%	**RCP 8.5**

5.4.4 Climate Risks and Vulnerability

Using our methodology, Luang Prabang's baeline risk score was 57, shown to increase under both RCP scenarios, with a very sharp risk increase by 2080 under a RCP85 scenario (Table 15). This score was driven by high food insecurity, highest number of female-led households, lack of diverse livelihoods, and over-reliance on rainfall for crop irrigation.

Table 15: Summary of risk scores, Luang Prabang

			RCP 4.5				RCP 8.5		
	Baseline	Total at 2030	Total at 2050	Total at 2080	mediam	Total at 2030	total at 2050	total at 2080	median
Luang Prabang	**57**	**64**	**55**	**60**	**60**	**80**	**89**	**88**	**88**
Muang Nan (19.49/101.88)	23	27	23	22	23	43	53	47	47
Xieng_Nguen (19.76/102.18)	31	37	27	34	34	53	60	57	57
Phonxai/Phon Sai (19.52/102.40)	27	33	23	30	30	44	49	48	48
Viengkham (19.36/102.42)	31	24	31	34	31	35	52	47	47
Phonthong (20.73/103.07)	17	24	16	27	24	28	35	37	35

Vulnerability is also fueled by coping and adaptive capacity. In favour of strong adaptive capacity, 92% of Luang Prabang's population has accessibility to road networks, but there are low percentages of accessibility to clean drinking water and sanitation facilities (19and a significant rate of stunting at 51% for ethnic groups and 59% for Laotian ethnic group. This is not surprising as Luang Prabang also ranked second in food insecurity. Given the over-reliance on rainfall for crop irrigation and having the most female-led households (10285), this inhibits adaptive capacity as the communities has less access to diverse livelihood and capacity-building resources.

Even though each of Luang Prabang's districts are not the most distressed (mostly fueled by a lower baseline exposure to climate hazards), it is important to note that Luang Prabang does have the highest risk in the form of food insecurity, stunting, and greatest number of female-led households. In Lao PDR, female-led households have far less accessibility to financial credit, land, and other resources. Especially as Luang Prabang's natural resources have reduced sensitivity, the high prevalence of stunting and food insecurity will have long-term impacts that will further decrease adaptation capacity. By increasing the usage of irrigation, accessibility to food assistance, and financial assistance tailored to the female population, the risk score will decrease over time.

5.5 Oudomxay

Oudomxay is nestled within the heart of the northwestern province, being bordered by Bokeo and Luang Namtha to its northwest, Luang Prabang to its east and south, and Sayaboury to its south, southwest. Mean annual temperature is 22 °C with a progressive rain season that peaks between June and August. Much like Bokeo and the other northern regions, Oudomxay's rainfall pattern is becoming more uniform with earlier shifts in the rain season and less rainfall during its peak, with increasing rainfall in other months. Unlike Bokeo and Luang Namtha, Oudomxay is not set to have a wetter future, but a dryer one with decreasing precipitation and increasing aridity. RCP 4.5 and 8.5 modeling shows that Oudomxay's mean annual surface temperatures will increase by 1.92°C and precipitation by 17.25%. While the increase in precipitation would indicate a wetter future, Oudomxay's aridity is projected to increase by 13.92%, largely undercutting gains in precipitation. This dryer future, coupled with Oudomxay's historically being prone to droughts, along with highly degraded land, makes Oudomxay especially sensitive to climate change impacts.

9.1 Historic Climate

World Bank data going back to the 1930's shows that Oudamxay's season mean temperatures range 17.65°C in January, rising to its peak in April at 24.3°C before gradually dropping 17.56°C in December. Precipitation follows an inverse pattern, with precipitation around 16.94 mms in January, increasing to 102.7 mms in April, increasing to 215.52 mms in Jun, and peaking in August at 307.66 mms before dropping to 177.5 mms in September, and back to 16.98 mms in December (Figure 66 to Figure 69).

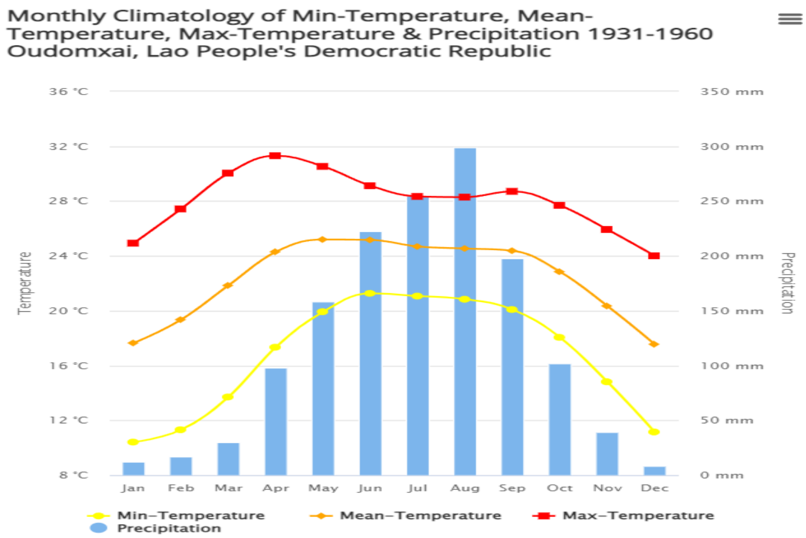


Figure 65 Oudomxay's Mean Temperature, Max-Temperature, and Precipitation 1931 – 1960; Source: World Bank, Lao Climate Profile

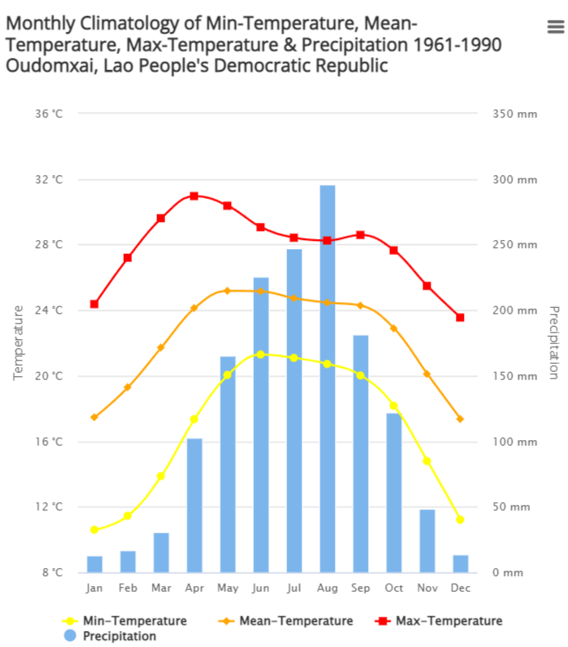


Figure 66 Oudomxay Mean-Temperature, Max-Temperature, and Precipitation 1961 - 1990; Source: World Bank, Lao Climate Profile

