Annex 2c

Climate Rationale of Adaption Activities

to the GCF Funding Proposal

Land-based mitigation and adaptation through a Jurisdictional Approach in West Kalimantan

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Version 4

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Abbreviations & Acronyms

AFOLU	Agriculture, Forestry, and Other Land Use
AR5	Fifth Assessment Report
BMKG	Badan Geofisika dan Meteorologi/ Meteorology and Geophysical Agency
BPDLH	Badan Pengelola Dana Lingkungan Hidup/ Indonesian Environment Fund (IEF)
CDD	Consecutive Dry Days
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CMIP6	Coupled Model Intercomparison Project Phase 6
CWD	Consecutive Wet Days
CRVA	Climate Risk and Vulnerability Assessment
DJF	December-January-February
ETCCDI	Expert Team on Climate Change Detection and Indices
E	Exposure
FP	Funding Proposal
H	Hazard
HGU	Hak Guna Usaha/ The Right of Exploitation
GCMs	Global Climate Models
IC	Impact Chains
IPCC	Intergovernmental Panel on Climate Change
IP	Indigenous People
JJA	June-July-August
KEE	Essential Ecosystem Areas
KLHK	Ministry of Environment and Forestry/ Ministry of Environmental and Forestry
MAM	March-April-May
PODES	Data Potensi Desa/ Village Potential Data
RTRW	Rencana Tata Ruang Wilayah/ Management Patterns with Spatial Plans
RX1DAY	Rainfall index of 1 consecutive days
RX5DAY	Rainfall index of 5 consecutive days
scPDSI	Self-Calibrated Palmer Drought Severity Index
SPEI	Standardized Precipitation and Evapotranspiration Index
SUSENAS	Survei Nasional Ekonomi Nasional/ The National Socioeconomic Survey
SPI	Standardized Precipitation Index
SON	September-October-November
SSPs	Shared Socioeconomic Pathways
SSP126	Shared Socioeconomic Pathways 126
SSP245	Shared Socioeconomic Pathways 245
SSP370	Shared Socioeconomic Pathways 370
SSP585	Shared Socioeconomic Pathways 585
TR	Tropical Nights
V	Vulnerability
WK	West Kalimantan
ZOM	Season Zone

1. Introduction

West Kalimantan, located in the western part of the Indonesian island of Borneo, is characterized by a tropical climate with high temperatures and high precipitation. However, West Kalimantan is also vulnerable to the impacts of climate change, including increased frequency and intensity of extreme weather events and changing rainfall patterns.

An ambitious project under the Green Climate Fund (GCF) is currently being prepared for West Kalimantan, aiming to tackle the challenges of climate change through a comprehensive approach that incorporates both adaptation and mitigation. To address these challenges, a collaborative effort is needed to develop a GCF project that will enhance the region's resilience to climate change and contribute to reducing greenhouse gas emissions.

The proposed project in West Kalimantan seeks to integrate adaptation measures to enhance the province's capacity to cope with the changing climate conditions. These measures will include strengthening of the institutional regulatory framework for climate-informed landscape planning, scaling up of climate-resilient and low-emission agricultural and agroforestry practices, and implementing community-based Forest and Landscape Management. At the same time, the project will promote sustainable practices and technologies that contribute to the reduction of greenhouse gas emissions. By combining these adaptation and mitigation measures, the GCF project in West Kalimantan holistically and sustainably addresses the challenges of climate change, while also promoting socio-economic development in the region.

The purpose of this document is to provide a climate rationale specifically for adaptation actions in response to the challenges posed by climate change in West Kalimantan. It aims to support the justification of the need for adaptation measures within the context of a changing climate. This document emphasizes the importance of understanding and addressing the climate risk assessment to enhance the resilience of the forest and agriculture sectors in West Kalimantan. It focuses on identifying and assessing the specific adaptation needs and priorities, as well as proposing strategies and approaches to effectively adapt to the impact of climate change. While the document primarily focuses on adaptation, it is also takes into account mitigation efforts to provide a comprehensive understanding of the overall climate response; the document also provides insights into the actions and measures aimed at reducing greenhouse gas emissions and mitigating the main drivers of climate change.

To assess the risk of climate-induced natural hazards in West Kalimantan, it is necessary to identify the risk indicators, including vulnerability, exposure, and hazard. This methodology uses GIZ approaches based on the Intergovernmental Panel on Climate Change (IPCC) fifth Assessment Report (AR5) to assess climate risk and vulnerability. Vulnerability encompasses a variety of concepts and elements, including sensitivity and lack of capacity to cope with the risk. Exposure refers to the extent to which a community or system is exposed to the potential impacts of climate change. Hazard refers to climatic elements' possible occurrence and magnitude, mostly in extreme conditions, such as high precipitation and temperature.

The GIZ approach, based on the IPCC AR5 report, enables a comprehensive assessment of the risk of climate change impact by considering the integration between vulnerability, exposure, and hazard. This approach helps to identify the most vulnerable communities and systems and prioritize adaptation and mitigation measures accordingly. By using this approach, West Kalimantan can develop effective strategies to reduce the risk of climate change impact, protect the environment and natural resources, and promote sustainable development.

2. Context

This assessment is aimed at the identification of e risks of climate-related hazards in West Kalimantan, including floods, droughts, and forest fires, and to develop effective strategies to reduce climate change risks. The assessment was conducted using the GIZ approach based on the Intergovernmental Panel on Climate Change (IPCC) fifth Assessment Report (AR5), which considers the integration of vulnerability, exposure, and hazard to comprehensively assess the risks of climate-related hazards. This assessment identifies the most vulnerable villages and systems in West Kalimantan and the extent to which they are exposed to the potential impacts of climate change.

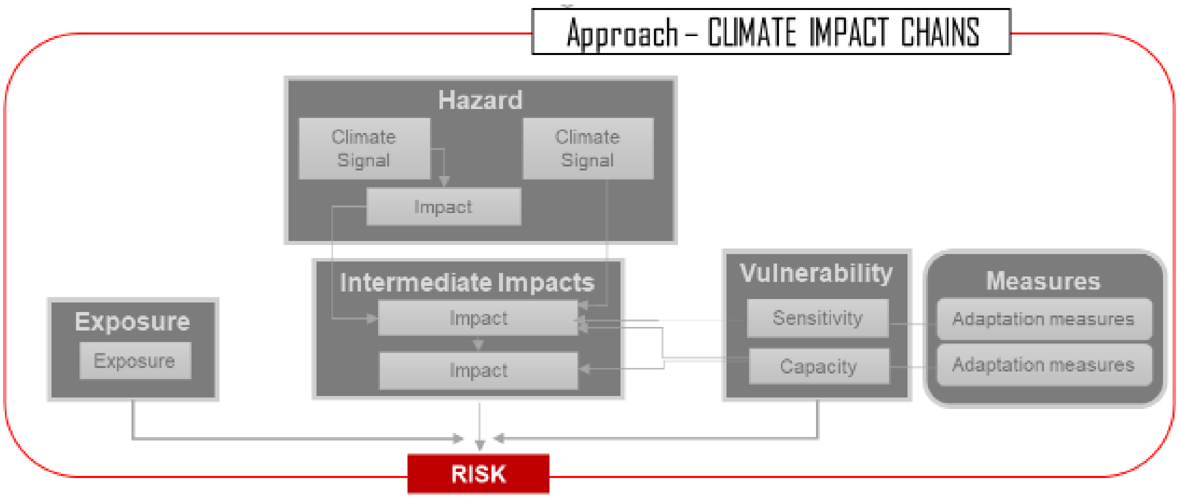
West Kalimantan (WK), located on Borneo Island - Indonesia, is characterized by specific climatic, biophysical, and socioeconomic conditions. WK has a tropical climate, with high temperatures and high precipitation, with diverse land covers such as rainforests, peatlands, and river systems that contribute to its rich biodiversity. The most prominent economic activities in West Kalimantan are agriculture – in particular palm oil production forestry, and mining. However, WK province also faces socioeconomic problems such as poverty and limited access to basic needs.

The proposed cross-cutting project has been designed in line with the objectives of the Indonesian social forestry initiative and the REDD+ strategy. By targeting the primary drivers and underlying causes of deforestation and forest degradation, it is aimed to contribute to the implementation of these initiatives. The focus is on enhancing forest governance, strengthening Forest Management Units, and scaling up of social forestry models. Additionally, the project seeks to foster sustainable agricultural practices among existing concessions and smallholders through collaborations with the private sector. Thereby environmentally friendly business approaches will be promoted. Through these efforts, the project envisions improving the climate resilience of more than 680,000 individuals and achieving an estimated reduction of 15.4 million tCO2eq in greenhouse gas emissions over seven years.

3. Problem Statement: Climate Risk

This chapter introduces the problem statement the proposed GCF project intends to address.

Figure 1: Problem statement section illustration



Source: GIZ

West Kalimantan is affected by climate change due to changes in both temperature and rainfall. Indonesia in general is experiencing changes in rainfall patterns. There has been an increase in rainfall, particularly during the wet season, and a decrease in rainfall intensity, especially during the dry season. This has led to a rise in the potential for floods and droughts.

These changes, especially drought, have led to an increase in the intensity of forest and land fires, which have become annual disasters in West Kalimantan. Fires generally occur in dry conditions such as droughts. In West Kalimantan, plantation and secondary swamp forest areas are highly vulnerable to fires during drought, especially in peat areas with depths of 50-200 cm. Forest and land fires also cause land degradation and changes in forest function, negatively impacting the local economy.

Smallholder farmers in West Kalimantan are increasingly at risk of the impacts of climate change. The effects of climate change in West Kalimantan are significant, particularly in the agricultural sector. The region is highly vulnerable to land and forest fires, as Jadmiko (2017b) indicated, with unmanaged plantation areas and peatlands at high risk. This vulnerability is exacerbated by the increasing intensity of droughts, which can have serious welfare consequences (Salafsky, 1994). The environmental impact of these changes is evident in the severe forest loss, leading to biodiversity loss and water storage shortages (Fawzi, 2019). The climate change-related risks to agricultural productions are compounded by several elements of vulnerability, such as inadequate agricultural practices, a lack of adequate irrigation systems, limited access to quality inputs, including climate-resilient seeds, and the use of essential agricultural equipment/ lack of mechanization of the agricultural sector, as well as a lack of information and limited access to land (Weiskopf et al., 2021).

In summary, smallholder farmers and other local agricultural actors in West Kalimantan, Indonesia, are increasingly at risk of decreased income and threatened livelihoods due to changing climate parameters.

This scenario arises from an interaction of hazards, exposure, and vulnerability, which are reviewed in depth in the following sections. The problem statement is based on the fact that specific **climate hazards**, namely temperature increases, floods, droughts, extreme rainfall, and forest fires, are affecting the agricultural sector. More information on the climate hazards and related indicators to measure their historical trends and projections is available in Chapter 5. The historical climate in West Kalimantan is outlined in Chapter 5.1, and the climate prediction for the future is in Chapter 5.2. The climate impacts on the crops are consequently assessed in Chapter 6. Under section 6.2, the variable exposure to hazards by smallholder farmers and other stakeholders in agriculture and forestry is analysed. The consideration of impact and exposure always needs to be interpreted in combination with the **vulnerability** of the system of concern, as the impacts on the same stakeholder can vary considerably according to, e.g., the governance, institutional and technical capacity, financial and access to market as identified to the vulnerability indicators.

Against the backdrop of these analyses, Chapter 7 introduces the identified adaptation actions to increase stakeholders' climate resilience, mapping them to one or several of the identified vulnerability factors. The description focuses on the vulnerability factors/potential impacts through barriers that require intervention. More detailed information about the adaptation measures can be retrieved from the feasibility study.

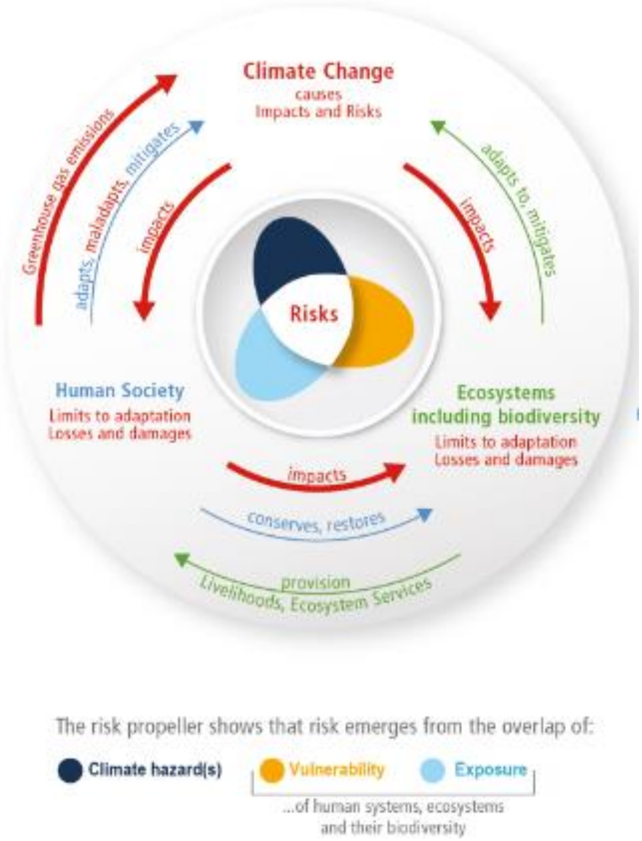
4. Methodology

The IPCC AR6 (IPCC, 2022) introduces a new approach and terminology that aligns with the concept of risk. The IPCC AR6 defines risk as the potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. Risk is often expressed as the result of dynamic interactions between climate-related hazards and the exposure and vulnerability of the affected human or ecological system (IPCC, 2022). Risk is determined by three main factors: hazard (H), exposure (E), and vulnerability (V), which can be stated as a function of:

$$R = f(H, E, V)$$

According to IPCC AR6, Exposure (E) is '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. Vulnerability (V) is the propensity or predisposition to be adversely affected. It encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. Hazard is a new term in AR6, defined as 'the potential occurrence of a natural or human-induced physical event or trend 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. Physical climate conditions that may be associated with hazards are climatic impact drivers.

Figure 2: Core concepts of the IPCC's WG II AR6



Source: IPCC 2022

The first step to conduct a risk assessment focusing on the impact of climate change on forests and agriculture in West Kalimantan, is to prepare a risk assessment by defining the scope of the evaluation, identifying the stakeholders, and establishing the objectives of the appraisal.

The next step is to develop impact chains that describe the causal linkages between climate hazards, exposure, vulnerability, and potential impacts on forests and agriculture. This step helps to identify the system's most critical elements and to accordingly prioritize the risk assessment.

After developing impact chains, the following steps are identifying and selecting indicators, acquiring and managing data, normalizing and weighting the indicators, aggregating risk components to risk, and presenting the risk assessment outcomes. Specific indicators for forests and agriculture in West Kalimantan include changes in temperature, precipitation patterns, soil moisture, and other factors that may affect crop yields or forest growth. More details about each step are described in the following sections.

Climate Risk Assessment

The assessment of the climate risks for the selected crops and the associated adaptation measures results from the use of GIZ-proven methodologies. Specifically, the GIZ Vulnerability sourcebook (GIZ, 2014) and its Risk Supplement (GIZ, 2017) were used to prepare climate impact chains and their related climate change adaptation activities.

While the GIZ Vulnerability Sourcebook (2014) offers a concept and step-by-step guidelines for standardized assessments of vulnerability to climate change, based on the fourth assessment report (AR4), the Risk Supplement (2017) provides practical guidance on how to apply the Vulnerability Sourcebook's approach using the AR5[1] risk concept. The main text contains all the crucial information needed to apply the AR5 risk concept in practice. In addition, throughout the Risk Supplement, impact chains illustrate the individual steps for a simplified example from the agricultural sector.

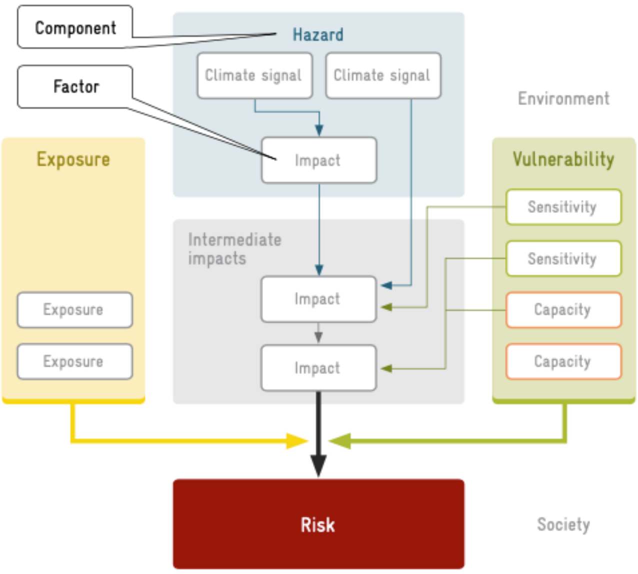
Figure 3: GIZ Vulnerability Sourcebook's modules

Source: GIZ

[1] As the changes in key concepts and definitions between AR6 and AR5 remain minor, the GIZ Risk Supplement of the Vulnerability Sourcebook can still be used as the methodological basis, although it was originally elaborated using AR5 terminologies.

Module 2 focuses on developing impact chains, which form the core of the Vulnerability Sourcebook's approach and lays the foundation for the entire risk assessment. An impact chain is an analytical tool that helps to better understand, systemize, and prioritize the factors that drive risk in a system of concern. The structure of the impact chain was developed according to the IPCC AR5 approach and is based on the understanding of risk and its components (see hazard, exposure, vulnerability, and risk in Figure 4.

Figure 4: Impact chain structure



Source: GIZ

The Risk Supplement's approach to developing impact chains according to the AR5 concept is based on five steps:

- **Step 1**: Identify climate impacts and risks: which significant impacts and risks affect your system of concern?
- **Step 2**: Determine hazard and intermediate impacts: which climate-related hazardous events or trends and their physical impacts pose a risk to your system of concern? Which intermediate impacts link the hazard and the risk?
- **Step 3**: Determine vulnerability: which attributes of the system contribute to the risk?
- **Step 4**: Determine exposure: which factors determine exposure?
- **Step 5**: Brainstorm adaptation measures (optional): what measures could help decrease vulnerability and exposure within the system of concern?

Climate impact chains are at the core of the methodological approach.

They are critical outputs based on GIZ's climate-above-risk assessment methodology. These climate impact chains can be applied on different levels and sectors; they need to be underpinned by appropriate qualitative and quantitative analyses. Overall, they allow to:

- Introduce the system of concern and its characteristics systematically.
- Identify and validate the physical trends of key climate variables and indices.
- Structure and assess the impact of climate change on the system of concern.
- Determine the key factors of vulnerability (including sensitivity and lack of adaptive capacity)
- Identify meaningful adaptation measures linked to specific vulnerability factors

5. Historical and projection climate analysis

5.1. Historical Climate of West Kalimantan

West Kalimantan is an Indonesian province situated in the western part of Borneo Island, between 2°08'N and 3°05'S and 108°0'E and 114°10'E. on the Equator line. Accordingly, West Kalimantan has a tropical climate with high temperatures and high humidity. The region is predominantly flat, with an elevation of approximately 50 meters above sea level. Only a small portion of the area is mountainous, but they are relatively low and not volcanic. The highest mountain in the region is Mount Baturaya, located in the Serawai District of Sintang Regency, with an altitude of 2,278 meters above sea level.

The data used for historical climate studies are CHIRPS and CRU (Table 1). This data is used as observation data for spatial and temporal historical climate studies. CHIRPS combines rainfall data from station- and satellite observation data, which is used as grid data. The CHIRPS data used in this study has a spatial resolution of 0.05° × 0.05° (~5 km). Detailed information regarding CHIRPS data and data downloads can be obtained from the following website: http://chg.geog.ucsb.edu/data/chirps/ (Funk et al. 2014; Funk et al. 2015). CRU is a collection of climate data compiled from various data sources, which are then interpolated to a spatial resolution of 0.5° × 0.5° (~50 km). Currently, version 4 of the CRU data is available with updates to the interpolation method used and the availability of the data period until 2022 (Harris et al. 2020). The CRU data used in this report is temperature data (average, maximum, and minimum). CRU data can be downloaded from the website http://www.cru.uea.ac.uk/data (Haris et al. 2020).

Table 1: List of climate data that was used for the historical analysis

NO	CLIMATE DATA	CLIMATE VARIABLE	TIMEFRAME	Sources
1	CHIRPS	Pre	Daily, 1981-2022	Funk *et al.* 2014; Funk *et al.* 2015
2	CRU	T, Tmn, Tmx	Monthly, 1951-2022	Harris *et al.* 2020

Usually the data analysis process carried out in historical climate studies is as follows:

1. Bias Correction of CHIRPS and CRU data

The CHIRPS data correction process is carried out to reduce bias in the data. CHIRPS data was corrected using BMKG (Badan Meteorologi, Klimatologi dan Geofisika/ Meteorology and Geophysical Agency) observation data in West Kalimantan Province. The correction model was obtained using the method by Piani et al. (2009) with the correction scheme described by Jadmiko et al. (2017). The correction model obtained was then applied to the entire grid in West Kalimantan.

The CRU data correction process follows the same method as the CHIRPS data correction process. In addition, altitude data was added as a second variable besides BMKG data in the CRU data correction process.