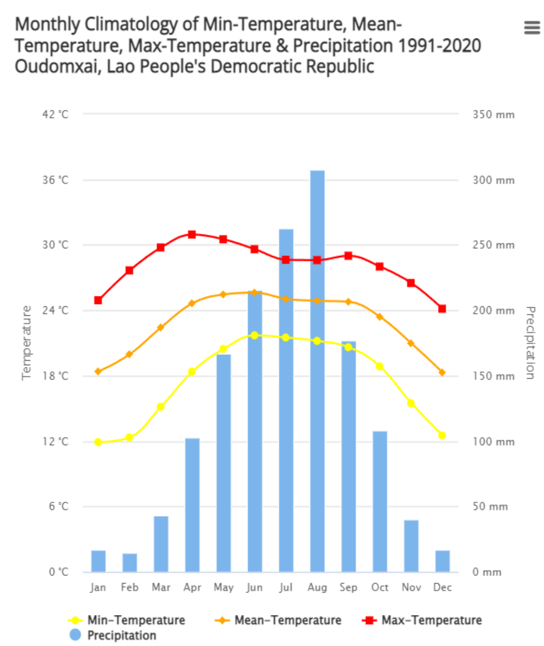


Figure 67 Oudomxay Mean Temperature, Max-Temperature, and Precipitation 1991 - 2020; Source: World Bank, Lao Climate Profile

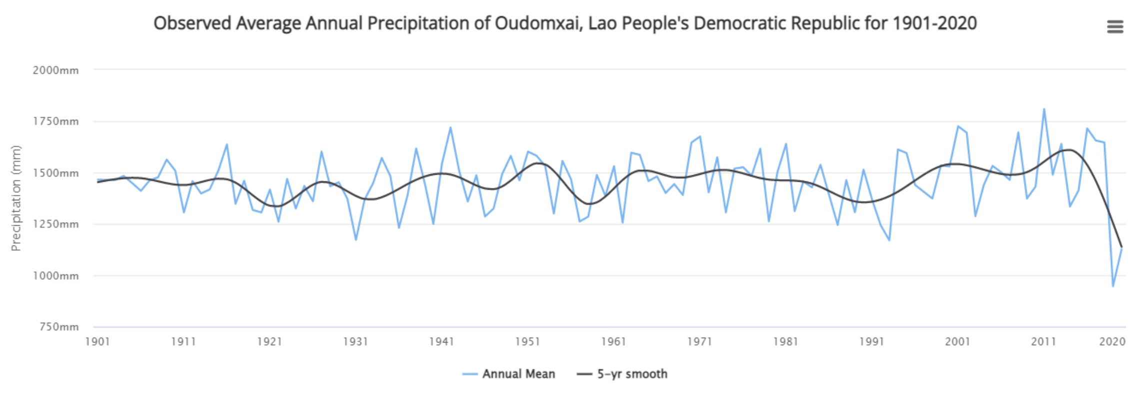


Figure 69 Change in Oudomxai Mean Annual Precipitation, 1901 - 2020; Source: World Bank, 2022

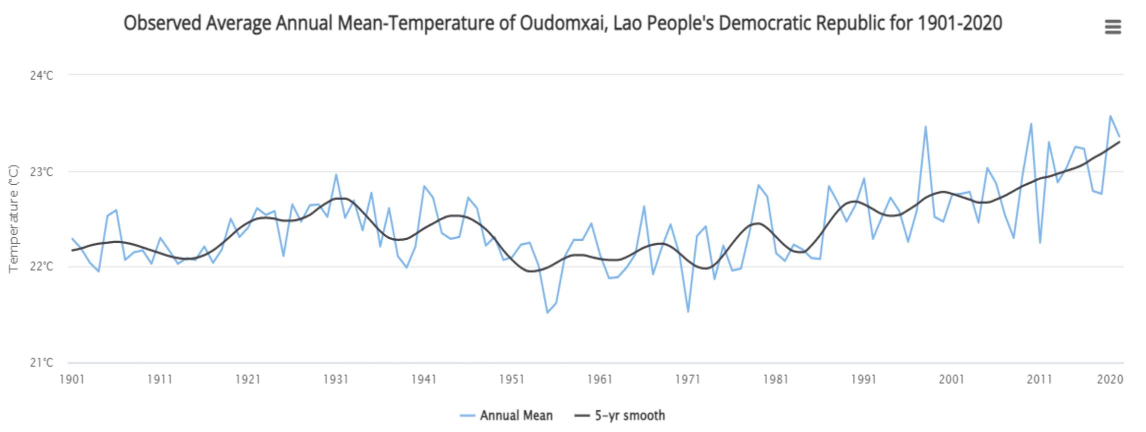


Figure 68 Change in Oudomxai's Mean Annual Surface Temperatures, 1901 - 2020; Source, World Bank, 2022

Unlike its neighbors, according to the WFP 2016 CLEAR report, Oudomxay has experienced minimal shifts in the onset of its rains season, though the amount falling during and at different times in its rain season has slightly decreased.[150] Oudomxay not only ranked second for greatest increase in mean annual surface temperatures, it also experienced the most droughts. According to the Think Hazard portal, Oudomxay, like its neighbours, is severely at risk of damages from cyclones, but also landslides, wildfires and to a lesser degree, extreme heat.

[150] WFP. 2016. *Lao PDR: CLEAR* report, pgs. 19 -20. Retrieved from: https://cdn.wfp.org/wfp.org/publications/LAO_CLEAR-%20English%20version-FINAL%201-9-2016-standard.pdf?_ga=2.178019557.1912144398.1648411551-583810545.1636743625