2. Historical Climate Analysis

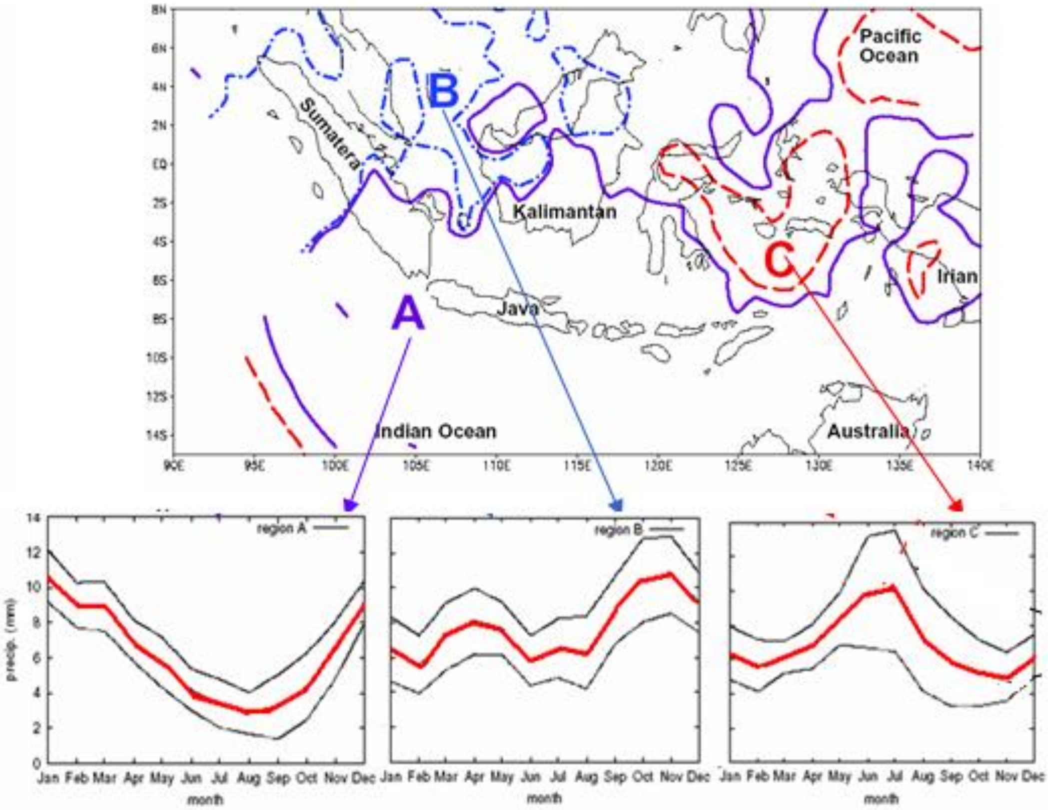
Corrected CHIRPS and CRU data are used for historical climate analysis, including trend analysis, onset analysis, extreme climate analysis, and drought index analysis. Trend analysis follows the available data patterns with monthly and seasonal trends to determine the climate patterns in West Kalimantan Province. Analysis of the onset includes the beginning of the rainy season and the beginning of the dry season, including the length of the two seasons. Extreme climate analysis includes several extreme climate indices developed by the Expert Team on Climate Change Detection and Indices (ETCCDI), such as CDD, CWD, RX1DAY, and RX5DAY. The drought index analysis uses two indicators: SPEI and scPDSI. The results of the analysis are presented in the graphs and maps depicting historical climate conditions in West Kalimantan Province.

The average temperature ranges from 24.8℃ to 28.9℃, with a maximum recorded temperature of 34.6℃ in 2022 and a minimum of 21.5℃. Humidity levels have fluctuated between 65% and 80%. Average wind speeds range from 1.37 m/s to 10 m/s; the highest recorded wind speed was 31 m/s in 2022. The average sunshine in West Kalimantan is between 45% and 70%. (BPS 2013-2023).

5.1.1. Rainfall

Indonesia's rainfall has three distinct patterns: monsoonal, equatorial, and local Figure 5). The monsoonal pattern has two distinct seasons: one rainy season from October to March, with the peak around December to January; and the dry season from April to September with the driest months around June-July. The monsoonal pattern is mostly affected by the monsoon circulation that changes direction every half year. The equatorial pattern reflects the semi-monsoonal pattern with two rainy season peaks, which occur around April and October. The local pattern, on the other hand, is the opposite to the monsoonal, where the rainy season peak occurs around June/July.

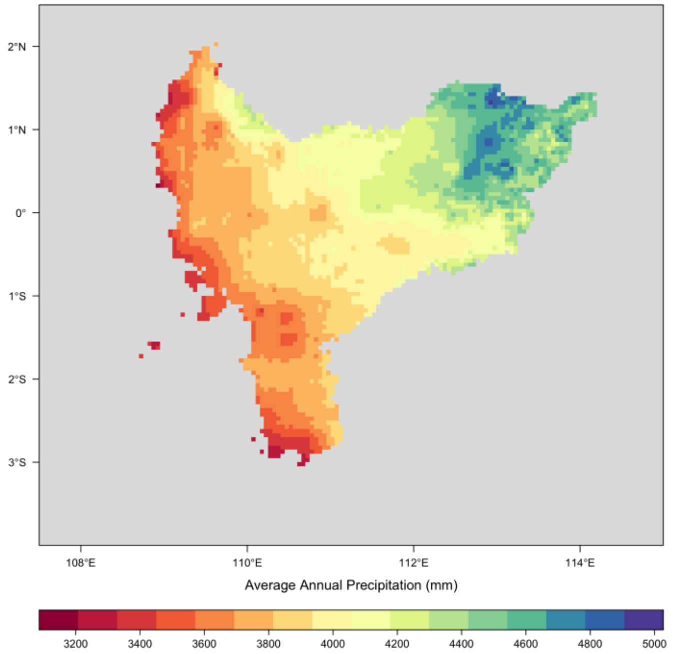
Figure 5: Rainfall pattern in Indonesia: Monsoon (region A), Equatorial (region B), and Local (region C). West Kalimantan has two types of rainfall patterns: Equatorial and Monsoon.



Source: Aldrian dan Susanto 2003

West Kalimantan is located along equatorial line (2N to 3S), which causes most of West Kalimantan to have an equatorial rainfall pattern. The annual rainfall ranges from about 3000 mm to 4500 mm. Rainfall in highland areas, dueto the orographic effect is higher than in inland regions (**Error! Reference source not found.**). Part of the southern region is affected by the monsoonal pattern (e.g., Ketapang Regency). The monsoonal rain pattern is driven by the movement of high-pressure air masses and low-pressure air masses alternately in the Asian and Australian continents (Hermawan 2010).

Figure 6: Distribution of annual rainfall in West Kalimantan

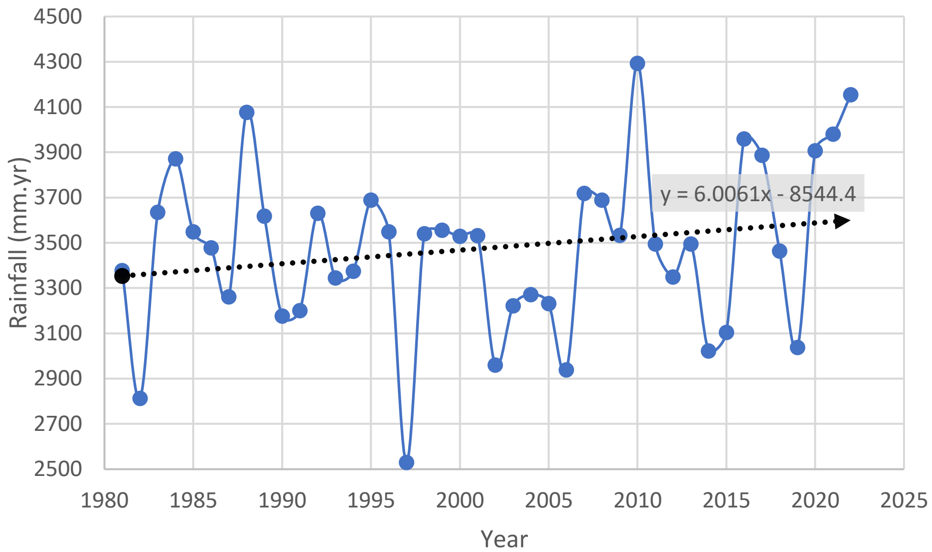


West Kalimantan is home to tropical rainforest areas, especially in the eastern part of the region around Lake Sentarum. With high forest vegetation, this region is wet and humid, with annual rainfall exceeding 4500 mm. The air temperature in this region is about 2 degrees lower than the other regions in West Kalimantan. The western part of West Kalimantan has comparably the lowest rain intensity. Annual rainfall in the western region ranges from 3200-3600 mm. This area includes Sambas Regency, Singkawang City, Mempawah Regency, Pontianak City, Kubu Raya Regency, North Kayong Regency, and part of Ketapang Regency. The central parts of West Kalimantan, such as Sanggau Regency, Sekadau Regency, Melawi Regency, and Sintang Regency, have higher rainfall than the western region. This region's annual rainfall ranges from 3800 mm to 4100 mm (Figure 6).

5.1.1.1. Rainfall Trend

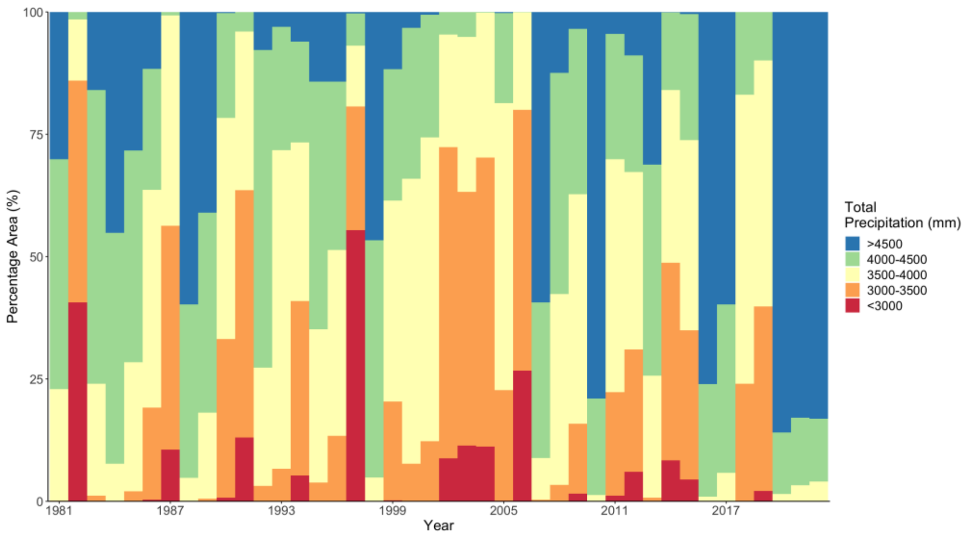
Annual rainfall in West Kalimantan generally shows an increasing trend from 1981 to the present at a rate of about 6 mm/year. However, during specific years, the rainfall in West Kalimantan shows high fluctuations, mainly when El Nino and La Nina phenomena occur (Figure 7). In 1982 and 1997, when strong El Nino occurred, rainfall in most of West Kalimantan showed a significant decrease, compared to the average (standard years; **Error! Reference source not found.**). Similarly, in the other El Nino years 2002, 2006, 2015, and 2019, rainfall in West Kalimantan also decreased compared to the normal. Opposite to El Nino, in the La-Nina years, such as 2010, 2021, and 2022, West Kalimantan experienced a significant increase in rainfall compared to the normal.

Figure 7: Annual rainfall trend of West Kalimantan[2]



The influence of rainfall variability in West Kalimantan is also reflected in the areas with low (high) rainfall during the El-Nino La-Nina period. In 1982 and 1997, when there was a strong El Nino, most areas in West Kalimantan had less than 3000 mm/year of rainfall. Similarly, during strong La-Nina events such as in 2010 and 2016/2017, some areas in West Kalimantan experienced a significant increase in rainfall. In those years, the annual rainfall in West Kalimantan was more than 4500 mm (Figure 8). In general, rainfall in West Kalimantan experienced an increasing trend in areas with high rainfall. Therefore, the risk of disaster events caused by high rainfall, such as floods and landslides, needs to be anticipated as early as possible.

Figure 8: Percentage of area in West Kalimantan by annual rainfall



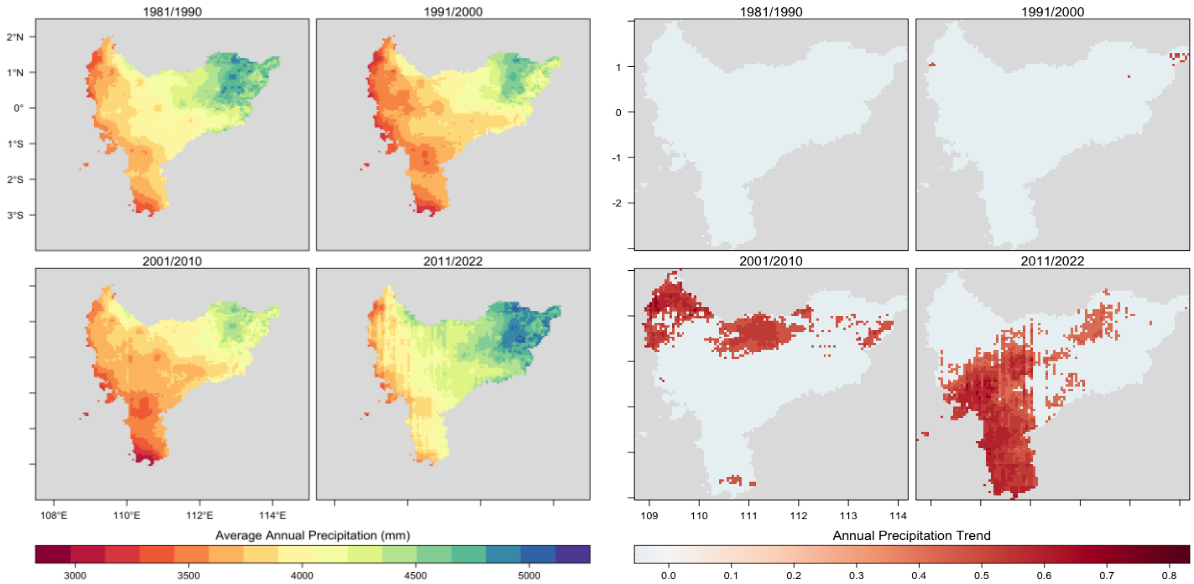
The spatial distribution of average annual precipitation in West Kalimantan shows distinct patterns across the region, mainly when divided into four periods: 1981-1990, 1991-2000, 2001-2010, and 2011-2022. The plot illustrates variations in rainfall amounts across different

[2] The analysis shows significance value of 0.03 < 0.05, indicating that the trend is statistically significant at the 95% confidence level

parts of West Kalimantan during these periods. Generally, the eastern areas retreat, while the western regions experience relatively lower average annual rainfall. However, the intensity level of annual rainfall varies across different periods. From 1991-2010, the intensity of annual precipitation was not particularly high, while from 2011-2022, there was an overall increase in average annual rainfall across all regions.

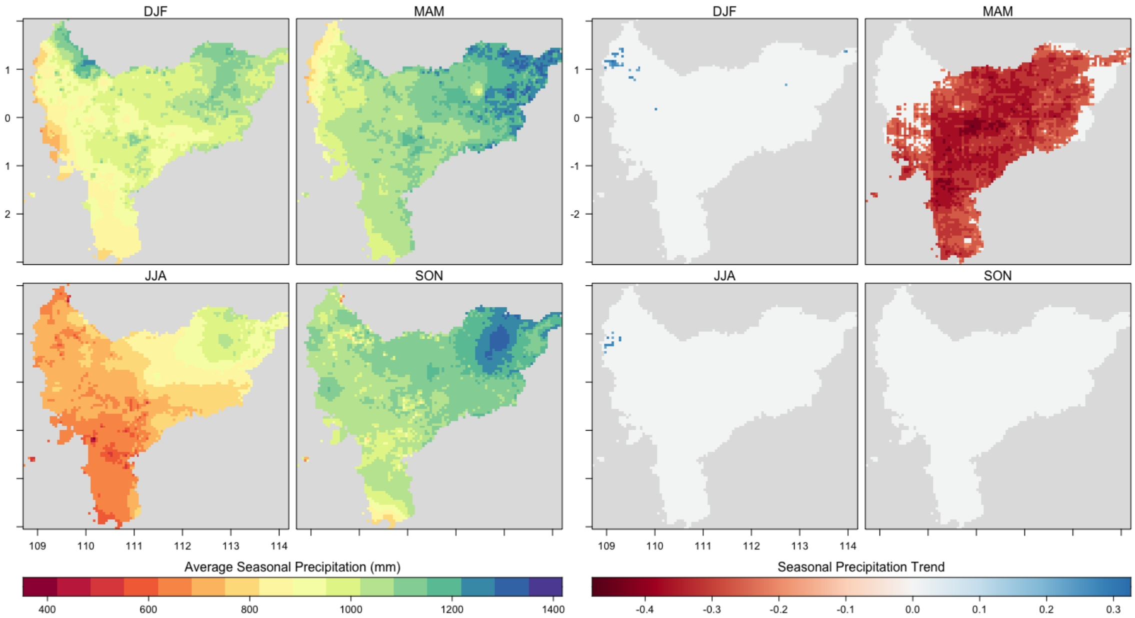
Examining the annual precipitation trend over these periods provides valuable insights into changes occurring in West Kalimantan. While there has been a stable trend in annual precipitation from 1981-2000, the data reveals a rising trend from 2001-2022 observed not only in the northern part region but also in the southern region, which usually has a low average annual precipitation, and which experienced the most significant rise in precipitation levels.

Figure 9: Spatial distribution of average annual precipitation (left) and annual precipitation trend (suitable) in West Kalimantan for the four periods.



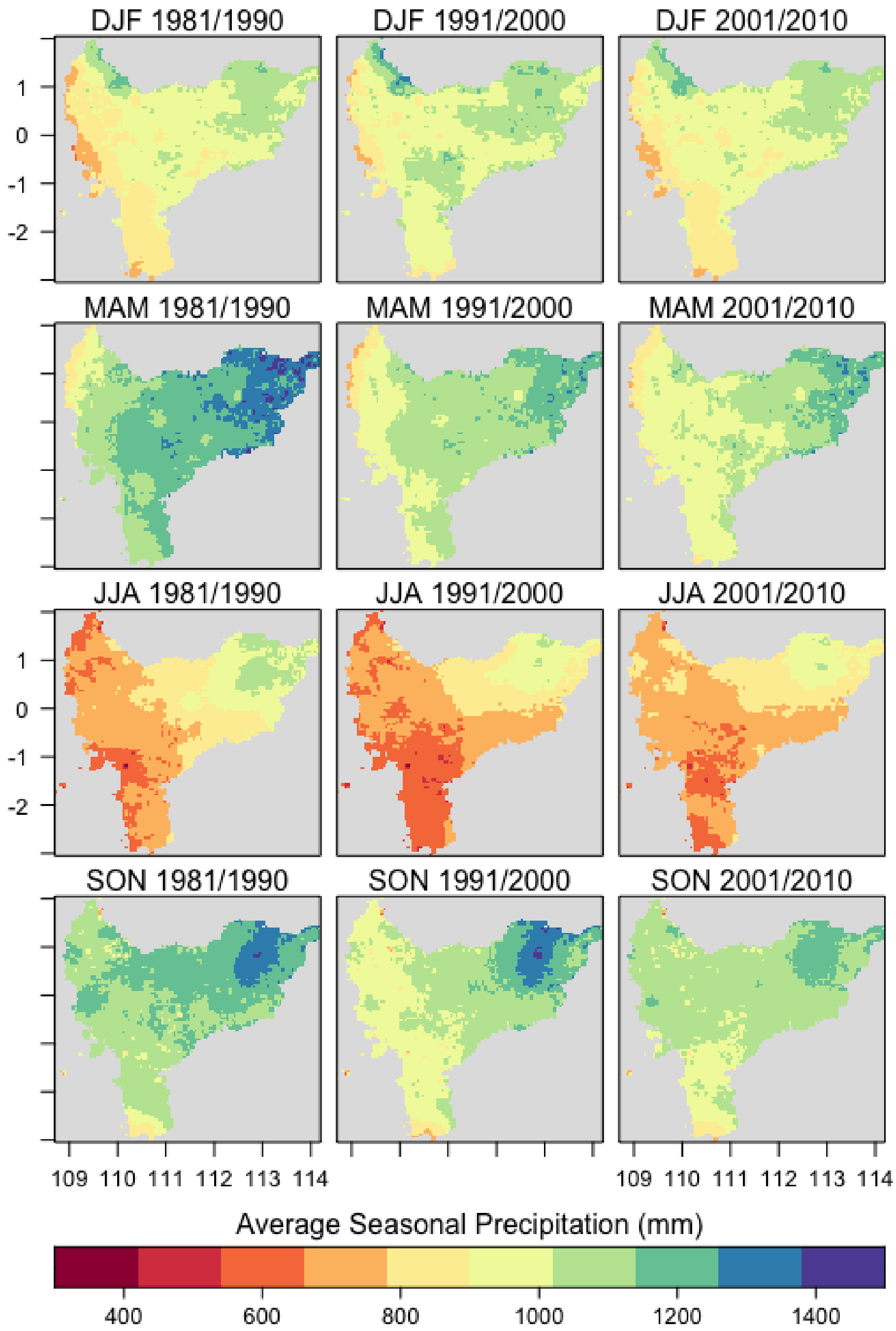
The plot of seasonal precipitation in West Kalimantan, divided into four distinct seasons, provides insights into the variations in rainfall patterns throughout the year. The seasons are categorized as follows: December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), and September-October-November (SON). As mentioned previously, with an equatorial rainfall pattern, the West Kalimantan region has two peaks in the rainy season. The first rainy season peak occurs in the MAM period, the second peak in the SON period, and the dry season peak occurs in the JJA period. Differences in rainfall conditions in each season affect the risk for disaster events and water availability. In the agricultural and plantation sectors, water is essential to maintain the productivity of agricultural and plantation commodities. ´Seasonal precipitation trends in West Kalimantan reveal a decreasing pattern in seasonal precipitation levels across most regions.