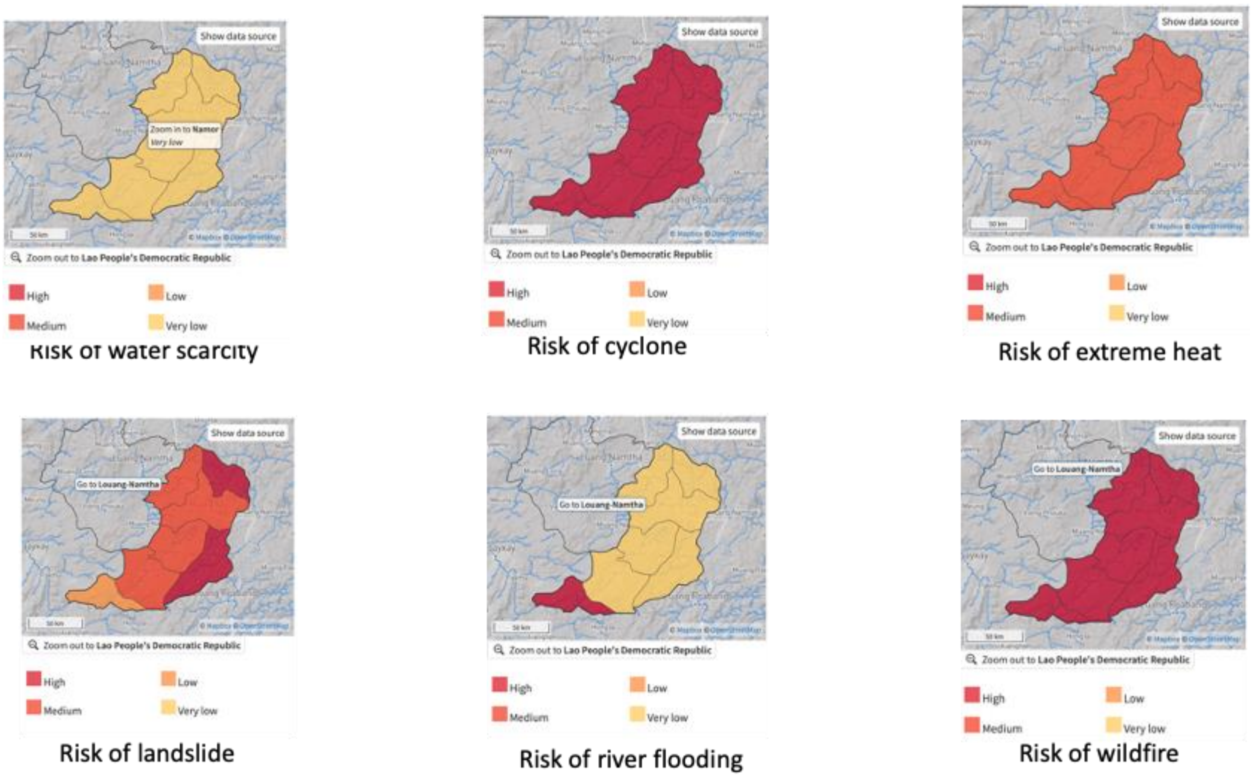


Figure 70: Risk of various climate hazards, Oudomxai

4.5.2 Projected Trends

When projecting potential climate change impacts under RCP 4.5 and 8.5 from 2020 – 2070, Oudomxay's mean annual surface temperatures would increase by 1°C (RCP 4.5) and 1.92°C (RCP 8.5). Precipitation projections show that Oudomxay's precipitation trends would increase, receiving 10.17% (RCP 4.5) and 17.25% (RCP 8.5) more rainfall. Despite the increasing rainfall, not only is Oudomxay the most historically affected by drought, having had 10 droughts in the past 30 years, it is projected to gain the most aridity under RCP 4.5 and 8.5 at 12.17% and 13.92%, which would negate any gain in rainfall under RCP 4.5 and severely diminish the gains in RCP 8.5. (See Table 16

Table 16: Projected changes in Temperature, precipitation and aridity for Oudomxai

Province	District	Parameter	2030	2050	2080	
Oudomxay	*Beng*	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 7%	+ 10%	+ 14%	**RCP 4.5**
		Aridity	+9%	+ 20%	+ 17%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**

		Precipitation	+ 8%	+ 16%	+ 29%	**RCP 8.5**
		Aridity	+ 9%	+ 7%	+ 18%	**RCP 8.5**
	Nga	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 4%	+ 11%	+ 14%	**RCP 4.5**
		Aridity	+ 8%	+ 16%	+ 13%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 7%	+ 12%	+ 26%	**RCP 8.5**
		Aridity	+ 3%	+ 22%	+ 8%	**RCP 8.5**
	Xai	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 4%	+ 10%	+ 13%	**RCP 4.5**
		Aridity	+ 6%	+ 14%	+ 16%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 9%	+ 12%	+ 28%	**RCP 8.5**
		Aridity	+ 3%	+ 6%	+ 16%	**RCP 8.5**
	Nam Mor	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 4%	+ 10%	+ 13%	**RCP 4.5**
		Aridity	+ 8%	+ 11%	+ 9%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 9%	+ 12%	+ 28%	**RCP 8.5**
		Aridity	+ 7%	+ 16%	+ 17%	**RCP 8.5**

4.5.3 Climate Risks and Vulnerabilities

Using our methodology, Oudomxay's baseline CRVA Risk score was 58, increasing to a median risk score of 62 under RCP 4.5 scores, and 88 under RCP 8.5. Risk scores for the province are fueld mostly by rates of land degradation and deforestation, which are fulling higher sensitivity and exposure. (see Table 17)

Table 17: Summary of Risk Scores for Oudomxay

		RCP 4.5				RCP 8.5			
	Baseline	Total at 2030	Total at 2050	Total at 2080	mediam	Total at 2030	total at 2050	total at 2080	median
Oudomxay	**58**	**63**	**62**	**60**	**62**	**84**	**88**	**88**	**88**
Beng (20.34/101.64)	37	43	40	40	40	45	51	51	51
Nga (20.57/102.11)	52	48	48	47	48	60	68	60	60
Xai (20.69/101.98)	65	66	66	67	66	72	75	77	75
Meuang Nam Mor/Na_Mo (20.9/101.76)	36	46	40	36	40	50	55	54	54

Oudomxay, while only having 7% of its land developed, has the least forest cover at 46%, most degraded forest land at 24%, and most land degradation at 35% of its provincial area[151]. With low adaptative capacity, high exposure to flood, drought, and wildfire hazards, the projected temperature and precipitation increases are expected to lower adaptative and coping capacity. Without an increase in forest cover and remediation of its land, the projected increases in surface temperatures, precipitation, and aridity are expected to cause increasing exposure to flood, drought, and wildfire hazards that would further reduce Oudomxay's coping and adaptive capacity.

Oudomxay's risk is driven by its exposure to flood, wildfire, and drought hazards, low adaptive capacity vis-à-vis its low forest cover, forest degradation, land degradation, and high sensitivity given its population's reliance on agriculture for livelihood and food security, low rates of accessible clean drinking water and sanitation (40%), and 48% of its population age 5 years or

[151] GIZ. 2019. District selection calculations; earthmap.org, 2022.

younger suffering from stunting/malnutrition[152]. Mitigating factors for Oudomxay's vulnerability is the extremely high level of accessible climate information and early warning for its population (78%) and high accessible to roadways for its population (87%)[153] adaptive and coping capacity. Other considerations are the crops grown in Oudomxay, primarily rice and maize. Maize is expected to do well with increase precipitation and surface temperatures, while rice may not do quite as well given excessive precipitation and/or surface temperatures increasing too much. This is highlighted by a 2019 FAO/WFP report that found that flooding had decreased rice production by 10%[154].

The risk scores are corroborated by the Third National Communication, which found that Oudomxay is highly sensitive and vulnerable, driven by its low adaptive capacity.[155] In particular, our CRVA Tool and the Third National Communication highlighted that Ouodomxay's vulnerability is influenced by one district, Xai, which had the highest risk score in the baseline analysis, even having higher risk score than Luang Prabang, Luang Namath, and Oudomxay. Xai's high population density increases exposure and has high sensitivity with low rates of access to clean drinking water and sanitation facility for its population (30%)[156].

It is highly recommended that for Oudomxay to adequately adapt to projected climate futures, reforestation efforts need to be carried out that also address soil remediation; increase access to clean drinking water and safe sanitation facilities, install systems that can capture excess water for use during drought periods, install conservation-friendly/low-impact systems to divert excess water from settlements, and increase diversity in crop production to address stunting.

5.6 Sayabouri

Sayabouri, along with Bokeo and Luang Namtha, forms the western border with Thailand, and shares its eastern border with Vientiane, the nation's capital province. Mean annual surface temperature is 23.78 °C and has a rain season from May to mid-October, peaking in April before steadily dropping. Sayabouri has seen its rain season steadily shift from 5 to 10 days earlier and precipitation has increased since 1979. Increasing precipitation has made Sayabouri prone to flooding. Despite being prone to flooding, Sayabouri's population has not been as affected by its exposure, in fact, Sayabouri's adaptive capacity and relatively low sensitivity reduce its risk. This is seen in climate future projections as Sayabouri had the lowest risk score increase when RCP 4.5 and 8.5 projections were considered.

5.6.1 Historic and Current Climate Context

The World Bank CCKP data going back to the 1930's shows that Sayabouri's seasonal mean temperature ranges from 18.93°C in January, increasing to 25.79°C in April, before gently

152 Lao 2015 Census; UNICEF, 2019
153 GIZ, 2022; Lao 2015 Census
154 WFP, FAO. 2019. CFSAM to the Lao People's Democratic Republic; pg. 5
155 Lao MNRD. 2022. Pgs. 23 - 25
156 Lao 2015 Population Census

descending until September, where it plateaus at 24.85°C before continuing to drop to 18.82°C by December. Precipitation follows an inverse pattern, with precipitation around 7.44 mms in January, increasing to 110.53 mms by April, before peaking in August at 270.93 mms, before dropping precipitously down to 2.5 mms by December (Figure 71).

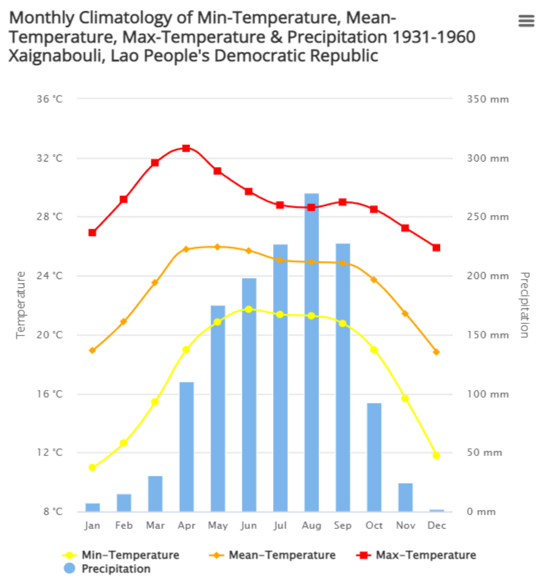


Figure 71 Xaiabouri Mean Temperature, Max-Temperature, and Precipitation 1931 – 1960; Source: World Bank, Lao Climate Profile

Sayabouri's historic precipitation and temperature trends are changing. According to earthmap.org, Sayabouri has experienced an increase of 1.3°C in mean annual surface temperatures (Figure 5) from 1975 to 2020[157]. This is corroborated by data from the World Bank CCKP that shows climbing annual surface temperatures from 1981 onward of 1°C in the past 40 years (Figure 77).[158] Data from earthmap.org shows that from 1979 to present, Sayabouri has experienced a reduction of an average of 2.42 mm per year or 104.6 mms in total Figure 76) in rainfall, though its southern tip has seen an increase in rainfall.[159] While precipitation has

[157] Analysis of historic temperature and precipitation trends used earthmap.org's 'mean temperature change' indicator on an interactive global map. From earthmap.org information on the indicator, "The 'Mean Temperature' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map represents the change (by year) of the average Mean Temperature per year for the whole period (thus the total change would be the multiplication of this number by the total number of years).A change of 0.1 degrees per year would thus represent a 4 degrees total change between the start and the end of the period.The pixel size is 0.25 deg (approx. 28km at the equator). Period of observations: 1979 to near-present (4 month lag time for processing). Monthly aggregates have been calculated based on the ERA5 hourly values of each parameter; Unit = °C."

[158] World Bank. *Lao PDR: Climate Profile*. Retrieved from: https://climateknowledgeportal.worldbank.org/country/lao-pdr/climate-data-historical

[159] From earthmap.org "The 'Total Precipitation' product is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric reanalysis of the global climate product. This map represents the change (by year) of the average total precipitation per year for the whole period (thus the total change would be the multiplication of this

averaged roughly 1450 mms since 1901, it has taken a nosedive in the past eight years, dropping to 1000 mms in 2021 (Figure 76). Despite the decrease in rainfall, Sayabouri had the highest exposure to flooding hazard, having 20 floods in the past 30 years[160]. This may be due in part to the relative low-lying nature of most of its districts, with the province as a whole having only 50% of its territory with an incline over 10%[161]. Other influences may be Sayabouri's rain season shifting to 5 – 10 days earlier since 2006 and increasing in volume.[162] Surprisingly, even though Sayabouri has suffered extensive flooding, only 8,681 people[163] or 0.02% of Sayabouri's total provincial population have been displaced in the past 30 years. Surprising too is that the reduction in precipitation and increase in surface temperature hasn't caused increase aridity in the past 30 years and evaporation rate has decreased by 39.7%[164].

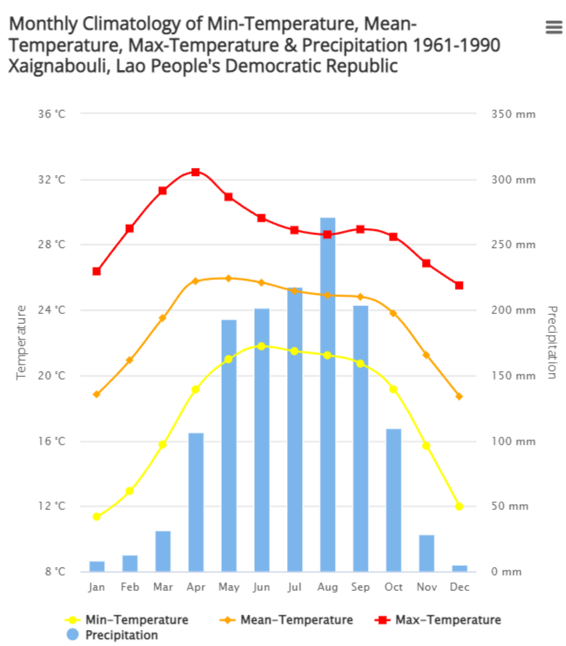


Figure 74 Xaiabouri Mean-Temperature, Max-Temperature, and Precipitation 1961 - 1990; Source: World Bank, Lao Climate Profile