Figure 10: Spatial distribution of average seasonal precipitation (left) and seasonal precipitation trend (suitable) in West Kalimantan



The plot of seasonal precipitation in West Kalimantan provides valuable insights into the variations in rainfall patterns across the regions, particularly when divided into three periods: 1981-1990, 1991-2000, and 2001-2010. Seasonal precipitation levels show a noticeable decreasing trend during 1991-2000 and 2001-2010 for MAM, 1991-2000 for JJA, and 2001-2010 for SON. For the MAM season, a decrease in rainfall occurs in all regions, but the decline is particularly distinct in the eastern region for 1991-2000 and the western region for 2001-2010. For the JJA season a noticeable decrease can be observed in the southern region. Meanwhile, a noticeable decrease was observed in a small part of the eastern region in 2001-2010 for the SON season. This indicates a substantial reduction in rainfall during the MAM and SON seasons. This should receive serious attention.

Figure 11: Spatial distribution of seasonal precipitation divided by periods in West Kalimantan



The spatial distribution of monthly rainfall in West Kalimantan can be seen in Figure 11. This figure shows that the rainfall pattern in West Kalimantan is strongly equatorial. The spatial distribution of monthly rainfall differs from the annual and seasonal rainfall patterns, where the western region tends to be lower than the eastern region. One factor that influences this is the different land cover and topography between the two parts of the region.

In February, the western region experiences relatively low average precipitation levels, indicating drier conditions than other parts of the province. Furthermore, from June to September, a notable decline in average precipitation levels can be observed across many western and southern regions. On the other hand, the eastern region consistently receives relatively higher precipitation, indicating a more consistent and abundant rainfall profile.

Figure 12: Spatial distribution of average monthly precipitation in West Kalimantan

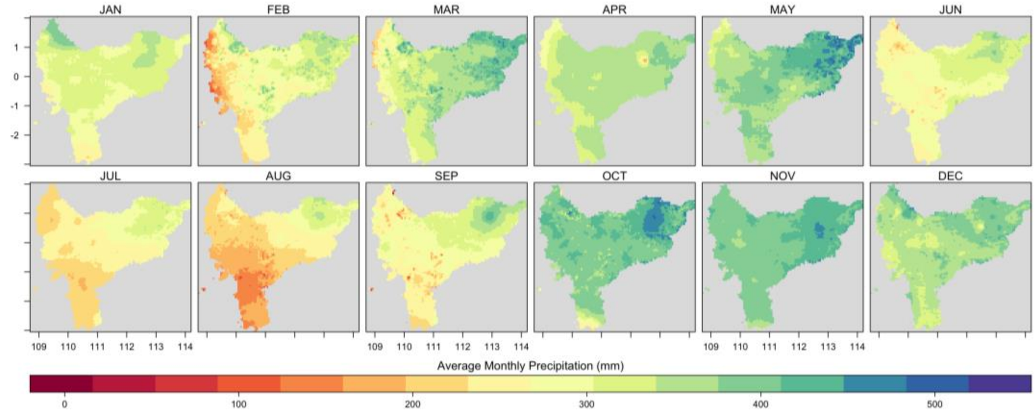
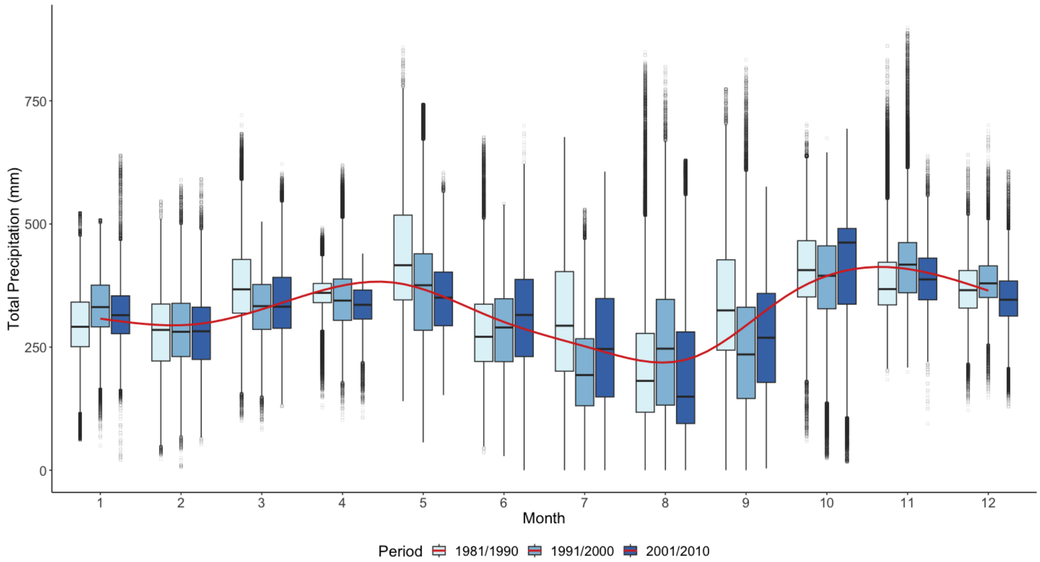


Figure 13: Boxplot of monthly total precipitation in West Kalimantan in three time periods, i.e., 1981-1990, 1991-2000, and 2001-2010

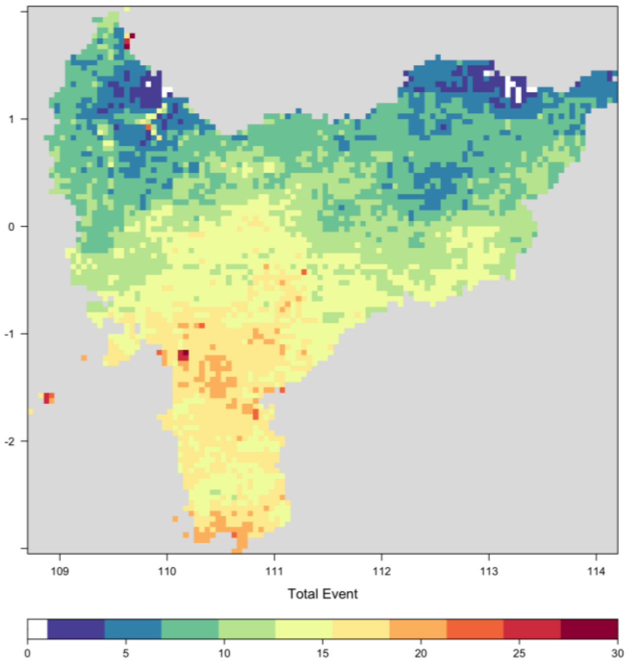


The boxplot of monthly total precipitation in West Kalimantan provides insights into the variability and patterns of monthly rainfall. Examining the boxplot reveals that the highest level of total precipitation occurs during April-May (350 mm/month) and October-November (400 mm/month). Furthermore, August exhibits the lowest total rainfall, with an average of 223 mm/month. This signifies a relatively drier period compared to other months. Also a relatively large variability in July, August, and September compared to other months can be observed. This indicates that the total precipitation during these months exhibits significant differences between individual precipitation events or periods. Furthermore, it can be observed that there are differences in the pattern of median total precipitation in July, August, and September when divided into three time periods: 1981-1990, 1991-2000, and 2001-2010. The pattern of median total precipitation in 1991-2000 is low in July and September but high in August. In contrast, in 1981-1990 and 1991-2000, it is low in August and high in July and September.

5.1.1.2. Rainfall Onset and Cessation

The start and end of the season is one of the essential types of information for the forestry and agriculture sectors. Information on the onset of the dry season can be a reference in anticipating the danger of forest and land fires. Likewise, information about the onset of the rainy season is a flag for farmers to start the planting season for several agricultural commodities such as rice. The advance and retreat of the start of the rainy season affects agricultural cycles.

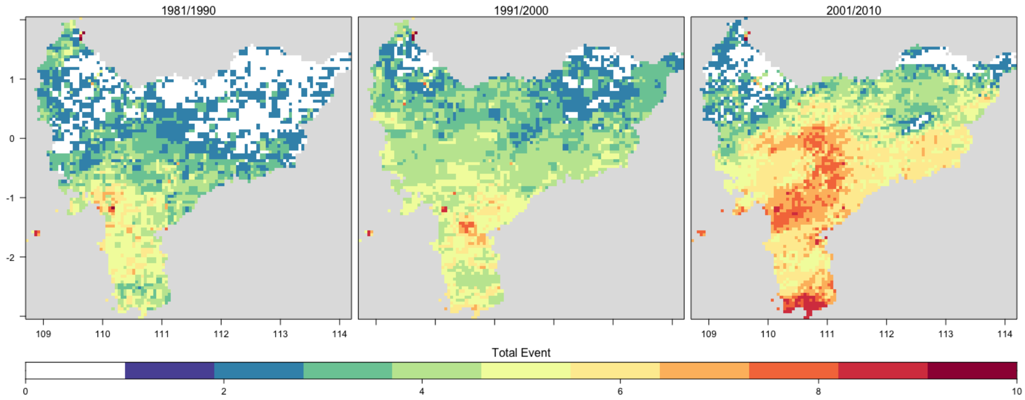
Figure 14: Spatial distribution of total event of dry season in West Kalimantan from 1981 to 2010



Based on BMKG criteria, the dry season begins with a rainfall of less than 50 mm during a 10-day period, followed by the next two 10-day periods. Therefore, a dry season occurs if an area experiences less than 50 mm of rainfall for three consecutive 10 day periods. Figure 10 shows the number of dry season events in West Kalimantan from 1981-2010. From the figure, the southern region is the region that experiences the dry season more frequently than the eastern region. The southern region includes Ketapang Regency and parts of North Kayong Regency. This region needs attention, primarily related to the potential disaster impacts such as forest and land fires and drought.

The spatial distribution of total events of dry season in West Kalimantan reveals distinct patterns across the region, particularly when divided into three time periods: 1981-1990, 1991-2000, and 2001-2010. It can be observed that there is an increasing trend in the total number of dry season events from period to period in all regions. In the period of 1981-1990, many areas in the northern region did not experience dry season events. However, in the period of 1991-2000, those areas started to increasingly experience dry season events. In the period of 2001-2010, several areas experienced more than 7 dry season events. Due to the limited occurrence of the dry season in the northern region and concerns regarding the representativeness of the analysis, the onset and cessation analysis will only utilize grid data from the southern region, specifically the Ketapang Regency.

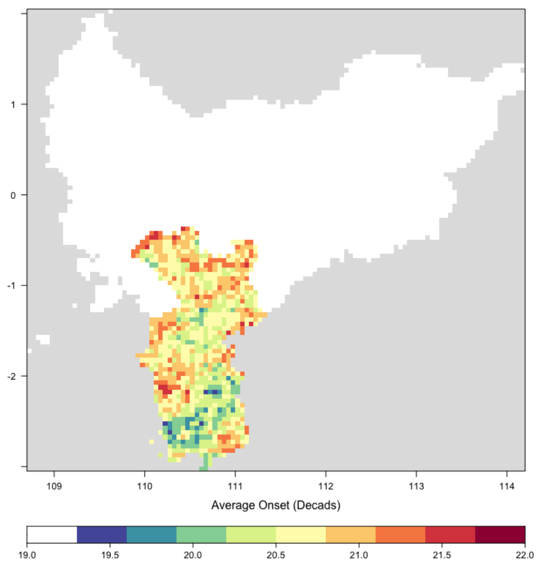
Figure 15: Spatial distribution of total event of dry season in West Kalimantan from 1981 to 1990 (left), 1991-2000 (middle) and 2001-2010 (right)



The timing of the onset of the dry season varies in each region. Therefore, the BMKG creates a season zone (ZOM) as a reference to determine when the onset has occurred. Based on the BMKG ZOM, the northern part of West Kalimantan is an area that is not included in the ZOM. Therefore, the forecast for the beginning of the season in this region is often unknown. Therefore, in this report, only the southern part of West Kalimantan, especially Ketapang Regency, will be analysed concerning the onset of the dry season.

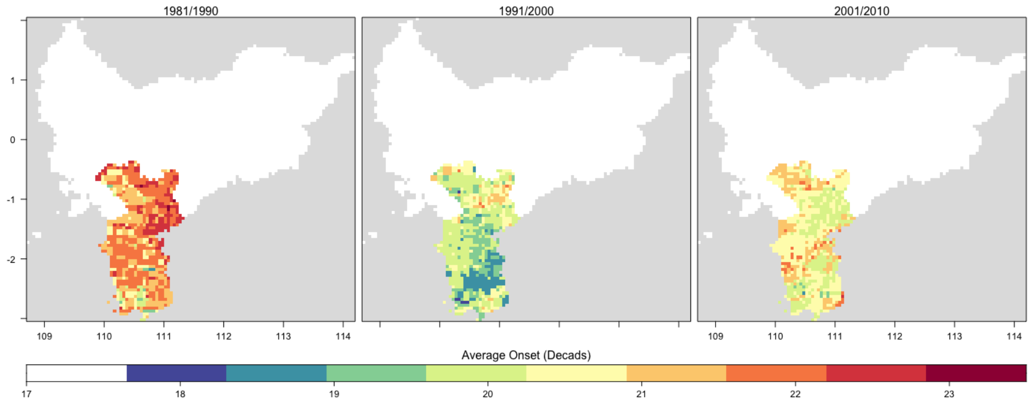
Figure 16 represents the average timing of the dry season onset in Ketapang Regency. In spatial patterns there are no significant differences in the onset of the dry season in the Ketapang Regency. However, there are certain grids in the southern part of the Ketapang Regency that experience an earlier onset compared to other grids. The average onset of the dry season in the Ketapang Regency from 1981-2010 ranged from the 19th 10 day period (early July) to the 22nd 10 day period (early August).

Figure 16: Spatial distribution of average dry season onset in Ketapang Regency



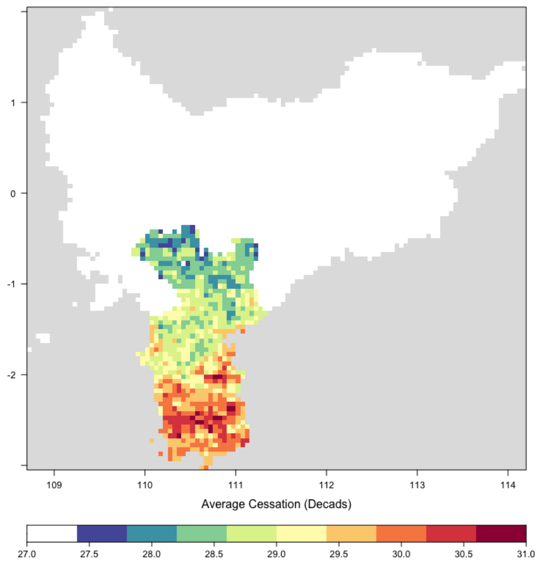
A distinct pattern emerges when examining the plot based on different time periods (1981-1990, 1991-2000, and 2001-2010). The onset of the dry season in the period of 1991-2000 occurred much earlier compared to the other periods. This is because of lower precipitation levels in July during the years 1991-2000, which contribute to the earlier onset of the dry season. On the other hand, the onset in the 1981-1990 period occurred later compared to the other periods due to higher precipitation levels in July.

Figure 17: Spatial distribution of average onset of the dry season divided by periods in West Kalimantan



The Figure 18 showcases the average cessation of the dry season in Ketapang Regency, represented in decades, revealing the end of the dry season across different regions of Ketapang Regency. In contrast to the onset, which does not exhibit a clear spatial pattern, the cessation shows a distinct spatial pattern. Specifically, the southern region of Ketapang Regency has higher average cessation values, suggesting that the end of the dry season in that area occurs later compared to other regions. The average cessation ranges from around 10-day period 27 (around end of September) to 10-day period 31 (around early November).

Figure 18: Spatial distribution of average cessation of the dry season in West Kalimantan



A distinct pattern emerges when examining the plot based on different time periods (1981-1990, 1991-2000, and 2001-2010). The cessation of the dry season in the period of 1991-2000 occurs much later compared to the other periods. This is because of lower precipitation levels in September during the years 1991-2000.On the other hand, the onset in the 1981-1990 and 2001-2010 periods occurred earlier due to lower precipitation levels in October than in the 1991-2001 period.

Figure 19: Spatial distribution of average cessation of the dry season divided by periods in West Kalimantan

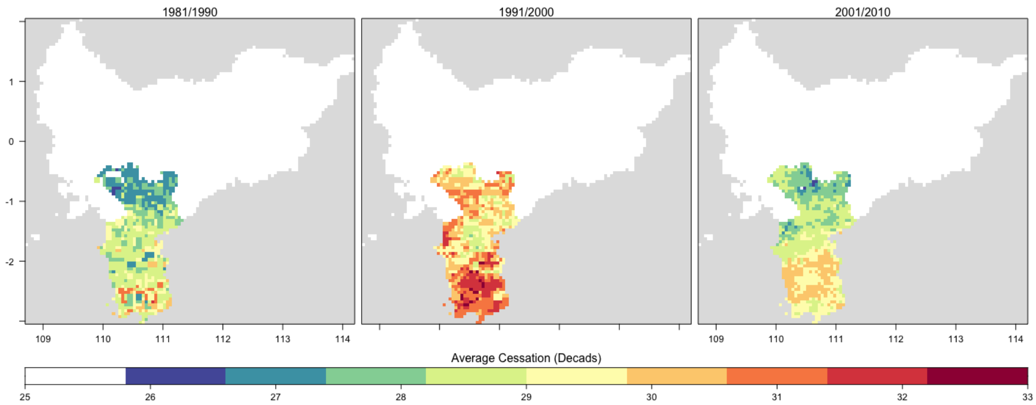
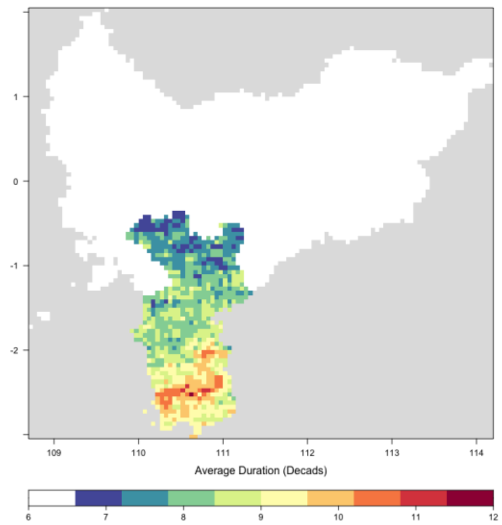


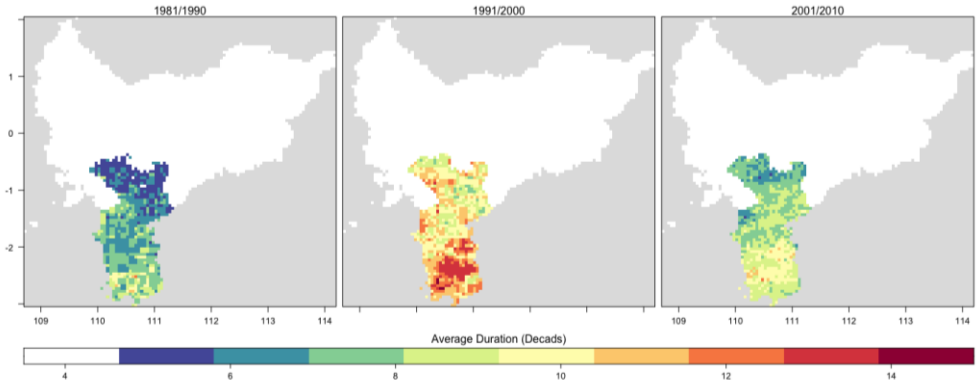
Figure 19 showcases the duration of the dry season in Ketapang Regency, represented in decades, revealing the duration of the dry season across different regions of Ketapang Regency. Based on the Figure 16, it can be observed that there is a spatial pattern where the southern region of Ketapang Regency has a longer duration of the dry season compared to the northern region of Ketapang Regency. This is caused by the fact that the onset and cessation in the southern region occurs earlier and later, respectively, compared to other regions. The average duration ranges from around 7th 10-day periods (2.3 months) to 12th 10-day period (4 months).

Figure 20: Spatial distribution of average duration of the dry season in West Kalimantan



A distinct pattern emerges when examining the plot based on different time periods (1981-1990, 1991-2000, and 2001-2010). The duration of the dry season in the period of 1991-2000 occurred much longer compared to the other periods. This is caused by lower precipitation levels in July and September during the years 1991-2000, which contribute to the earlier onset and later cessation of the dry season. The average dry season duration in 1991-2000 is around three to four months, whereas in other periods it is around two to three months.

Figure 21: Spatial distribution of average duration of the dry season divided by periods in West Kalimantan



5.1.1.3. Extreme Events of Rainfall

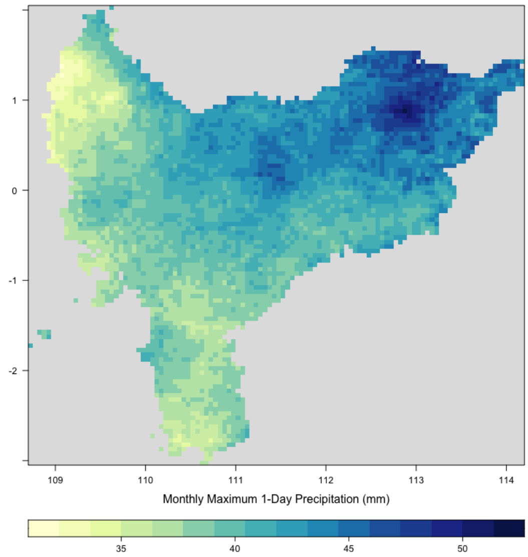
Climate extreme indices are essential to assess and analyse various aspects of extreme climate events. The ETCCDI (Expert Team on Climate Change Detection and Indices) has developed a set of standardized indices to quantify and monitor climate extremes. These indices provide valuable insights into the changing patterns of extreme events, helping researchers to better understand the impacts of climate change.

The climate extreme indices cover a wide range of variables, such as temperature, precipitation, wind, and humidity. They allow to examine extreme climate phenomena such as heatwaves, cold spells, heavy rainfall, droughts, and strong winds. By analysing these indices, trends, variations, and potential shifts in the occurrence and intensity of extreme events over time can be identified. In this study, the percentile method is used to interpret the results of these extreme indices. By interpreting these indices using percentiles, the magnitude and occurrence of extreme events across different thresholds can be assessed.

For instance, considering the 50^{th} percentile provides the median value, representing the typical occurrence of a particular extreme event. Moving to the 90^{th} percentile, values that exceed the median and indicate more intense events occurring more frequently are encountered. At the 95^{th} percentile, even higher values, indicating less frequent but still significant extreme events are observed. Finally, the 99^{th} percentile represents extremely rare and severe events that have a substantial impact on the region. Understanding these percentile thresholds helps evaluate the severity, frequency, and temporal patterns of extreme events. It enables to identify regions or time periods with higher probabilities of experiencing intense weather phenomena. This information facilitates effective climate adaptation and resilience strategies.

The RX1DAY index is one of the climate extreme indices that quantify the maximum amount of precipitation that falls within a single day during a specified period, usually daily. This index provides valuable information about the intensity and severity of heavy rainfall events. It helps identify days with exceptionally high precipitation values, which can lead to flash floods, landslides, and other weather-related hazards. By analysing the RX1DAY index, the changing patterns and trends in extreme rainfall events, especially those occurring within a single day, can be assessed.

Figure 22: Spatial distribution of monthly maximum 1-day precipitation in West Kalimantan



The spatial distribution of average conditions (percentile 50) of RX1DAY in West Kalimantan in the period 1981-2010 can be seen in Figure 21. On average, the maximum daily rainfall in West Kalimantan ranges between 30-50 mm. Based on the BMKG rainfall category, rainfall of 30-50 mm/day is categorized as moderate rainfall. The impact of the rain intensity is categorized as moderate. The eastern region, which is mostly tropical rainforest, RX1DAY index than other regions.

Figure 23: Spatial distribution of 90th, 95th, and 99th percentile of monthly maximum 1-day precipitation in West Kalimantan, 1981-2010

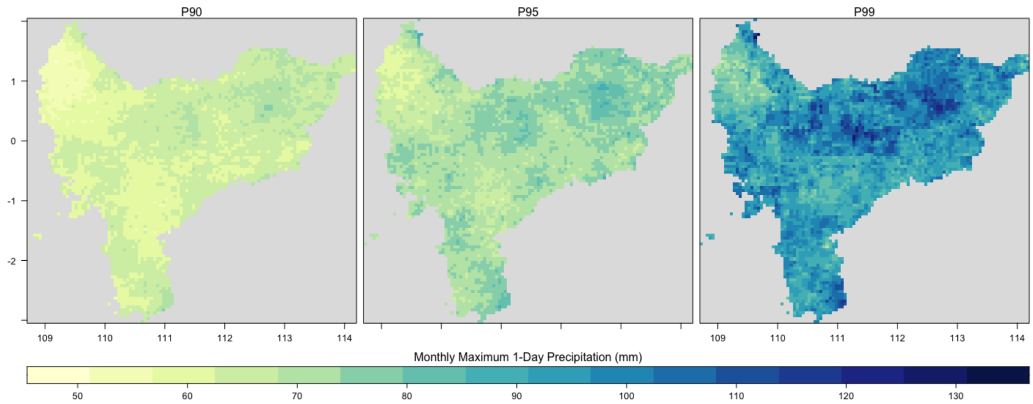
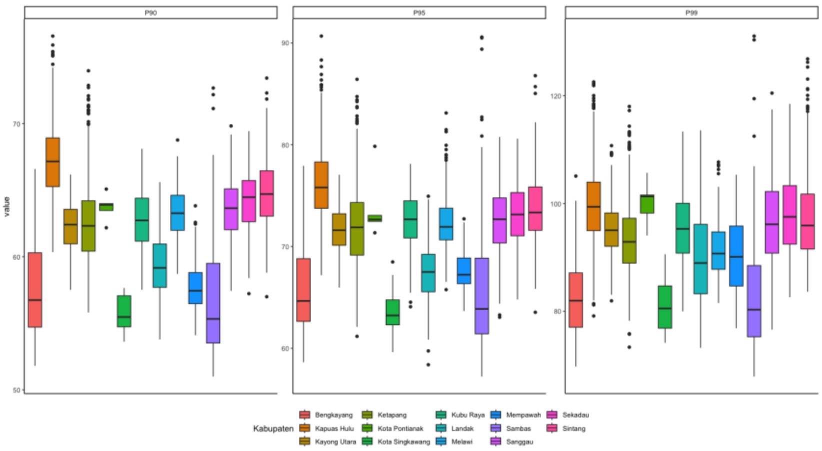


Figure 24 shows the RX1DAY conditions at percentile 90, percentile 95, and percentile 99. These percentile value categories are usually used for a threshold of extreme value. Under the 90th percentile category, the maximum daily rainfall ranges from 50-60 mm. Under the 95th percentile category, the maximum daily rainfall value ranges from 70-90 mm. As for the 99th percentile category, the maximum daily rainfall ranges from 110-130 mm. Based on the BMKG category, rainfall values in the 90th percentile and 95th percentile fall into the heavy rain category, while the 99th percentile falls into the heavy rain category. These conditions can have an impact on the risk of disasters. In general, the Kapuas Hulu district is the area with the highest daily rainfall intensity compared to other regions for all percentile categories. The lowest daily rain intensity occurs in Singkawang City.

Figure 24: Area average of RX1DAY for 90th, 95th, and 99th percentile for City/District in West Kalimantan



Floods and landslides are often not caused by only one day of extreme rainfall. They are usually caused by an accumulation of rain over several days. ECTCDI identifies a rainfall index of five consecutive days (RX5DAY) to illustrate the potential disaster risk due to rainfall. By examining the maximum 5-day rainfall totals, the areas or periods with an increased risk of flooding, or other water-related hazards, can be identified.

Figure 25 shows the average spatial distribution (50th percentile) of RX5DAY in West Kalimantan. At the 50th percentile, like RX1DAY, a spatial pattern emerges, indicating that the western and southern regions experience lower intensity of RX5DAY compared to other regions. The RX5DAY values in the western and southern regions range from 90 mm to 100 mm, indicating a relatively lower intensity of extreme precipitation events. On the other hand, the RX1DAY values in the different regions range from 110 mm to 130 mm, suggesting a higher intensity of extreme precipitation events.

Figure 25: Spatial distribution of 50th percentile of monthly maximum consecutive 5-day precipitation in West Kalimantan, 1981-2010

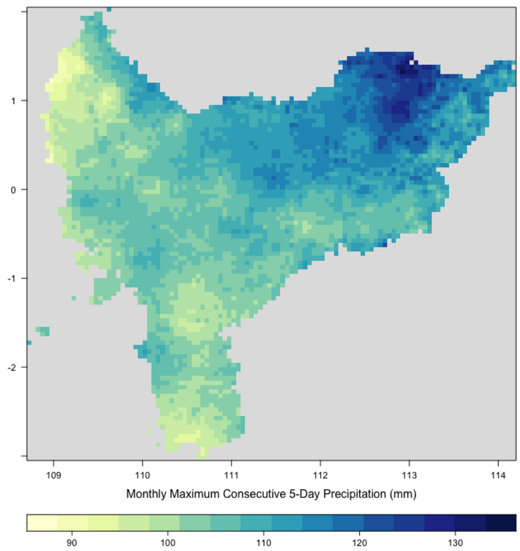


Figure 26: Spatial distribution of 50th, 90th, and 99th percentile of monthly maximum consecutive 5-day precipitation in West Kalimantan, 1981-2010

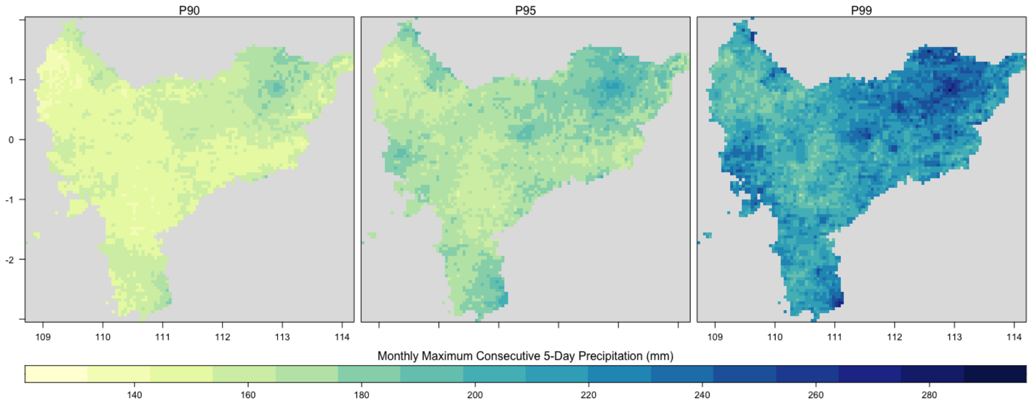
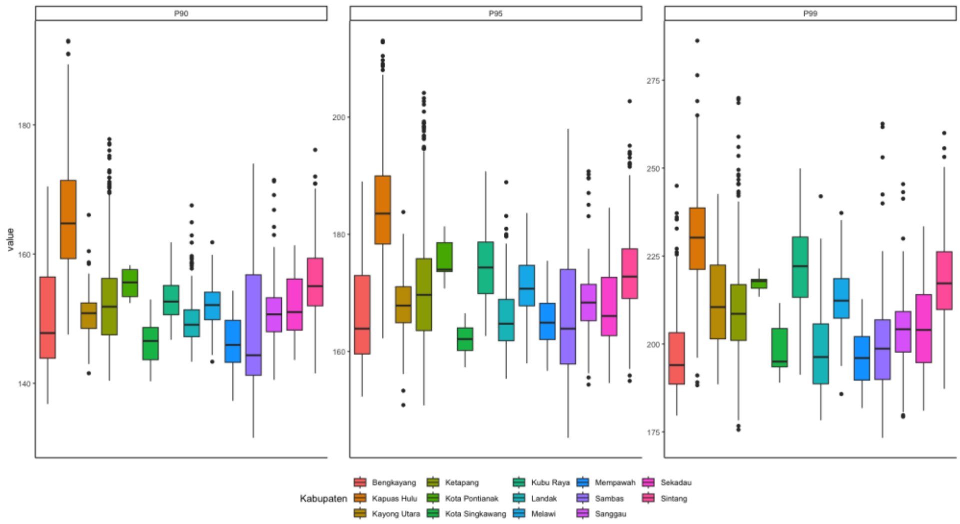


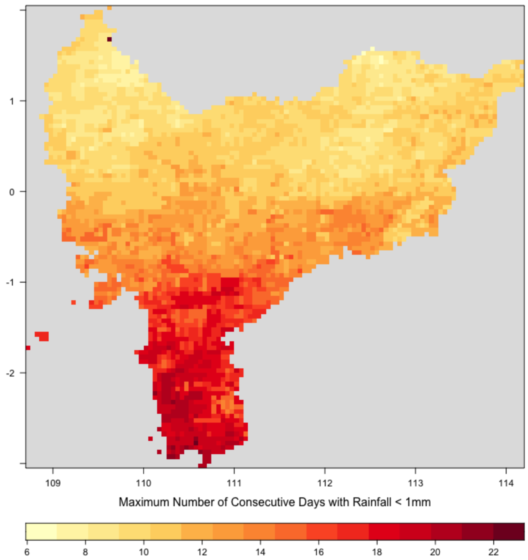
Figure 27: Area average of RX5DAY for 90th, 95th, and 99th percentile for City/District in West Kalimantan



The spatial distribution of the RX5DAY index in West Kalimantan is generally like the RX1DAY index. The eastern region has the highest index value compared to other regions. However, the 5-day rainfall in West Kalimantan is much higher than the maximum daily rainfall. At the 90^{th} percentile, RX5DAY in West Kalimantan ranges from 140 mm - 160 mm. For to the 95^{th} percentile, the RX5DAY value ranges from 170 mm - 190 mm. As for the 99^{th} percentile, the RX5DAY value ranges from 200 mm - 260 mm (**Error! Reference source not found.**). Kapuas Hulu district has the highest RX5DAY index compared to the other districts. The RX5DAY value in the district reached 230 mm. This rainfall is quite high and has a relatively a high potential risk for disasters, such as floods and landslides. Bengkayang Regency and Singkawang City are the areas with the lowest RX5DAY index. Details of the RX5DAY index value for each district/city can be seen in Figure 27.

In the agricultural sector, water availability is crucial and can be met in several ways, such as using reservoirs, ponds, or other water storage. In addition, in the rain, water availability is highly dependent on rain in the rain catchment area. In the event of no rain over the long term, water availability will be disrupted. Therefore, information on CDD needs to be known to anticipate the failure of agricultural commodities. Consecutive Dry Days (CDD) represent the maximum length of a period with consecutive days having no precipitation. It measures the duration of dry spells or prolonged periods without significant rainfall. CDD is particularly useful in assessing drought conditions, water resource management, and understanding the impacts of prolonged dry periods on ecosystems, agriculture, and water availability. It provides valuable information on the length and severity of dry spells, allowing for the identification of regions that are more prone to drought events and the evaluation of their frequency and duration over time.

Figure 28: Spatial distribution of 50th percentile of annual maximum number of consecutive days with rainfall < 1 mm in West Kalimantan, 1981-2010



In general, the average (50th percentile) length of CDD in West Kalimantan ranges from 8-22 days. The southern region, such as Ketapang District has the longest CDD (22 days) compared with other regions (Figure 28). This condition is in line with the general rainfall conditions in West Kalimantan, where the southern region is drier than the wetter eastern region. Based on the BMKG classification, 22 days without rain is considered a "long" period. Therefore, monitoring and anticipating the impact of this information is very important, especially in relation to agricultural cultivation.

Figure 29: Spatial distribution of 90th, 95th, and 99th percentile of annual maximum number of consecutive days with rainfall < 1 mm in West Kalimantan, 1981-2010

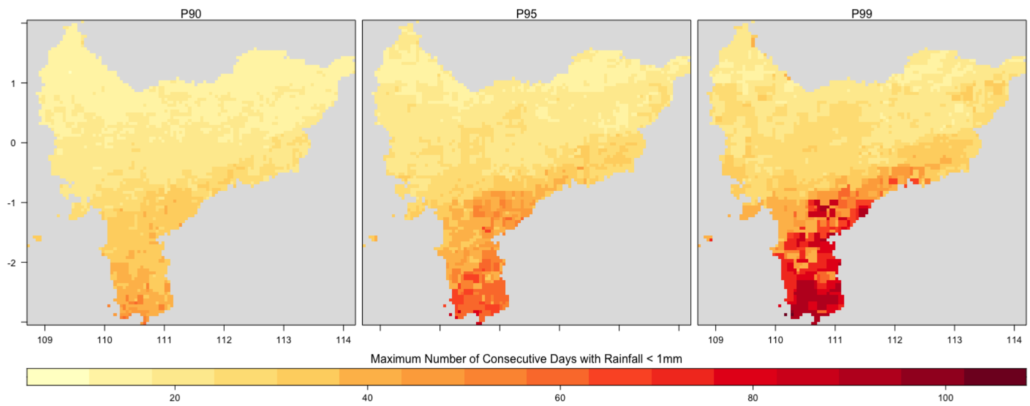
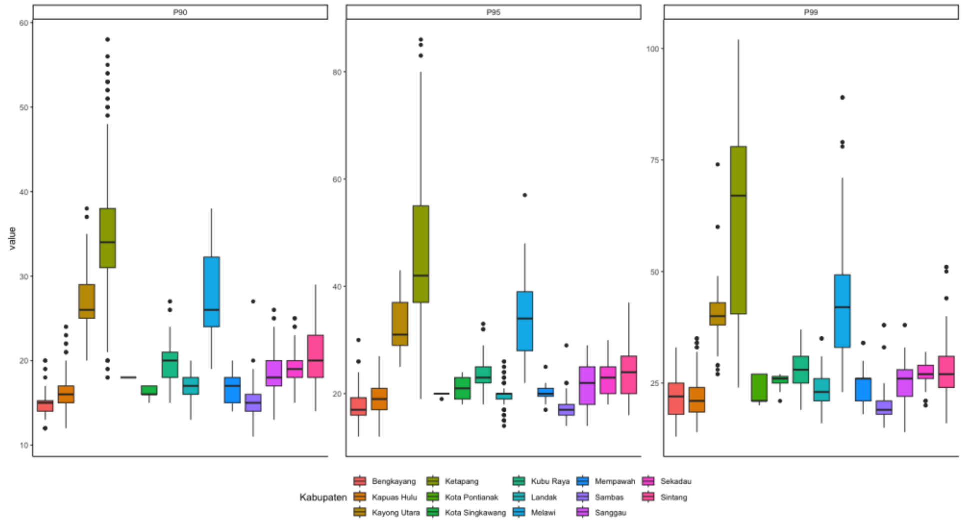


Figure 30: Area average of CDD for 90th, 95th, and 99th percentile for City/District in West Kalimantan



Error! Reference source not found. shows the CDD conditions at percentile 90, percentile 95, and percentile 99 values. Based on the 90th percentile category, the length of CDD generally ranges from 15-30 days. At percentile 95, the length of days without rain ranges from 20-60 days. As for the 99th percentile category, the length of days without rain reaches 30-100 days a year. Based on BMKG categories, rainfall values in the 90th percentile category are classified as "long" and the 95th percentile as "very long", while the," while the 99th percentile category is classified as "extremely long". These conditions can have an impact on the risk of major disasters. In general, Ketapang Regency is the area with the longest series of days with most extended dry spells in comparison to other regions for all percentile limit categories. The areas with the shortest rainy-day series occur in Sambas, Bengkayang, and Kapuas Hulu districts (Figure 30).

The Consecutive Wet Days (CWD) is defined as the longest extended period of consecutive days with precipitation. It measures the continuity of wet conditions and helps to identify periods of prolonged rainfall. The CWD index is useful for several applications. Firstly, it aids the better understanding of hydrological systems and water resource management. By quantifying the duration of wet spells, it helps to assess the risk of flooding, soil saturation, and groundwater replenishment. The CWD index is also beneficial for agricultural planning and crop management. Farmers can utilize this information to assess crop water requirements, to optimize their irrigation strategies, and anticipate periods of excessive soil moisture that may impact crop growth or increase the risk for diseases.

Figure 31: Spatial distribution of 50th percentile of annual maximum number of consecutive days with rainfall ≥ 1 mm in West Kalimantan, 1981-2010

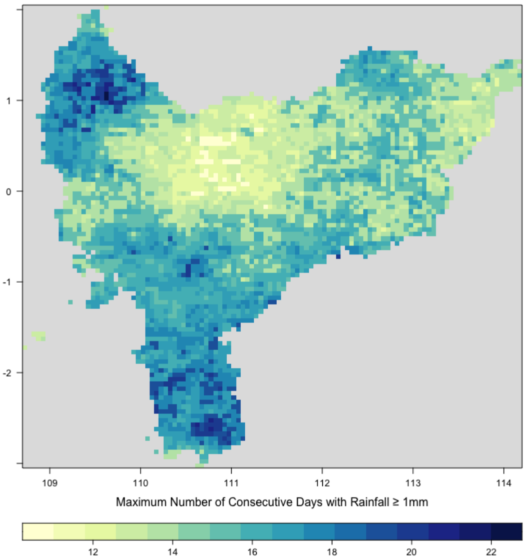


Figure 32 displays the average condition (50th percentile) of CWD in West Kalimantan. The southern (Ketapang District) and northern (Bengkayang District, Sambas District) regions have the most extended CWD. In these areas, the average CWD lasted 20-22 days. In other regions the CWD value ranges from 12-18 days. The CWD distribution pattern is different from the rain distribution pattern and the RX1DAY distribution pattern. This indicates that, in relatively wet areas, such as around Danau Sentarum National Park, the accumulation of annual rainfall increases strongly due to the intensity of very heavy daily rainfalls. This condition differs from Ketapang district, where annual rainfall tends to be low, but rain can occur over several days.