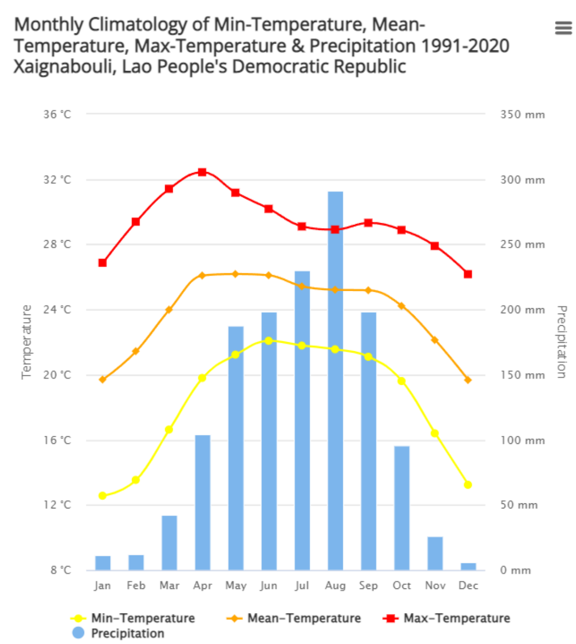


Figure 75 Xaiabouri's Mean Temperature, Max-Temperature, and Precipitation 1991 - 2020; Source: World Bank, Lao Climate Profile

number by the total number of years). A change of 2 millimeters per year would thus represent a 80 mm total change between the start and the end of the period."

160 EMDAT, 2022; DesInventar Sendai, 2022; GIZ, 2022

161 Earthmap.org, 2022

162 WFP. 2016. *Lao PDR: CLEAR* report. Retrieved from: https://cdn.wfp.org/wfp.org/publications/LAO_CLEAR-%20English%20version-FINAL%201-9-2016-standard.pdf?_ga=2.178019557.1912144398.1648411551-583810545.1636743625

163 2015 Lao Census, Sendai Desinventar, 2022

164 Earthmap.org, 2022.

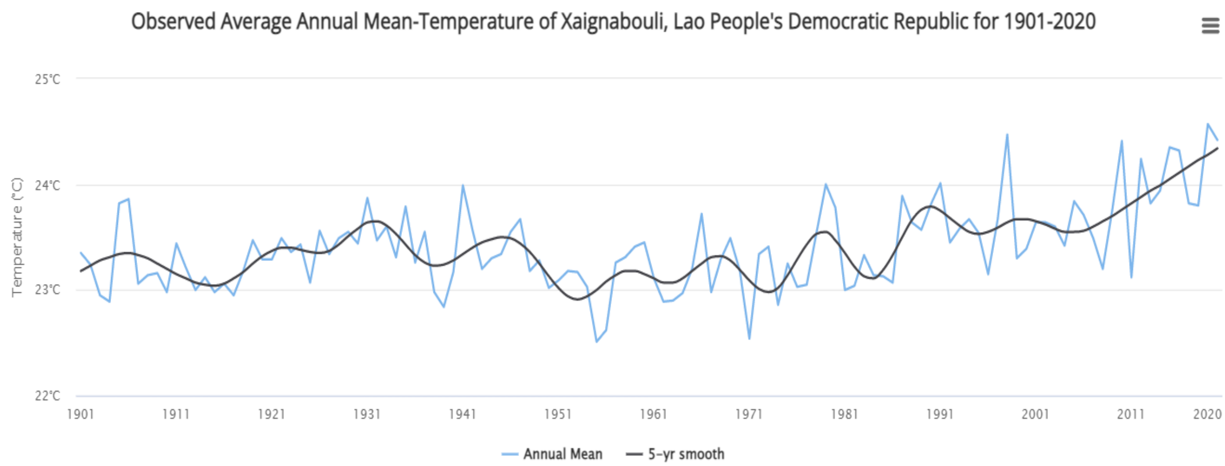


Figure 77 Change in Xaiabouri's Mean Annual Surface Temperatures, 1901 - 2020; Source, World Bank, 2022

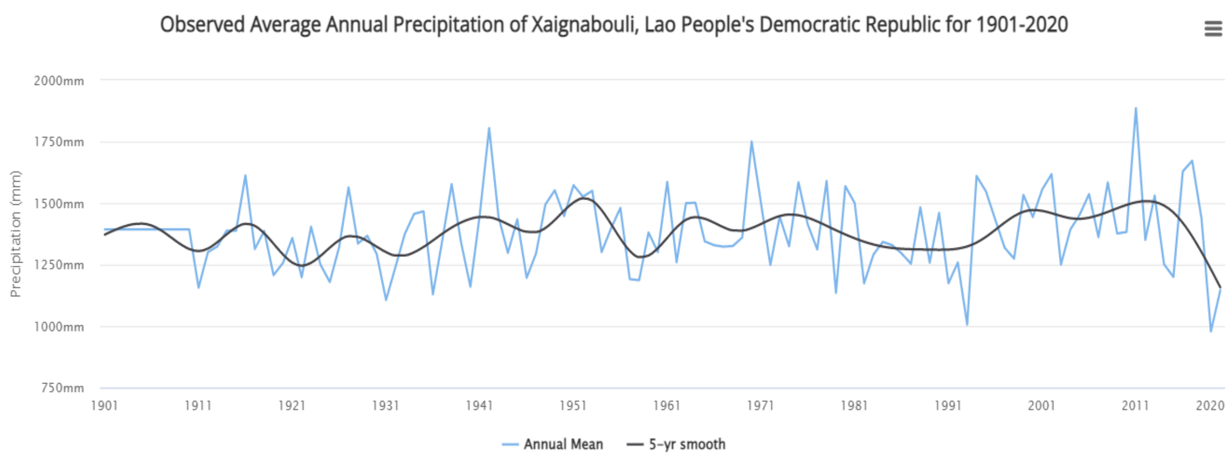


Figure 76 Change in Xaiabouri Mean Annual Precipitation, 1901 - 2020; Source: World Bank, 2022

While 14% of Sayabouri's province has been developed[165], 54% of the province still has forest cover[166], 10% of the forest degraded, and only 22% of its land degraded[167]. Combined with 93% of its population having access to roads[168], 76% of the population having access to climate change information and early warning systems[169], and 94% of its population having access to safe drinking water and sanitation facilities[170], Sayabouri has high adaptative capacity. Sayabouri's sensitivity is high, with 43% of its population age five or younger suffering from

165 GIZ. 2019. District site selection tool.
166 *Ibid.*
167 *Ibid.*
168 Lao 2015 Census
169 GIZ. 2022. EWS Survey
170 Lao 2015 Census

stunting/malnutrition[171] and 14,019 of its households are female-led or 18.4% of its total households[172]. As Lao has a patriarchal society, women tend to have far fewer accessibility to financial or other support services, capacity-building resources. While 1,759 people are at risk of food insecurity[173], this only represents 0.004% of Sayabouri's total population.