Figure 32: Spatial distribution of 90th, 95th, and 99th percentile of annual maximum number of consecutive days with rainfall ≥ 1 mm in West Kalimantan, 1981-2010

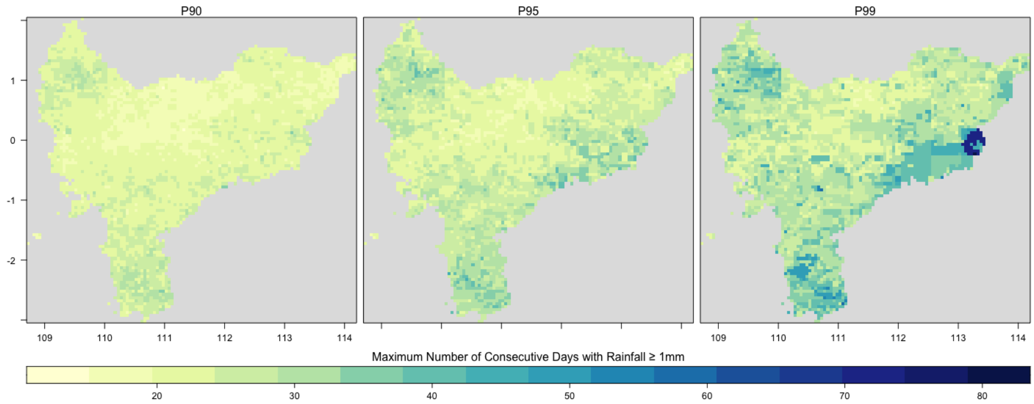
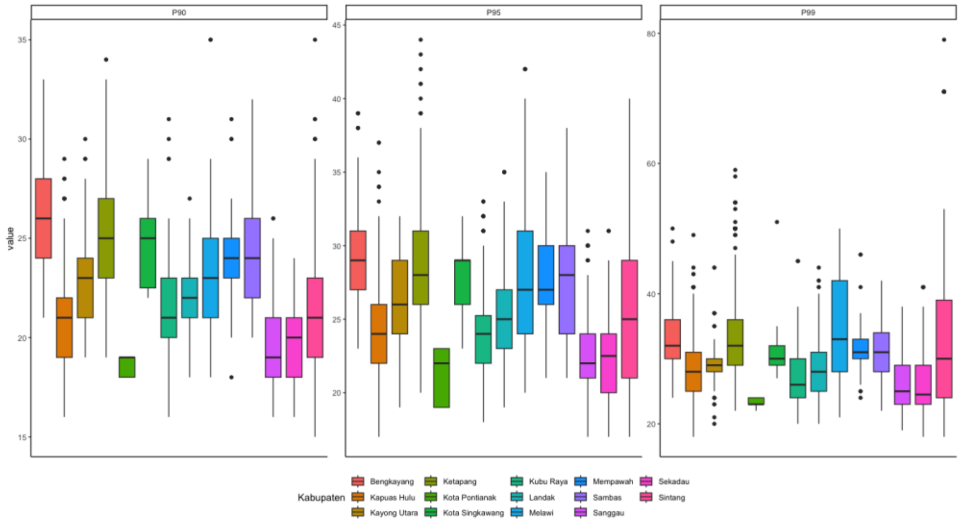


Figure 33: Area average of CWD for 90th, 95th, and 99th percentile for City/District in West Kalimantan



Error! Reference source not found. shows the CWD conditions at percentile 90, percentile 95, and percentile 99 values. In the 90th percentile category, the length of CWD ranges from 18-30 days. Under the 95th percentile category, the CWD length generally ranges from 20-35 days. As for the 99th percentile category, the length of CWD reaches 30-88 days. Bengkayang District typically has the longest rainy-day sequence compared to other regions across all percentile limit categories. The area with the shortest rainy-day sequence occurs in Pontianak City.

5.1.2. Drought Index

5.1.2.1. The Standardized Precipitation and Evapotranspiration Index (SPEI)

SPEI is a climate index that combines both precipitation and evapotranspiration data to assess drought conditions. It offers a comprehensive measure of the balance between an area's water supply (precipitation) and demand (evapotranspiration). The real strength of the SPEI is its ability to be calculated for many timescales, which makes it capable to register many drought types.

Unlike the Standardized Precipitation Index (SPI), which solely considers precipitation, the SPEI incorporates evapotranspiration, representing the water lost from the land surface due to evaporation and plant transpiration. By incorporating evapotranspiration, the SPEI provides a more holistic and accurate understanding of the moisture conditions in an area.

The SPEI values can be interpreted as the number of standard deviations by which the observed precipitation anomaly deviates from the long-term mean. But for this analysis, the SPEI values are summarized into categories (Table 2) and aggregated across the entire region using a grid-based approach.

Table 2: Classification of the SPEI Index

CATEGORY	THRESHOLD
Exceptionally Dry	-2.00 and below
Extremely Dry	-2.00 to -1.50
Severely Dry	-1.50 to -1.20
Moderately Dry	-1.20 to -0.70
Abnormally Dry	-0.70 to -0.50

CATEGORY	THRESHOLD
Near Normal	-0.50 to +0.50
Abnormally Moist	+0.50 to +0.70
Moderately Moist	+0.70 to +1.20
Very Moist	+1.20 to +1.50
Extremely Moist	+1.50 to +2.00
Exceptionally Moist	+2.00 and above

A 3-month SPEI captures short- and medium-term moisture conditions and offers a seasonal perspective on precipitation patterns. In agricultural areas, the 3-month SPEI may prove more valuable than slower-responding indices like the Palmer Index or other hydrological indicators, as it can effectively highlight the prevailing moisture conditions available for agricultural purposes. A 6-month SPEI indicates seasonal to medium-term moisture conditions and their effects on water availability, agriculture, and ecosystems. A 6-month SPI can effectively show the precipitation over distinct seasons. The 12-month SPEI is an indicator that looks at moisture conditions over a longer period, specifically one year. It considers the amount of rainfall and evapotranspiration during this time and assesses the overall water availability and hydrological balance in a region.

Figure 34 shows the SPEI for West Kalimantan from 1981 to 2010 and provides the relationship between standardized average monthly precipitation and standardized average monthly temperature. When a particular month has a high value of standardized average monthly temperature and a low value of standardized average monthly precipitation, the number of grids categorized as dry will be higher. On shorter time scales (3 and 6 months), the SPEI values tend to be more responsive to the gap between standardized average monthly precipitation and standardized average monthly temperature. This implies that dry periods during these periods are relatively brief and occur more frequent. However, when considering a longer time scale (12 months), the SPEI values are less affected by the gap, resulting in less frequent occurrences but longer lasting droughts. The notable driest years based on SPEI in terms of spatial coverage affected by drought were 1982-1983, 1997-1998, and 2002-2007.

Figure 34: Share of 1-month SPEI classification in West Kalimantan, 1981-2010. The solid line indicates the average monthly precipitation and the dashed line indicates the average monthly temperature.

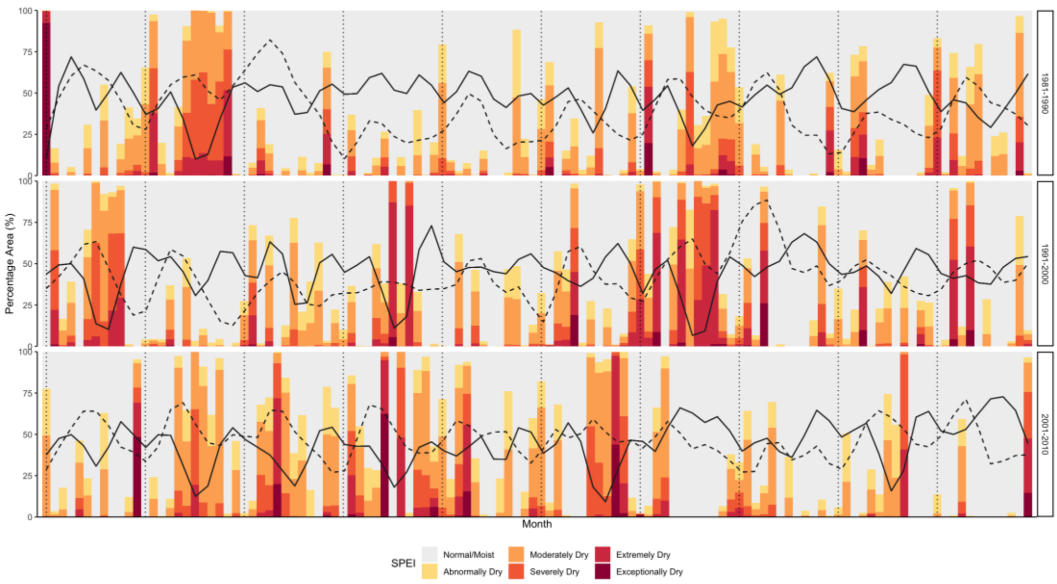


Figure 35: Share of 3-month SPEI classification in West Kalimantan, 1981-2010. The solid line indicates the average monthly precipitation and the dashed line indicates the average monthly temperature.

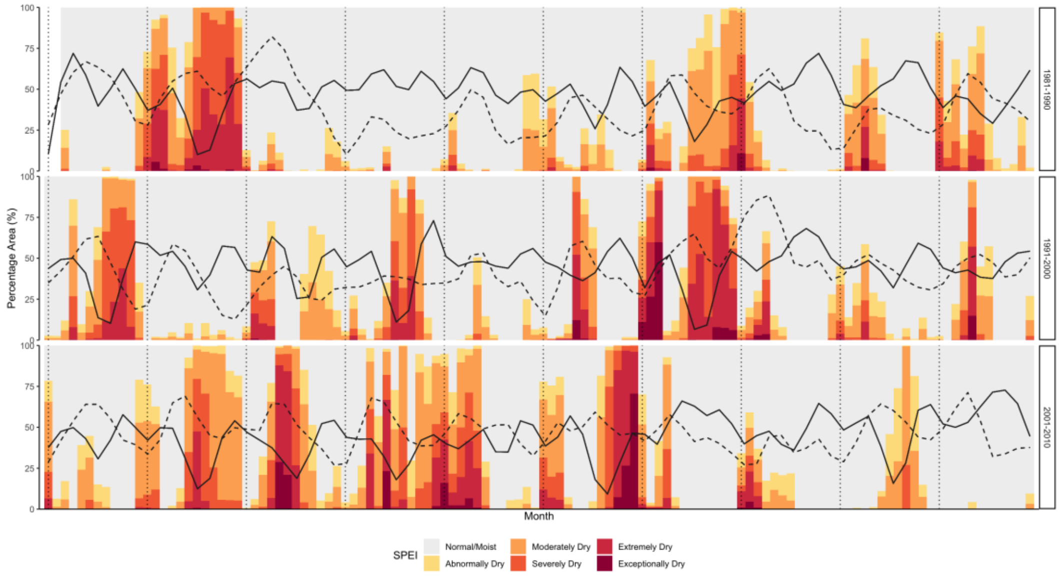


Figure 36: Share of 6-month SPEI classification in West Kalimantan, 1981-2010: The solid line indicates the average monthly precipitation, and the dashed line indicates the average monthly temperature.

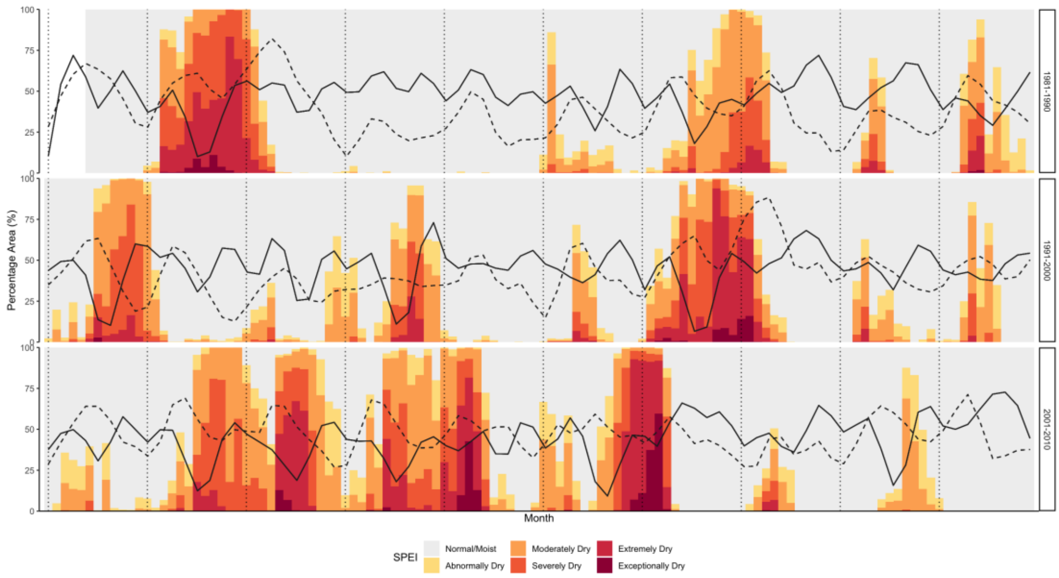
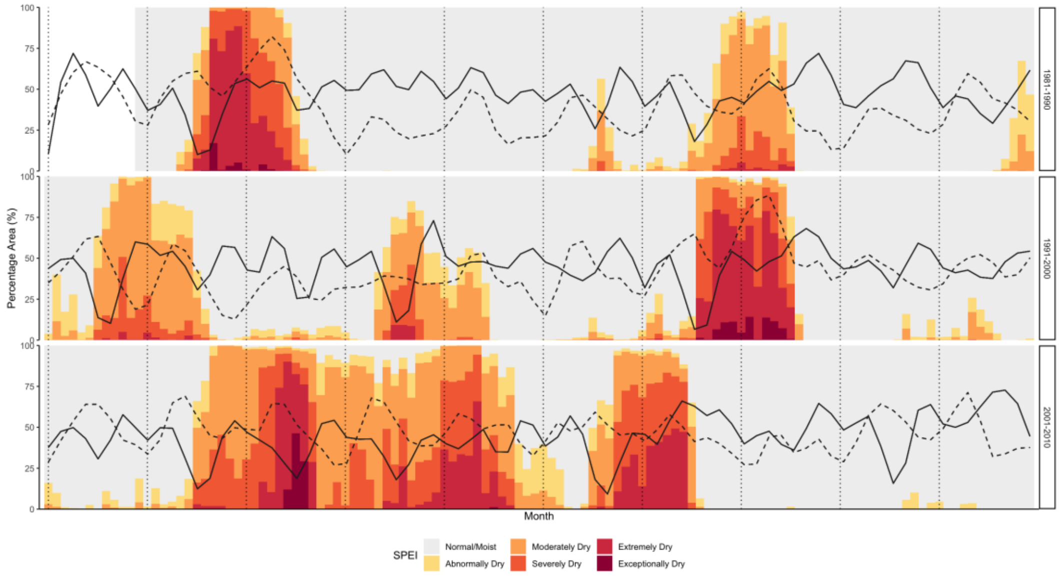


Figure 37: Share of 12-month SPEI classification in West Kalimantan, 1981-2010. The solid line indicates the average monthly precipitation, and the dashed line indicates the average monthly temperature.



5.1.2.2. The Self-Calibrated Palmer Drought Severity Index (scPDSI)

The scPDS is a drought assessment tool that provides a standardized measure of drought conditions based on the balance between moisture supply and demand. It is an improvement over the traditional Palmer Drought Severity Index (PDSI) as it addresses some of its limitations. The scPDSI considers not only precipitation but also temperature and potential evapotranspiration, allowing for a more comprehensive evaluation of drought.

Unlike the PDSI, which requires manual calibration, based on local climate characteristics, the scPDSI is self-calibrating, adjusting its parameters based on the specific climate conditions of the analyzed region. This eliminates the need for manual adjustments and makes the scPDSI more suitable for assessing drought across different locations and climatic regimes. Like the SPEI, in this analysis, scPDSI values are summarized into categories (Table 3) and aggregated across the entire region using a grid-based approach.

Table 3. Classification of the scPDSI Index

CATEGORY	THRESHOLD
Extremely Drought	-4.0 and below
Severe Drought	-4.0 to -3.0
Moderate Drought	-3.0 to -2.0
Mild Drought	-2.0 to -1.0
Incipient Dry Spell	-1.0 to -0.5
Near Normal	-0.50 to +0.50
Incipient Wet Spell	+0.5 to +1.0
Slightly Wet	+1.0 to +2.0
Moderate Wet	+2.0 to +3.0
Very Wet	+3.0 to +4.0
Extremely Wet	+4.0 and above

Figure 38: Share of scPDSI classification in West Kalimantan, 1981-2010. The solid line indicates the average monthly precipitation, and the dashed line indicates the average monthly temperature.

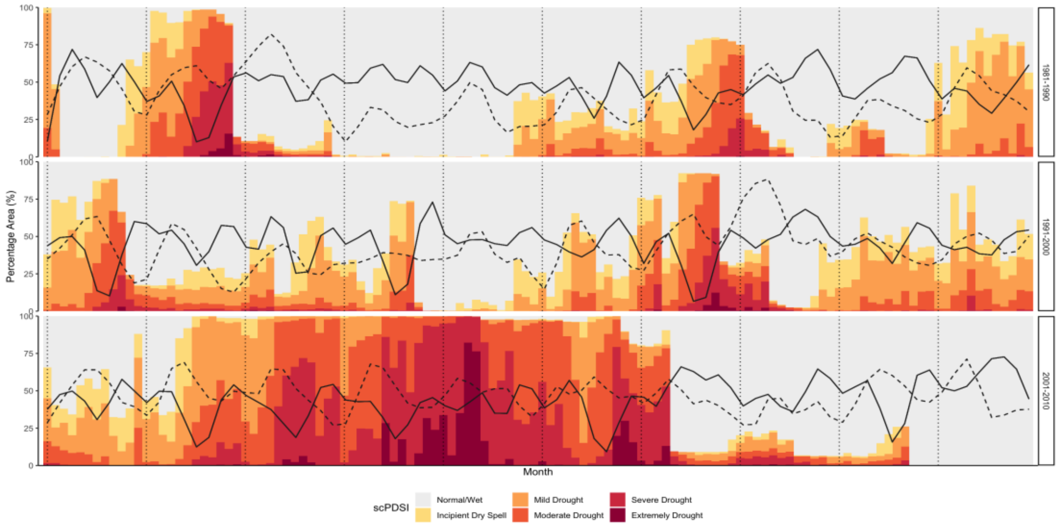


Figure 39 shows the scPDSI at West Kalimantan from 1981 to 2010. Like for SPEI, the relationship between standardized average monthly precipitation and standard average monthly temperature can be observed. The results of scPDSI are generally in line with the 12-month SPEI in terms of frequency and duration.

Figure 39: Spatial distribution of scPDSI in West Kalimantan

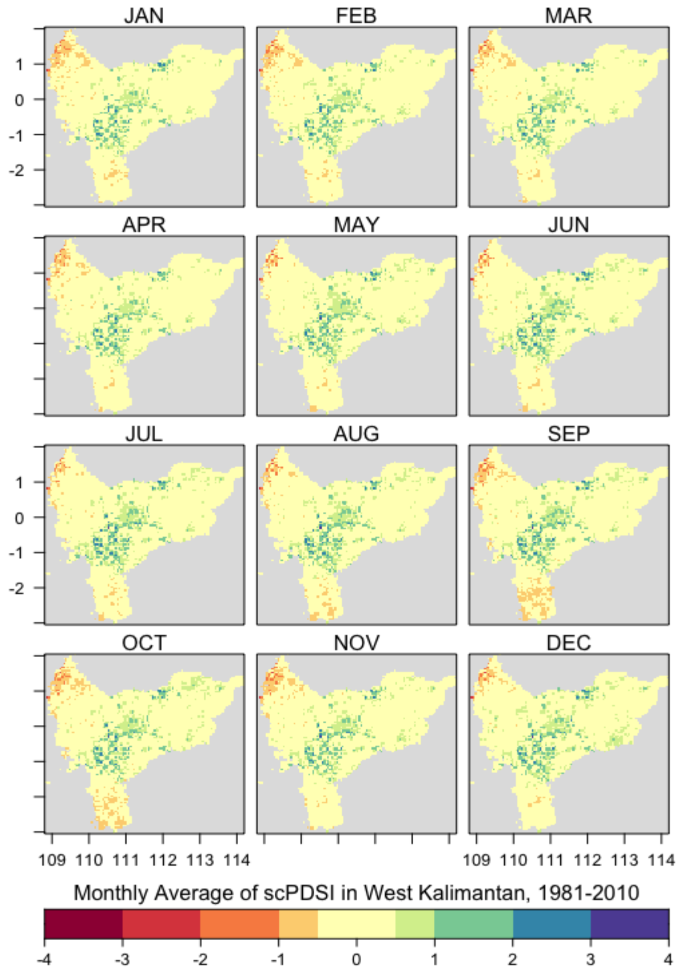


Figure 39 shows the spatial distribution of monthly average scPDSI in West Kalimantan from 1981-2010. In general, scPDSI conditions during this period tended to be normal in almost all regions and all months. However, during the dry season, the areas experiencing drought are wider than those during the wet season. Areas that often experience drought are Sambas Regency and Ketapang Regency. The areas that tend to be wet are Sekadau District and parts of Sanggau and Sintang.