When considering Saiabouri's overall exposure to climate related natural hazards, it is in a better position than the other provinces. For example, the risk of extreme heat, river flooding and landslides are less significant than in other provinces (low to medium) and only the risk of wildfire and cyclones is high (see Figure 78).[174]

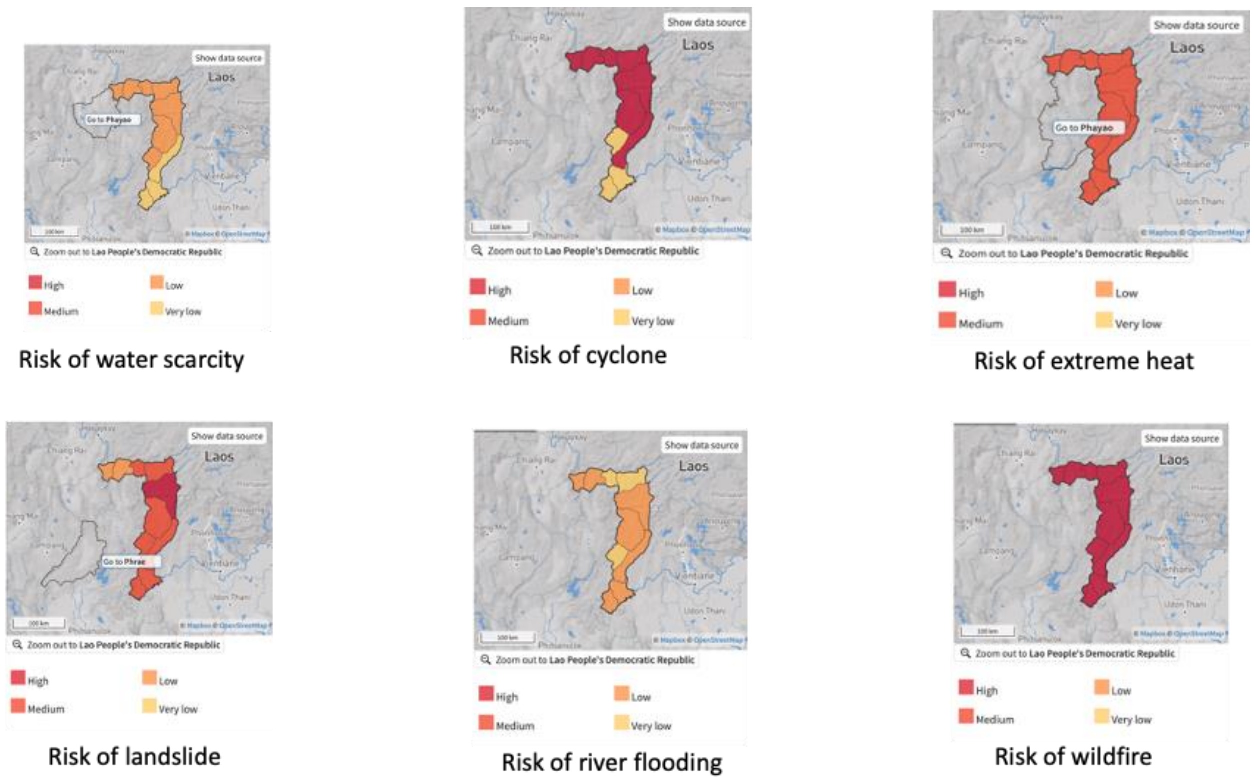


Figure 78: Risk of various natural hazards for Sayabouri

4.6.2 Projected Trends

We used climateinformation.org's "Site-specific tool" to project climate future for RCP 4.5 and 8.5 for 2030, 2050, and 2080. Sayabouri's mean annual surface temperatures would increase by 1°C (RCP 4.5) for 2030, 2050, and 2080. For RCP 8.5, Sayabouri 1°C by 2030, 2°C by 2050, and 3°C by 2080[175]. Precipitation projections show that Sayabouri would 8% more rainfall by

[171] UNICEF. 2017. *MICS Social Indicator Survey II Survey Findings Report*; Lao 2015 Census
[172] Lao 2015 Census
[173] FAO/WFP. 2019. *CFSAM to the Lao People's Democratic Republic*, pg. 38
[174] Think Hazard, 2022
[175] Okapi Environmental Consulting, Inc. 2022. CRVA Tool

2030, increasing to 13% by 2080 under an RCP 4.5 model. Under RCP 8.5, Sayabouri's precipitation would increase by 7% by 2030, but by 2080 would have increased by 26%. Aridity, under RCP 4.5, increase by 7% by 2030, before decreasing by 4% by 2050, and increasing again by 4% by 2080. Under RCP 8.5, aridity decreases by 1% by 2030, increases to 7% by 2050, and decrease 2% by 2080. (see Table 18: Projected changes for temperature, precipitation and aridity for Sayabouri under various scenarios at different time points

Table 18: Projected changes for temperature, precipitation and aridity for Sayabouri under various scenarios at different time points

Province	District	Parameter	2030	2050	2080	
Sayabouri	*Paklay*	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 8%	+ 11%	+ 13%	**RCP 4.5**
		Aridity	- 3%	- 11%	- 4%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 7%	+ 18%	+ 26%	**RCP 8.5**
		Aridity	- 4%	- 4%	- 11%	**RCP 8.5**
	Muang Thongmixay	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 8%	+ 11%	+ 13%	**RCP 4.5**
		Aridity	+ 7%	- 4%	+ 3%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 7%	+ 18%	+ 26%	**RCP 8.5**
		Aridity	- 1%	+ 7%	- 3%	**RCP 8.5**
	Phiang	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**

		Precipitation	+ 5%	+ 10%	+ 9%	**RCP 4.5**
		Aridity	+ 6%	- 4%	+ 4%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 6%	+ 10%	+ 13%	**RCP 8.5**
		Aridity	0%	+ 9%	- 2%	**RCP 8.5**
	Xayabouly	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 5%	+ 10%	+ 9%	**RCP 4.5**
		Aridity	+ 12%	+ 9%	+ 18%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 6%	+ 10%	+ 13%	**RCP 8.5**
		Aridity	+ 8%	+ 30%	+ 17%	**RCP 8.5**
	Hongsa	Temperature	+ 1°C	+ 1°C	+ 1°C	**RCP 4.5**
		Precipitation	+ 10%	+ 13%	+ 18%	**RCP 4.5**
		Aridity	+ 11%	+ 21%	+ 29%	**RCP 4.5**
		Temperature	+ 1°C	+ 2°C	+ 3°C	**RCP 8.5**
		Precipitation	+ 9%	+ 22%	+ 28%	**RCP 8.5**
		Aridity	- 6%	+ 7%	+ 5%	**RCP 8.5**

Under both scenarios, aridity shows minimal gains, while RCP 8.5 presents a much wetter future that could potentially overcome Sayabouri's adaptive and coping capacity, increasing its population sensitivity, thus increasing vulnerability to risk.

4.6.3 Risk and Vulnerability Assessment

Using our methodology, Sayabouri's CRVA Total baseline Risk score was 69, decreasing to a median score of 62 with RCP 4.5, but rising to a median score of 78 with RCP 8.5. The median scores hide variability in terms of the periods concerned. For example, by 2030 under a RCP 4.5 scenrio, the risk score for the province would increase to 70, but decrease by 2050 (see Table 19: Summary of risk scores for Sayabouri)

Table 19: Summary of risk scores for Sayabouri

		RCP 4.5				RCP 8.5			
	Baseline	Total at 2030	Total at 2050	Total at 2080	mediam	Total at 2030	total at 2050	total at 2080	median
Sayabouri	**69**	**70**	**61**	**62**	**62**	**72**	**86**	**78**	**78**
Paklay (18.23/101.40)	50	59	51	53	53	53	65	60	60
Muang Thongmixay/ Muang Thong (18.4/101.17)	24	28	19	20	20	25	39	32	32
Phiang (19.10/101.53)	51	53	47	46	47	48	57	51	51
Xayabouly (19.25/101.70)	53	56	52	51	52	58	69	62	62

Hongsa (19.7/101.34)	24	36	32	34	34	47	60	53	53

For both RCP 4.5 and 8.5, Sayabouri is the least affected of all the project-targeted provinces that we assessed. Sayabouri's vulnerability is mitigated by its access to communication technologies (88%), access to climate change impact and early warning information (78%), population with the most diverse livelihoods of all targeted provinces, 96% of its population being able to access road networks year-round, 92% of its population having access to safe drinking water and sanitation. With the infrastructure and population ability to anticipate climatic changes, Sayabouri's risk is mitigated.

While Sayabouri has the greatest adaptive and coping capacity, and least sensitivity of all provinces, the number of female-led households need to be considered for special consideration. Financial resource and other capacity-building services need to be increased for this especially vulnerable population, especially as it comprises almost 20% of all of Sayabouri's households.

6. Conclusions and Recommendations

6.1 Summary of findings

In summary, the analysis of the different parameters of climate risk for the 6 provinces shows a few important trends. First, as noted earlier, the most significant change in terms of climate signals and hazards for all provinces appear to originate in the anticipated increase in precipitation. If precipitation has decreased over the past, all scenarios point to a drastic and dramatic reversal of this trend which should not be ignored. On the other hand, temperatures have and will continue to increase, albeit at a slower rate and pace than over the past 30 years. This is true regardless of the RCP scenario considered, though of course, the magnitude of rainfall increases expected under a RCP 8.5 scenario is significantly higher.

The impact pathway loop that starts with rainfall increases is also modulated by runoff and erosion rates. As noted in the Section 5, provinces where erosion rates are higher (for example where slopes are significantly higher, or where land is more degraded) are more at risk of flooding impact. Perhaps counter-intuitively, some of the districts where land was flat were set to experience higher rates of flooding impact: this is perhaps due to the fact that highlands are less cultivated, or less accessible for development and soil cover removal, or to the fact that severe rainfall has no drainage outlet and therefore causes waterlogging and flooding. In both cases, however, the mitigating factor for exposure to flooding is the state of forest and land degradation.

One mitigating factor for vulnerability to flooding appears to be the proximity to capital and urban centers, which comes with access to social safety nets, evacuation routes, livelihood alternatives and access to information. The key exacerbating factor for vulnerability to all climate hazards is the baseline state of poverty and food security. Areas exhibiting more food insecurity and higher rates of childhood stunting, are also significantly more at risk of collapse under any scenario. In this regard our analysis shows a clear West-East divide, where eastern provinces are more vulnerable than western provinces.

It is well known that past temperature increases have already caused decreases in food production and land productivity in Northern Laos. However, projected temperature increases did not seem to generate much of a signal except when considered in conjunction with land degradation subjected to increased rainfall. In both 4.5 and 8.5 RCP projections, the evapotranspiration rates are downgraded by the sharper increases in rainfall. However, long-term crop yield declines and changes in crop suitability, particularly for the key crops such as rice, maize and cassava, will appear under both scenarios.

Dependence on rainfed crops is a significant factor in vulnerability, and most provinces appear to have similar rates. Irrigation as an adaptation strategy may be more relevant as a strategy to adapt to past trends of temperature increases and aridification than as a strategy to adapt to projected trends, while run-off management will take on full signification in the longer-term. In the same vein, overdependence on traditional varieties of staple crops will fuel continued vulnerability. Adaption measures in the crop sector that include adapted varieties, shifting cultivation dates, improved management practices and diversification, should be promoted in consideration of both past trends and projected likely scenarios.

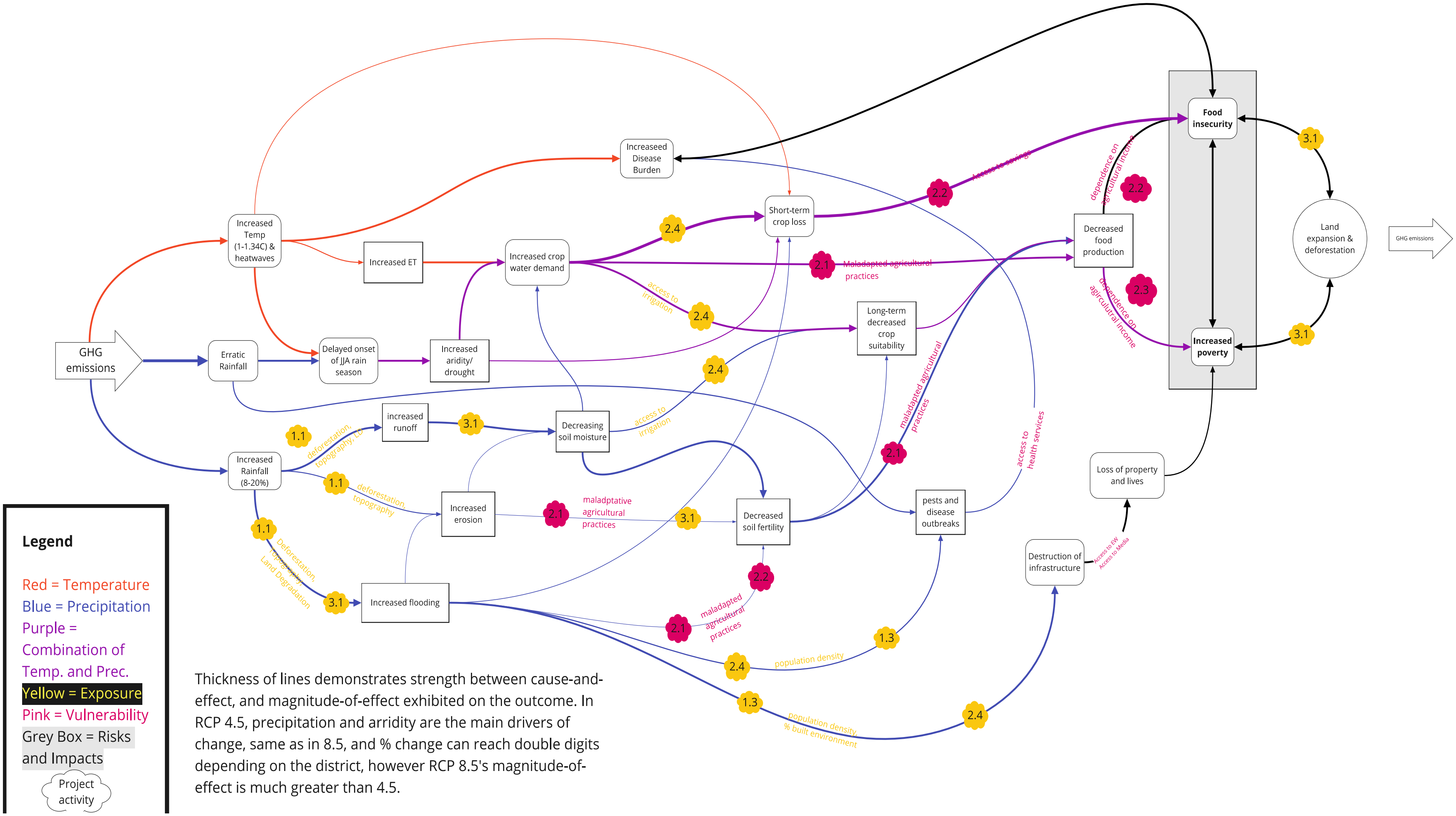
6.2 Mapping project interventions to impact pathways