5.1.3. Temperature

As a tropical climate, air temperatures in West Kalimantan are relatively high, about 28°C in the coastal area, 26°C in the inland, and 23°C in the higher mountain area.

5.1.3.1. Temperature Trend

Topography and land cover strongly influence air temperature conditions in an area. Generally, areas with high topography have lower (cooler) air temperatures than areas with low topography, such as coastal areas. Similarly, areas with land cover in the form of natural forests tend to have lower temperatures than areas with non-forest land cover.

Air temperature conditions in West Kalimantan vary greatly due to the impact of diverse topography and land cover. In general, the air temperature in West Kalimantan ranges from 18℃ to 32℃. The minimum temperature ranges from 18℃ - 23℃, and the maximum temperature ranges from 29℃ - 32℃ with the average ranging from 24℃ to 28℃. Spatially, the eastern part of West Kalimantan has the lowest temperature compared to the western and southern parts of West Kalimantan (Figure 40). As stated above, one element that most affects this condition is the difference in land cover, where the eastern part is still dominated by forest land around the Danau Sentarum National Park.

Figure 40: Spatial distribution of average annual min, mean, and max temperature in West Kalimantan from 1981 to 2015

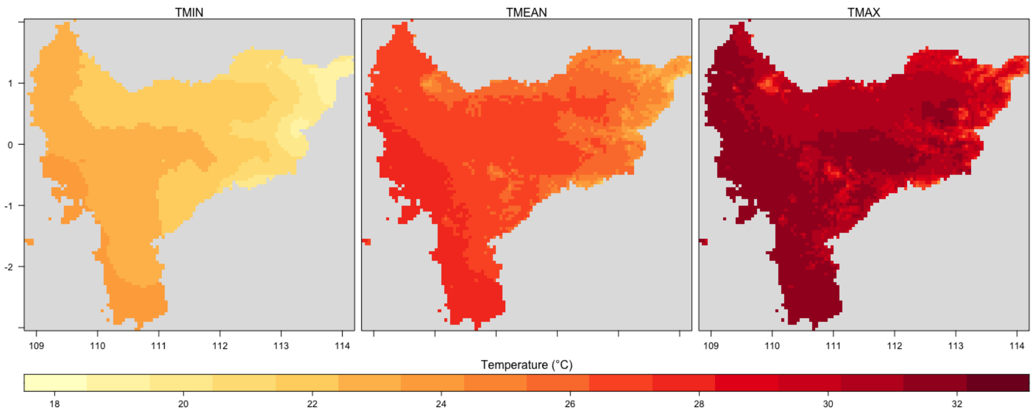
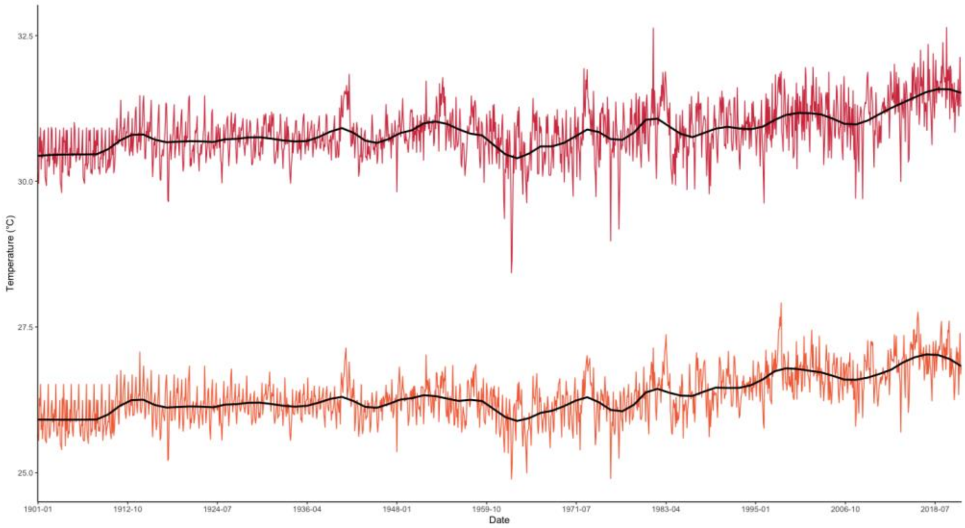


Figure 41: Line chart of monthly average temperature in West Kalimantan, 1901-2021. The orange line indicates the mean temperature and the red line indicates the maximum temperature



The IPCC report shows that in the last 100 years, globally, there has been an increase in air temperature by 0.85℃ (IPCC 2013). Similarly, air temperature condition in West Kalimantan is experiencing an increasing trend. Figure 41 shows the increasing temperature trend from 1901-2021, especially during the 1970s. Spatially, in the 1981-2015 time period, all regions in West Kalimantan experienced an increasing trend of up to 0.6℃. The highest temperature increase trend occurs in the minimum temperature, while the maximum temperature has a lower increasing trend. This condition will affect the diurnal variation between minimum and maximum air temperature, which becomes narrower. One of the impacts is that the temperature comfort level for humans is disrupted. This condition will also allegedly affect the life cycle of pests and diseases in plantations and agricultural crops.

Figure 42: Spatial distribution of annual min, mean, and max temperature trend in West Kalimantan, 1981-2015

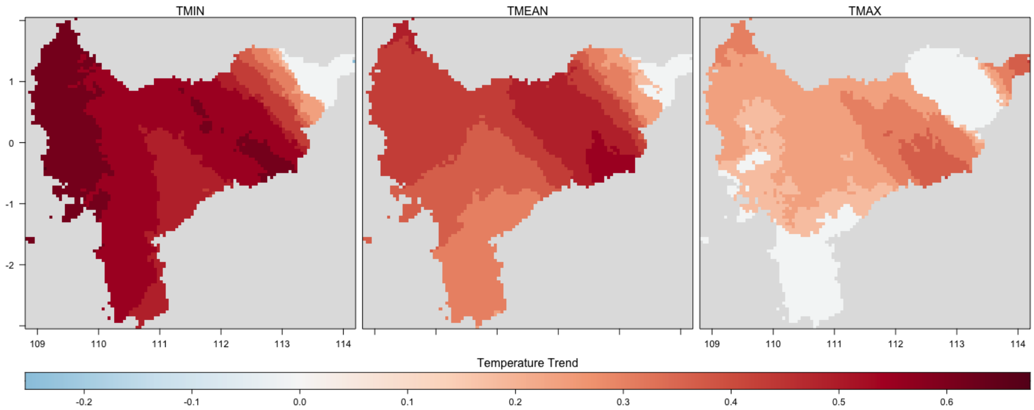
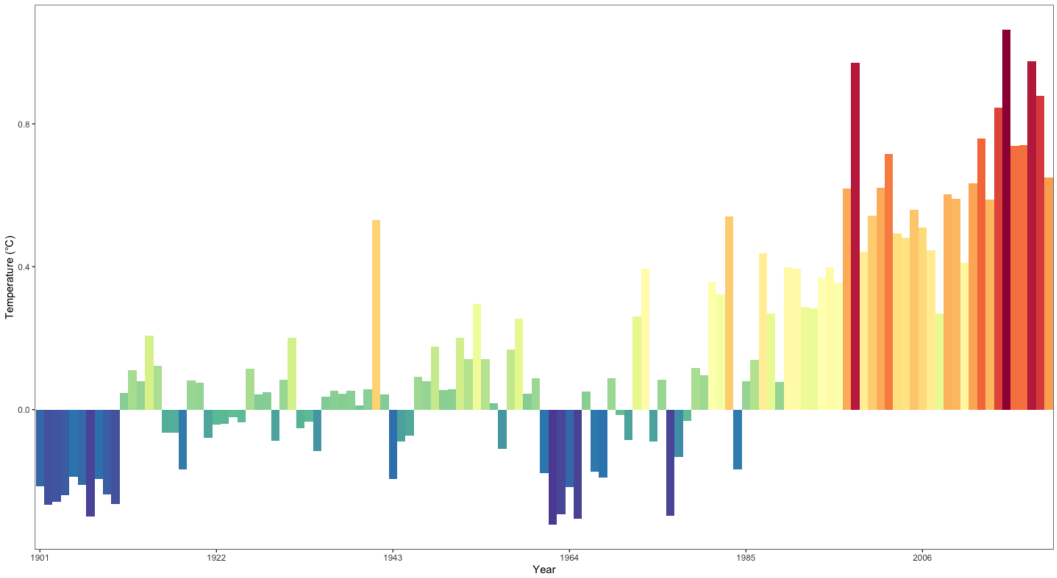
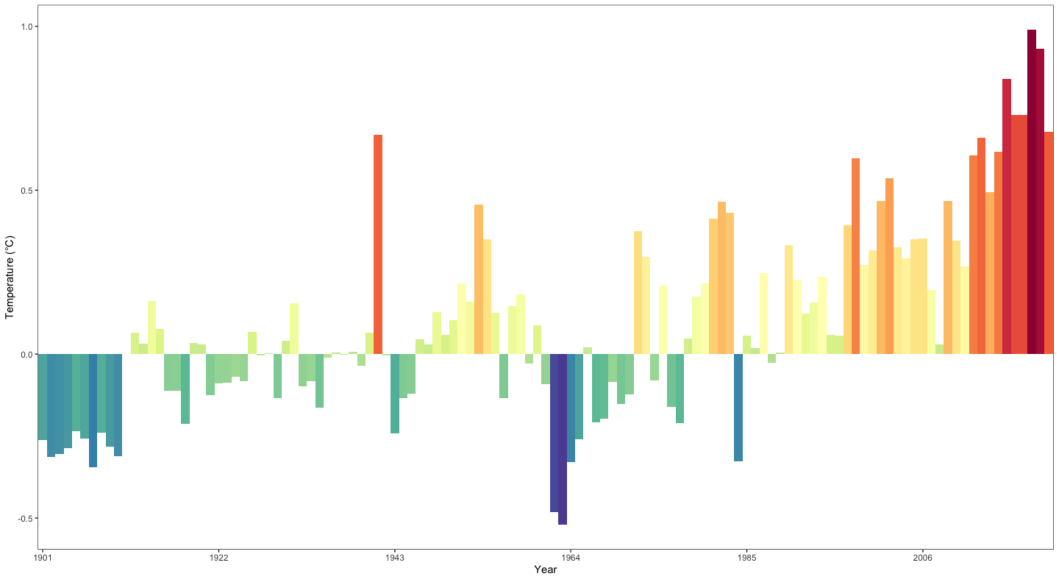


Figure 43 shows that in the last 40 years, the temperature anomaly in West Kalimantan has consistently been positive. This indicates that the temperature increase has occurred massively and will continue to occur in the next few decades. This prediction is supported by the hottest temperature records that have occurred in recent years. The most recent record, July 3rd, 2023, was the hottest day in 125 years (National Centers for Environmental Prediction Data 2023/https://www.bloomberg.com/news/articles/2023-07-04/world-records-hottest-dayever-on-july-3). Extreme temperature events have also occurred frequently in recent years and have caused fatalities.

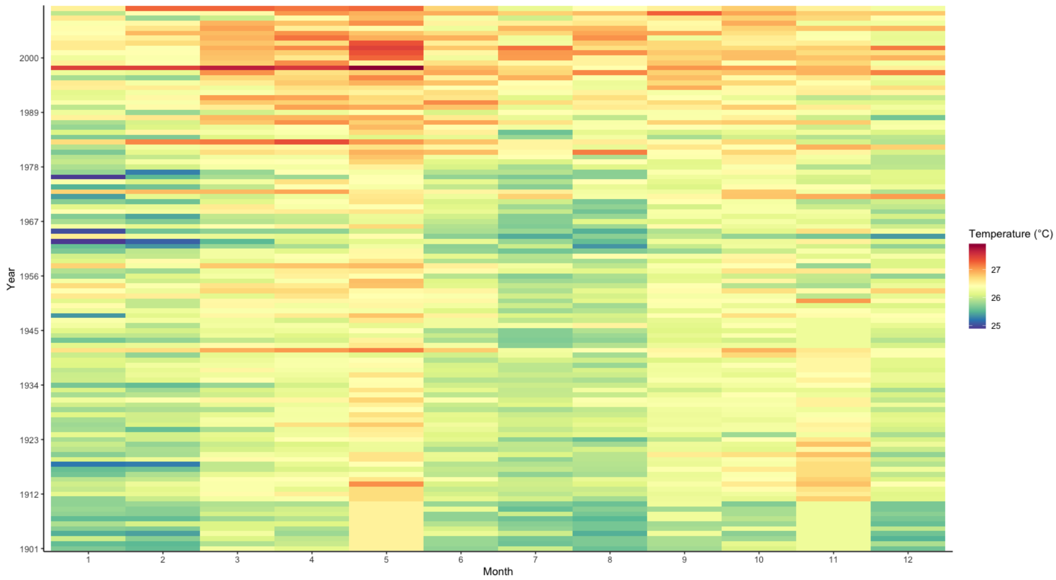
Figure 43: Anomaly trend of annual mean (above) and max (below) temperature (relative to 1951-1980 average) in West Kalimantan, 1901-2021





The temporal distribution of temperature conditions in West Kalimantan can be seen in **Error! Reference source not found.** In general, May is the hottest month in West Kalimantan. May is usually the peak of heat in West Kalimantan. The average temperature peak in West Kalimantan reached 27℃ (Figure 44 top) while the maximum temperature peak reached 32℃ (Figure 44 bottom). The monthly temperature increase trend can be seen in **Error! Reference source not found.** The temperature increase trend tends to be the same as the annual temperature pattern, where the 1970s period was the beginning of a massive temperature increase, compared to the previous periods.

Figure 44: Heatmap of monthly average mean (above) and max (below) temperature trend in West Kalimantan, 1901-2021



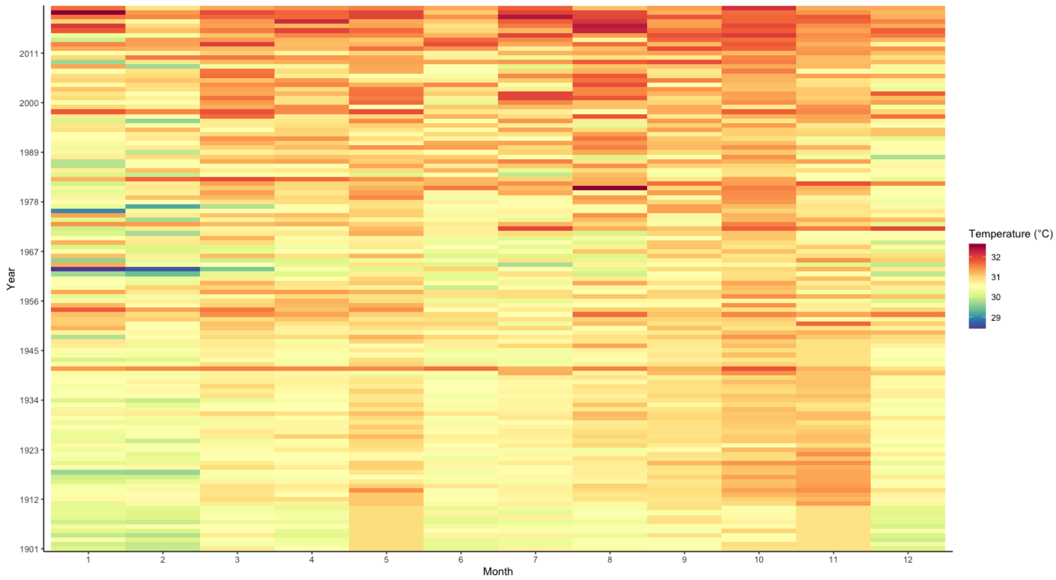
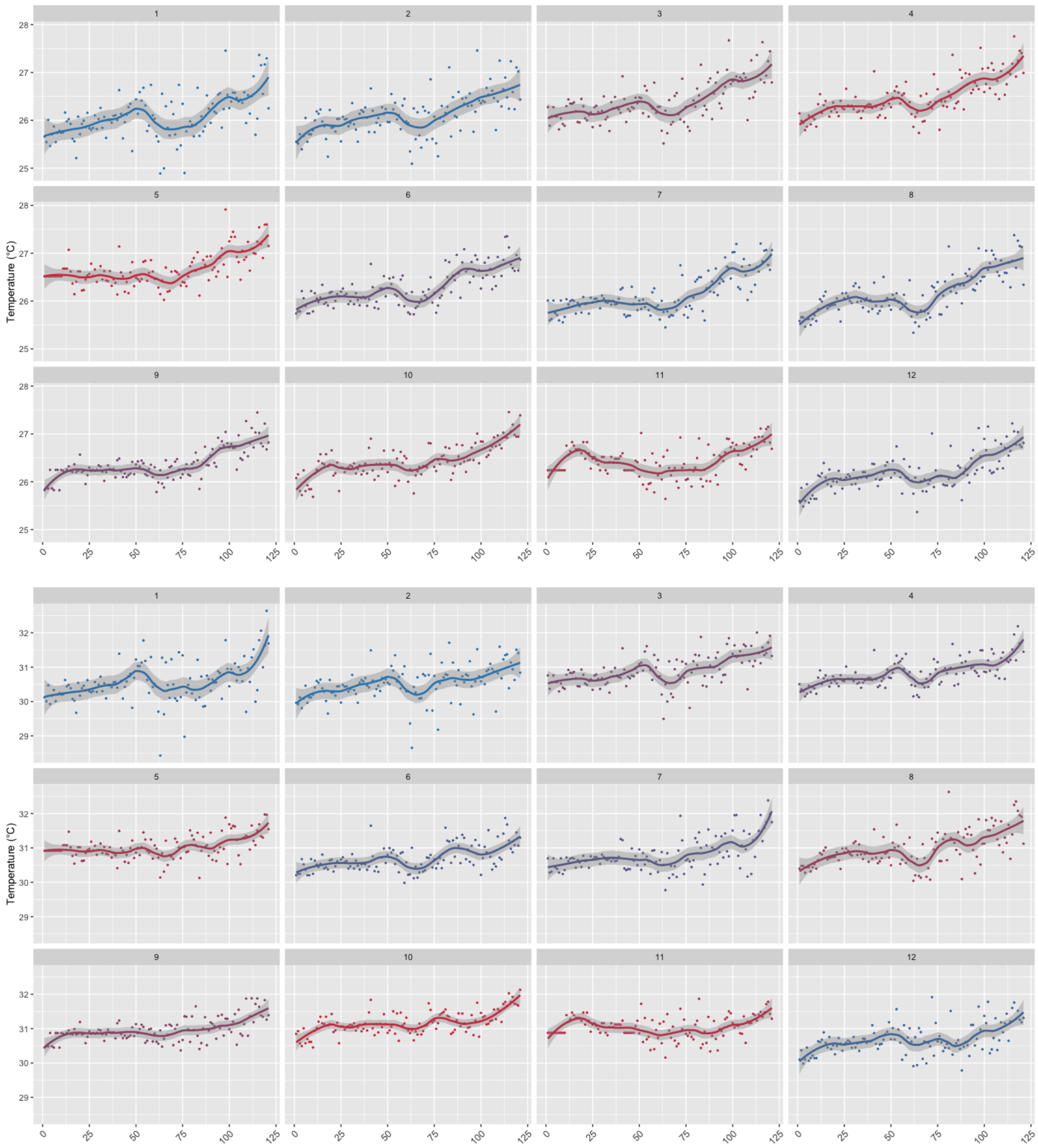


Figure 45: Monthly average mean (above) and max (below) temperature trend in West Kalimantan, 1901-2021[3]



5.1.3.2. Extreme Temperature

Extreme Temperature is a condition where the temperature exceeds (or is lower) than the usual conditions. Humans perceive extreme temperatures as uncomfortable condition that affects human activities. Similarly, extreme temperatures also affect the forestry and agriculture sectors. These conditions need to be anticipated in the future. Therefore, database information on extreme temperature conditions is required.

Figure 46 shows the spatial distribution of extreme hot maximum temperature conditions at the boundary values of percentile 90, percentile 95, and percentile 99. With a percentile of 90, extreme maximum temperatures occur during 8-9 days annually. The maximum extreme heat

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3 Overall, the trend shown in the graph indicates that both average maximum and minimum temperatures tend to increase. This can be observed from the year-to-year changes in the average temperature

temperature spreads evenly throughout West Kalimantan. At percentile 95, the average number of days with extreme hot maximum temperatures is 4-5 days, while at percentile 99, there are 2-3 days with extreme hot maximum temperatures in a year. Figure 46 is the opposite condition of Figure 47, which is the spatial distribution of extreme cold maximum temperature conditions in West Kalimantan with percentile 10, percentile 5, and percentile 1. In these conditions, in general, the West Kalimantan region experienced extreme cold maximum temperatures for ten days (p10), five days (p5), and one day (p1).