The impact pathways highlighted in Section 3 and detailed in Sections 4-5 are moderated, or exacerbated, by non-climate drivers and variables. For example, deforestation and land degradation can escalate the link between rainfall and run-off or rainfall and flooding by multiple orders of magnitude. Conversely, well-adapted agricultural practices (including improved breeds and varieties, cropping methods, land preparation and tillage, water conservation and soil fertility management) can compensate for some of the impact pathways.

From the analysis of the impact pathways above and from the analysis of the data presented in section 5, it is possible to conclude that acting upon the health of forests and land can be the most important set of mitigating interventions to either reduce the magnitude or slow down the pace of change. The second-most important strategy would be improved management of water, irrigation in particular, but run-off as well.

In the figure that follows, we have represented the impact pathways (using a 4.5 scenario) along with the key project activities to show how the program's theory of change influences the impact pathways. This highlights the fact that some of the project activities act upon various impact chains simultaneously. For example, the village forestry activities under Output 3.1 contribute to reducing the scope of impact in the rainfall-flooding impact chain and also to reducing the feedback loop between vulnerability (food insecurity) and increased emissions. Similarly, improving water management impacts both the rainfall-flood impact chain and addresses one key aspect of maladapted agricultural practices.

Avenues that are not addressed or included in this project can be addressed through other projects or interventions.



Thickness of lines demonstrates strength between cause-and-effect, and magnitude-of-effect exhibited on the outcome. In RCP 4.5, precipitation and arridity are the main drivers of change, same as in 8.5, and % change can reach double digits depending on the district, however RCP 8.5's magnitude-of-effect is much greater than 4.5.

Figure 79: Mapping project interventions onto impact pathways. please click here for a larger screen version

6.3 Recommendations

On the basis of the analysis above, the CRVA recommends the following for integration into the design and implementation of the program.

1) **Plan for adaptation strategies that respond to past visible climate change trends as well as to the trends that would be felt in a RCP 8.5 worst-case scenario.**

As a key design principle, the program should adopt a two-pronged adaptation strategy that responds to the past trends but is also relevant to the worst case long-term scenario (2080+). We advise that the program considers the 8.5 scenario when planning adaptation strategies, as this scenario gives the strongest signal in terms of rainfall, erosion, and flooding, with significant level of risk across all provinces. Given the scope of intervention, it does not appear that planning interventions in line with the 8.5 scenario would lead to increased costs (compared to planning for the 4.5 magnitude of change).

2) **Adaptation strategies should focus on reducing exposure and increasing adaptive capacity to rainfall modification hazards.**

Planning with the worst-case scenario in mind would mean that the project should focus its adaptation strategies and activities on reducing exposure to the rainfall modification hazards, as well as increasing adaptive capacity. Two key areas should be included in the program design from an "exposure" point of view:

- Reduce land degradation, erosion risk, and deforestation; and
- Controlling run-off, water management and flood control.

From the standpoint of increasing adaptive capacity, the program should focus on means to reduce food insecurity, which appears as the greatest threat to coping and adapting in the region and which, as we saw in the analysis of impact pathways, remains a key driver of deforestation and land degradation – and hence of emissions increases.

In this regard, strategies to increase coping and adaptive capacities should be undertaken with a socially inclusive lens, with particular attention paid to the higher levels of food insecurity faced by women and children and people with disabilities. Some attention should also be paid to increasing access to social safety nets taken in their broadest sense. While this CRVA analysis does not reveal any major contribution of access to savings or alternative livelihoods to the reduction of vulnerability, the fact that provinces to the west are less vulnerable than those in the east indicates that the overall level of access to social structures and services may play a role in mitigating vulnerability.

The following approaches may be included in the project. The below list contains approaches and technologies that respond to the main threats and risks summarized above. Some of the approaches meet multiple objectives and should be prioritized.

a. **Reduce land degradation, deforestation and erosion risk**:
    a. Implementation of natural barriers and ecological landscaping to reduce erosion on slopes higher than 10%.
    b. Stone terracing and creation of drainage pathways in agricultural lands
    c. Reforestation, afforestation, and forest conservation
    d. Land rehabilitation on severely degraded land; natural regeneration or conservation on moderately degraded non-cultivated land.
    e. Promote sustainable land management in agricultural landscapes

b. **Control run-off, flood control and water management**
    a. Improvement of drainage pathways in agricultural lands and urban areas, including flatlands
    b. Natural barriers and stone terracing on slopes
    c. Flood barriers, retention walls and run-off catchment ponds
    d. Reforestation, afforestation and forest conservation, maintenance of soil vegetative cover using agroforestry
    e. Improvement of water management in agricultural lands
    f. Provide access to safe drinking water and sanitation

c. **Promote climate-smart high productivity food production for increased food yields in all seasons**.
    a. Integrate diversification, crop rotation and agroforestry systems for improved variety of food sources
    b. Promote use of flood-tolerant and heat tolerant varieties and species
    c. For selected crops promote greenhouse agriculture
    d. Improve post-harvest practices to reduce household food losses
    e. Continue increasing access to flood and drought early warning systems.