Figure 46: Spatial distribution of 90th, 95th, and 99th percentile of TXnP (very warm days percent) in West Kalimantan, 1981-2010

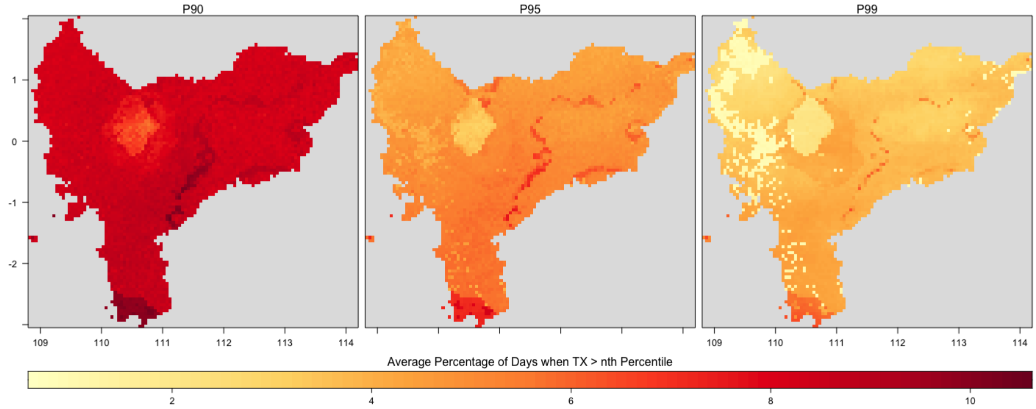


Figure 47: Spatial distribution of 10th, 5th, and 1st percentile of TXnP (very cold days percent) in West Kalimantan, 1981-2010

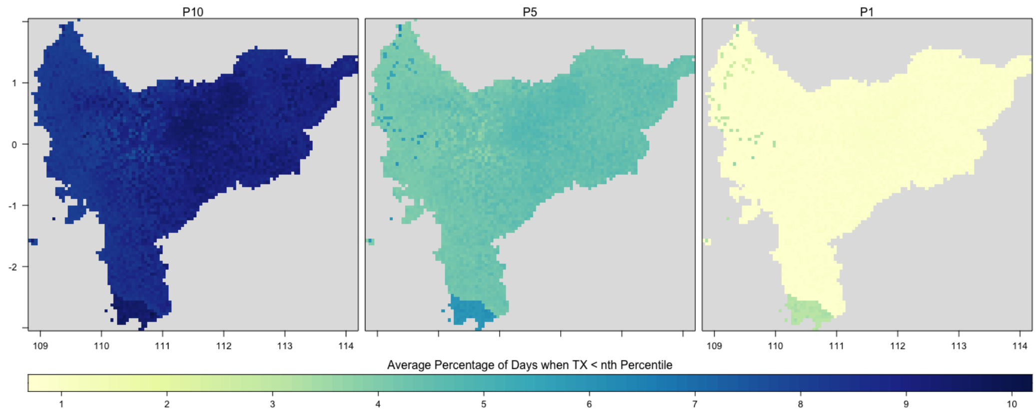


Figure 48 shows the spatial distribution of extreme hot minimum temperature conditions at the 90^{th} percentile, 95^{th} percentile, and 99^{th} percentile value limits. With a percentile of 90, there are generally 9-10 days where there is an extremely hot minimum temperature, and the extreme hot minimum temperature spreads evenly across West Kalimantan. At percentile 95, there are 5-6 days that experience extreme hot minimum temperatures, while at percentile 99, there are 2-4 days with extreme hot minimum temperatures. Figure 48 is the opposite condition of **Error! Reference source not found.**, which is the spatial distribution of extreme cold minimum temperature conditions in West Kalimantan with percentile 10, percentile 5, and percentile 1. In these conditions the West Kalimantan region generally experienced extreme cold minimum temperatures for 10 days (p10), 5 days (p5), and 2 days (p1).

Figure 48: Spatial distribution of 90th, 95th, and 99th percentile of TNnP (warm nights percent) in West Kalimantan, 1981-2010

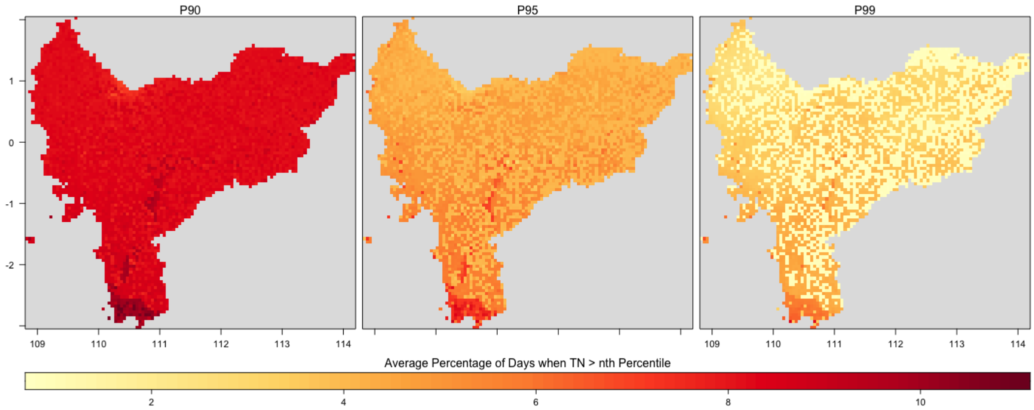
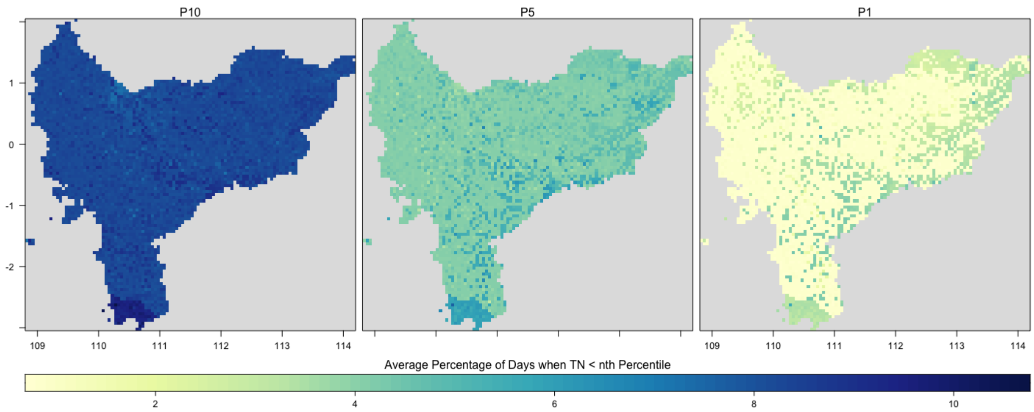
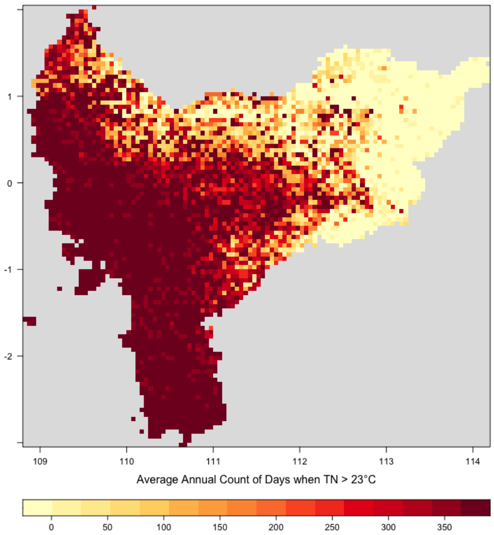


Figure 49: Spatial distribution of 10th, 5th, and 1st percentile of TNnP (cold nights percent) in West Kalimantan, 1981-2010



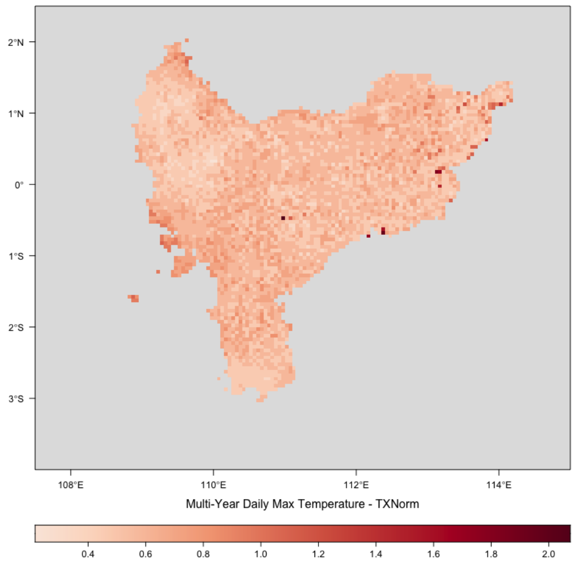
The other extreme temperature index is the number of tropical nights (TR). This index indicates the number of days in a year with minimum temperatures exceeding 23℃. The analysis shows that most of the western and southern parts of West Kalimantan experience tropical nights almost all year round.; As for the eastern part of West Kalimantan, which is still dominated by tropical rainforests, the number of tropical nights is lower than 50 days. This demonstrates that this region still has cooler air than other parts.

Figure 50: Spatial distribution of TR (number of tropical nights) in West Kalimantan, 1981-2010



Heatwave index is defined as a temperature anomaly of more than 5°C. The results of this analysis show that in West Kalimantan there are no areas that experience heatwaves. This is because the maximum temperature anomaly in the 1981-2010 period is generally still below 2°C (Figure 50).

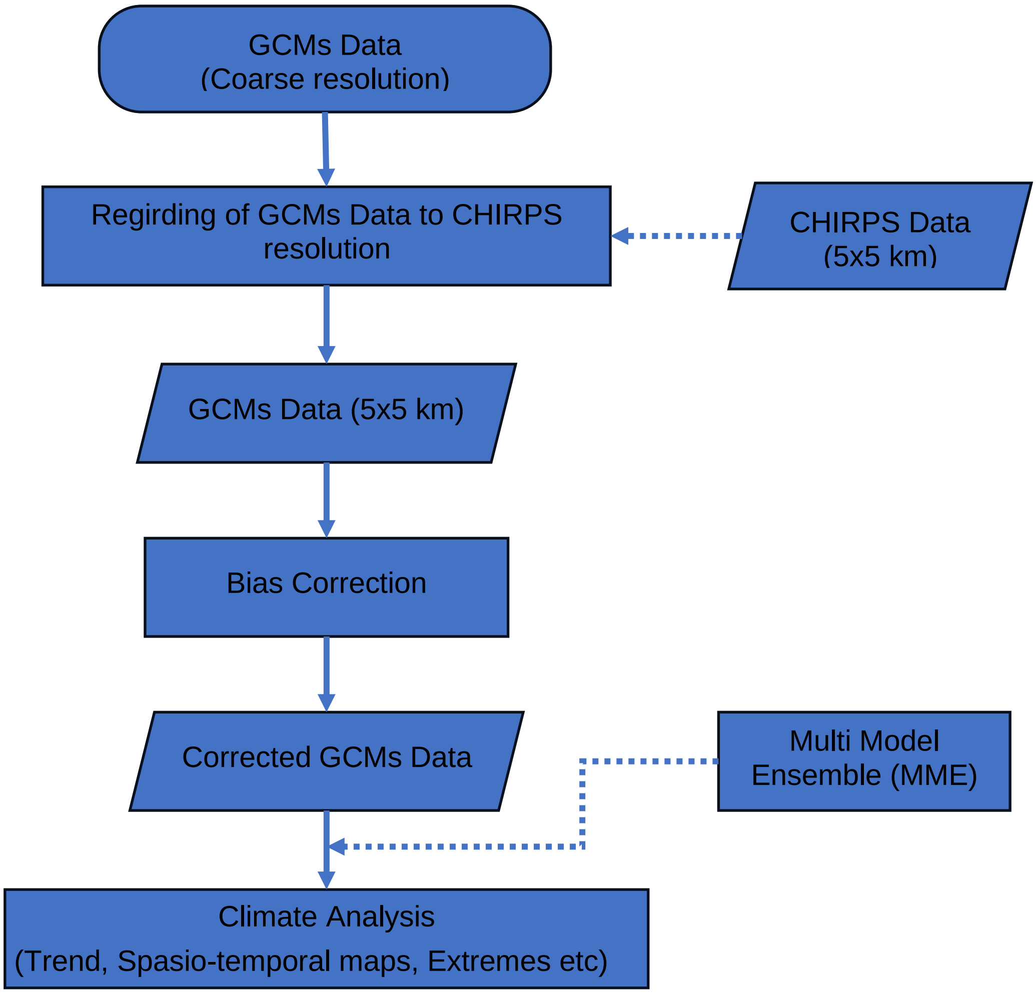
Figure 51: Spatial distribution of max temperature anomaly in West Kalimantan, 1981-2010



5.2. Future Climate of West Kalimantan

The climate projection analysis was conducted using Global Climate Models (GCMs). There are nine climate models are used in this study. The models include the latest climate scenarios (Shared Socio-economic Pathways/SSPs) incorporated in the Coupled Model Intercomparison Project Phase 6 (CMIP6). The climate data is available on the website https://esgf-node.llnl.gov/search/cmip6/. The application of Global Climate Models for local climate study has limitations. One of these has to do with coarse spatial resolution. Furthermore, global climate data outputs have biases that must be adjusted (Mearns et al., 2013; Sillmann et al., 2013). As a result, before they can be used for climate projection analysis in West Kalimantan, GCM data must first be processed.

Figure 52: Flowchart for climate analysis from GCM Data



This study contains multiple steps, ranging from grid modification to higher resolution to the ensemble model process (Figure 52). The global climate model has a coarse resolution, so it is unsuitable for a localized climate study, such as for West Kalimantan. The international climate model's grid is gridded 5x5 km to match the CHIRPS data grid. After GCMS data had been increased in spatial resolution, the next step was to perform bias correction on GCM data using CHIRPS as a reference. The statistical bias correction method (Piani, 2010) was used in this work, applying the procedure carried out by Jadmiko et al. (2017a). The next stage was to use the median value to perform a multi-model ensemble. The third stage was to undertake climate analysis, which includes climate trends, climate change, and a extreme climate analysis.

Table 4: The climate models that were used in this analysis.

NO	CLIMATE MODELS	CLIMATE VARIABLE[1]	LAT/LON GRID (DEGREE)	TEMPORAL RESOLUTION	CLIMATE SCENARIOS[2]	PERIOD	SOURCES
1	ACCESS-ESM1-5 (Australia)	Pr, T, Tmn, Tmx	1.2 x 1.8	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Ziehn et al. 2009
2	BCC-CSM2-MR (China)	Pr, T, Tmn, Tmx	1.1 x 1.1	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Wu et al., 2018
3	CRNM-CM6-1 (France)	Pr, T, Tmn, Tmx	1.4 x 1.4	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Voldoire 2019
4	CanESM5 (Canada)	Pr, T, Tmn, Tmx	2.8 x 2.8	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Sigmond et al. 2019
5	HadGEM3-GC31-LL (UK)	Pr, T, Tmn, Tmx	1.3 x 1.9	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Webb 2020
6	IPSL-CM6A-LR (France)	Pr, T, Tmn, Tmx	1.3 x 2.5	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Boucher et al. 2019
7	KACE-1-0-G (South Korea)	Pr, T, Tmn, Tmx	1.25 x 1.35	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Byun et al. 2019
8	MIROC6 (Japan)	Pr, T, Tmn, Tmx	1.4 x 1.4	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Tatebe and Watanabe 2018
9	MPI-ESM1-2-LR (Germany)	Pr, T, Tmn, Tmx	1.9 x 1.9	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Fiedler et al. 2019
10	NESM3 (China)	Pr, T, Tmn, Tmx	1.9 x 1.9	Daily	Historis, SSP126, SSP245, SSP585	1950-2014 & 2015-2100	Cao 2019
11	NorESM2-LM (Norway)	Pr, T, Tmn, Tmx	1.9 x 2.5	Daily	Historis, SSP126, SSP245, SSP370, SSP585	1950-2014 & 2015-2100	Graff et al. 2019

Note:

1 The climate variables used in this study are Pr (precipitation), T (mean temperature), Tmn (minimum temperature), Tmx (maximum temperature)

2 The climate scenario used in this study is the SSP scenario. SSP is a climate scenario created to determine possible global social and economic changes that could influence greenhouse gas emissions and climate change. In contrast to the RCP scenario, which determines the path for GHG emissions and global warming that can occur until the end of the 21st century, the SSP scenario determines whether the emission reduction target can be achieved. Four SSP scenarios are used in this study, namely SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5.

5.2.1. Rainfall

5.2.1.1. Projection of Rainfall

Annual rainfall is expected to rise across almost the whole of West Kalimantan. The nine climate models used in this study are consistent that yearly rainfall will increase in the future. Only specific locations in the Ketapang and Sambas districts are expected to have a decrease in annual rainfall. The annual rainfall in Kapuas Hulu District will increase by 15% from the baseline condition. Rainfall will decrease by 6% in Ketapang District and 3% in Sambas District, compared to the baseline condition (Figure 53).

An increase in rainfall tends to occur during the peak of the rainy season (MAM), and a decrease in rainfall occurs during the dry season (JJA). In the MAM period, more than 70% of the models conclude that rainfall will increase. The opposite condition occurs in the JJA period, where more than 70% of the models conclude that rainfall will decrease. The increase in rainfall in the MAM period will reach 15%, while the decrease in rainfall in the JJA period will reach 20% from the baseline conditions.

Figure 53: Model agreement for projection of annual rainfall (left) and change of annual rainfall (right)

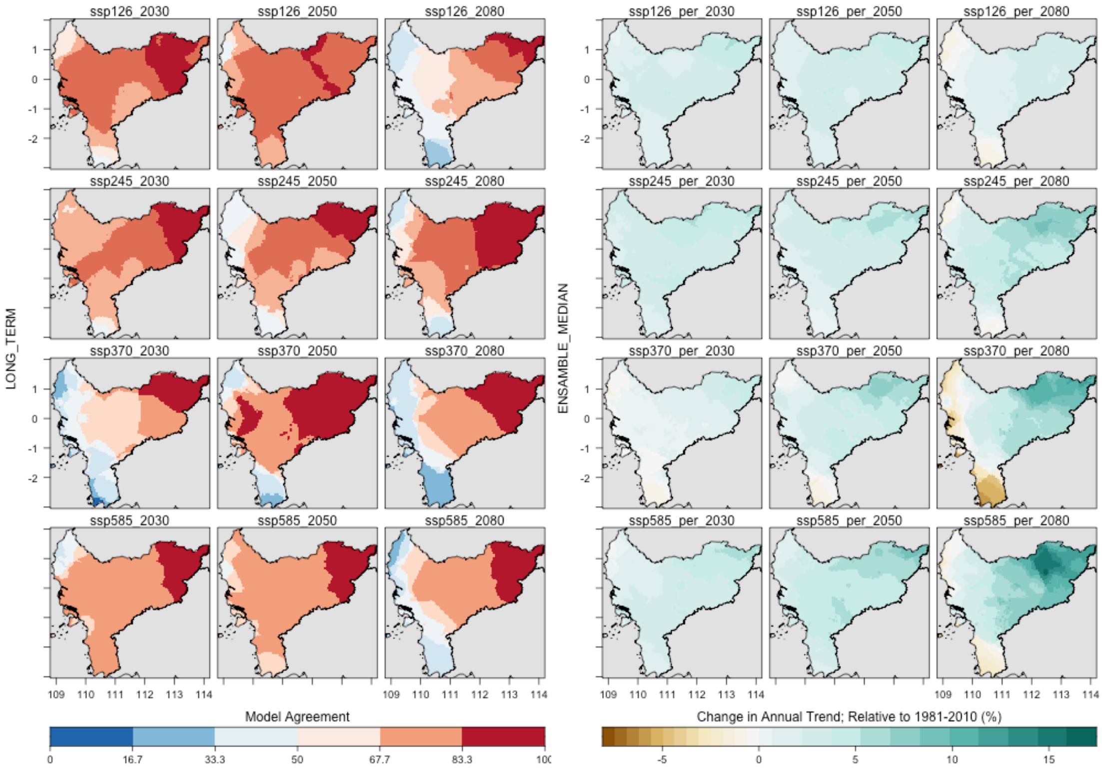


Figure 54: Model agreement for projection of DJF rainfall (left) and change of DJF rainfall (right)

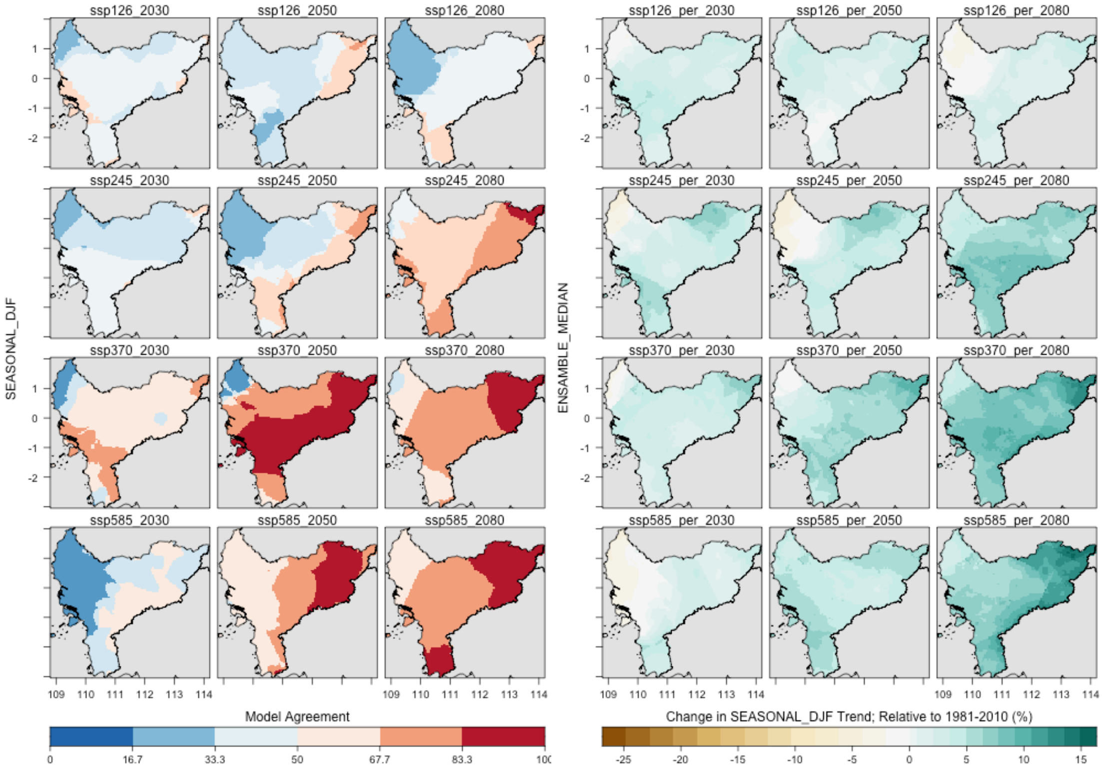


Figure 55: Model agreement for projection of MAM rainfall (left) and change of MAM rainfall (right)

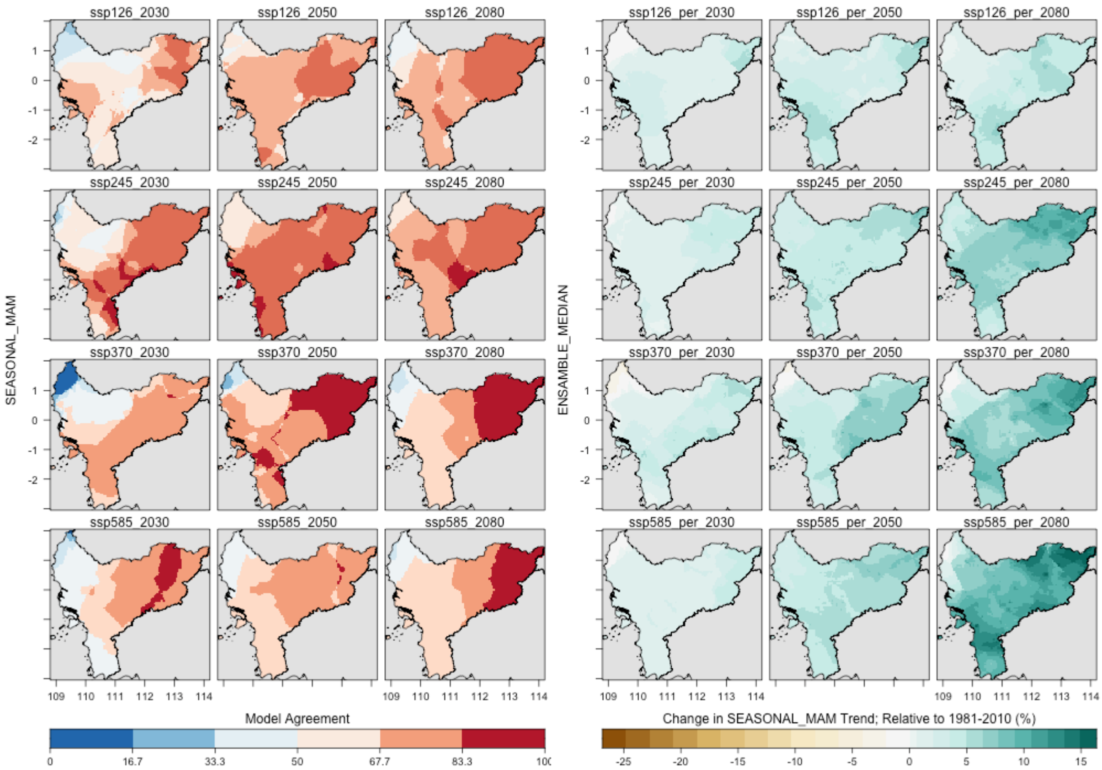


Figure 56: Model agreement for projection of JJA rainfall (left) and change of JJA rainfall (right)

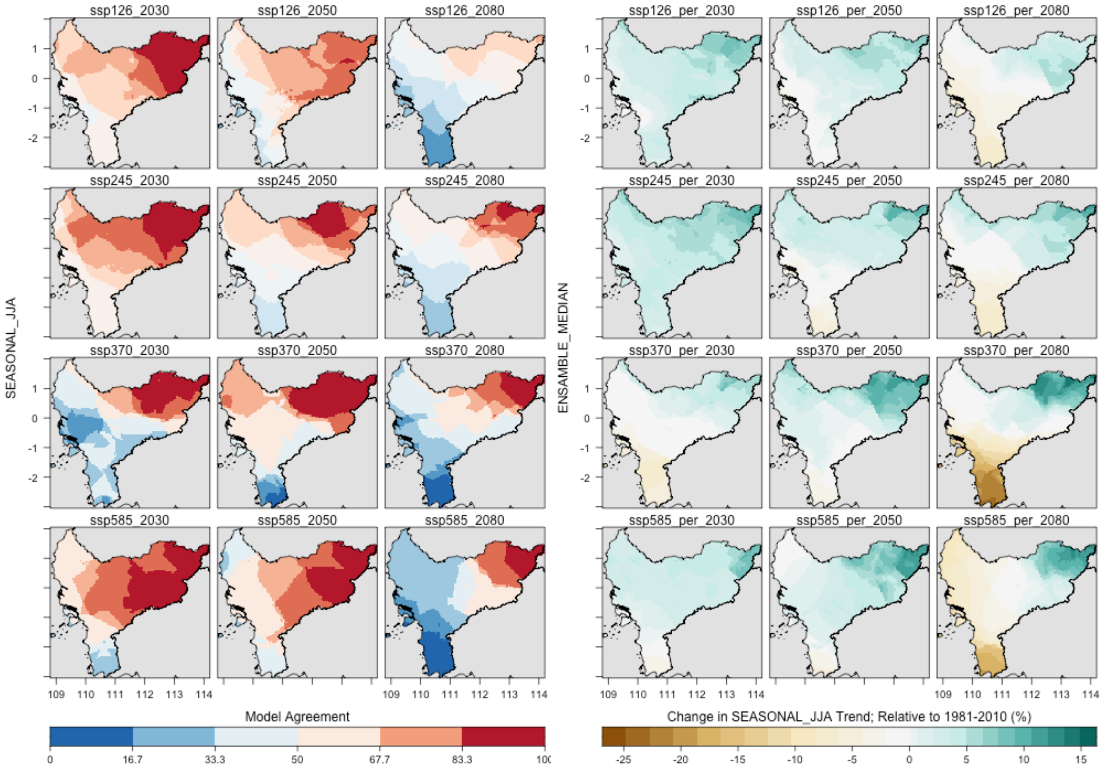
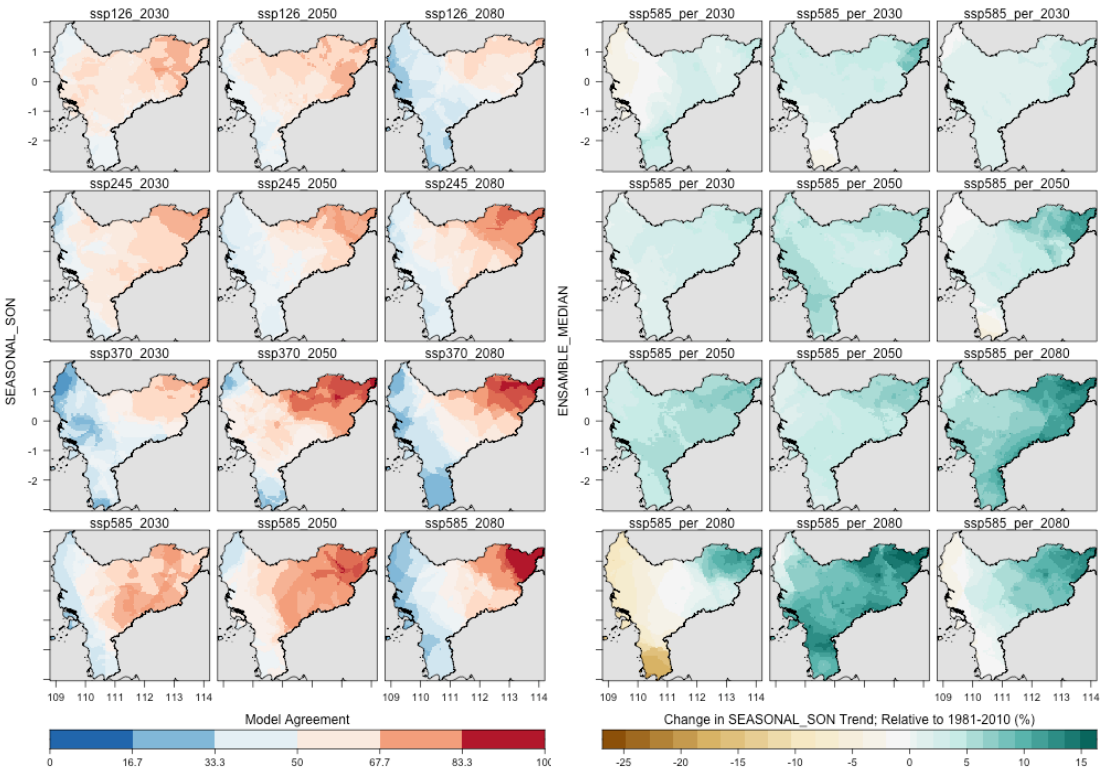


Figure 57: Model agreement for projection of SON rainfall (left) and change of SON rainfall (right)



The analysis of rainfall change trends in this study is divided into 4 regional clusters, as shown in **Error! Reference source not found.**. The selection of these cluster areas is based on the rainfall characteristics of each cluster. Cluster 2 and Cluster 3 are the areas with the highest increase in annual rainfall, while Cluster 4 tends to remain generally constant. The Cluster 1 region experiences a downward trend in annual rainfall in the future. The trend of seasonal rainfall is shown in Figures 60 to.

Figure 58: Clusters in West Kalimantan for Trend Analysis in Projected Climate

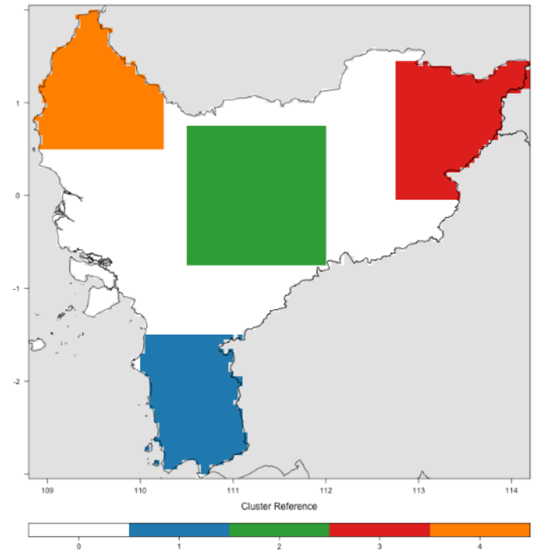


Figure 59: Trend of annual rainfall in West Kalimantan for 4 Clusters

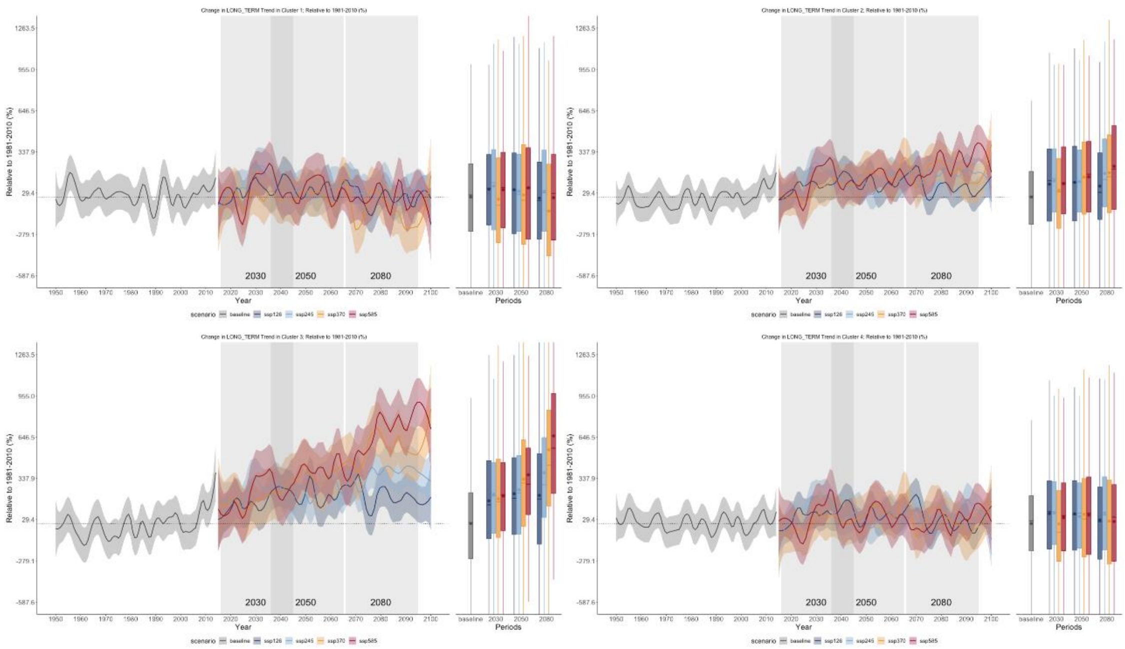


Figure 60: Trend of DJF rainfall in West Kalimantan for 4 Clusters

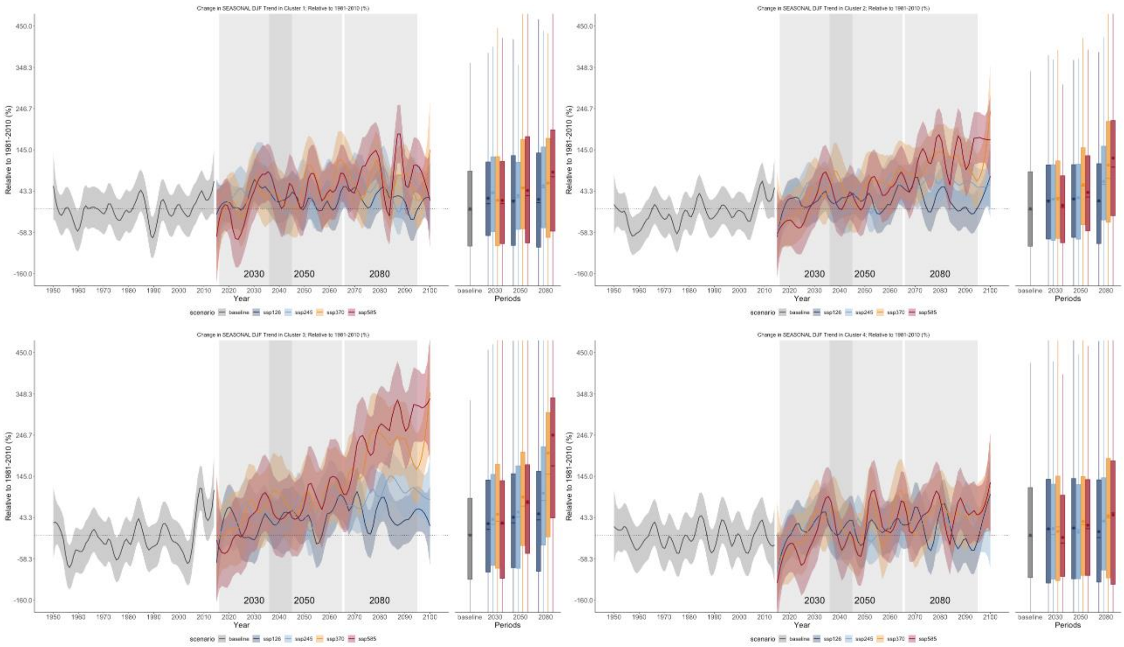


Figure 61: Trend of MAM rainfall in West Kalimantan for 4 Clusters

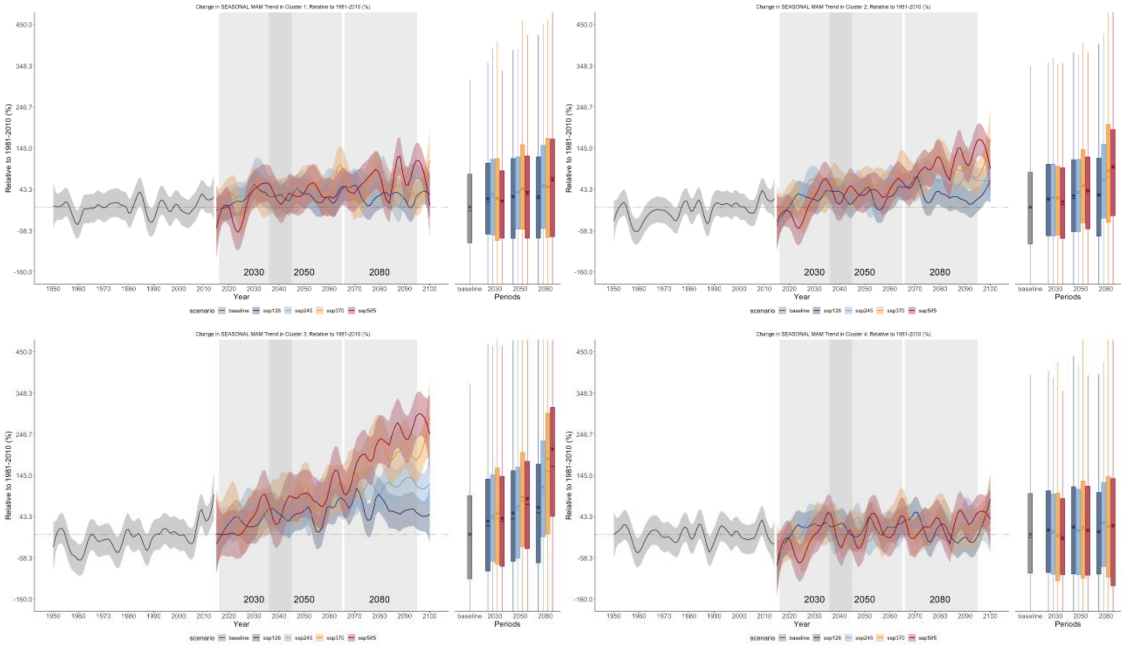


Figure 62: Trend of JJA rainfall in West Kalimantan for 4 Clusters

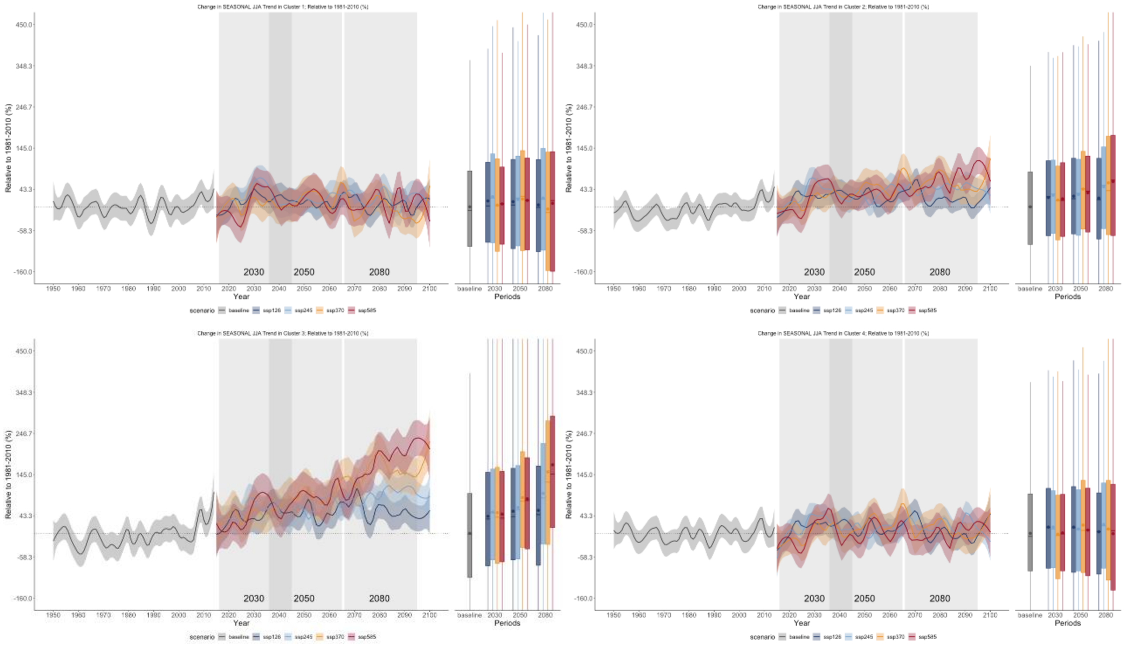
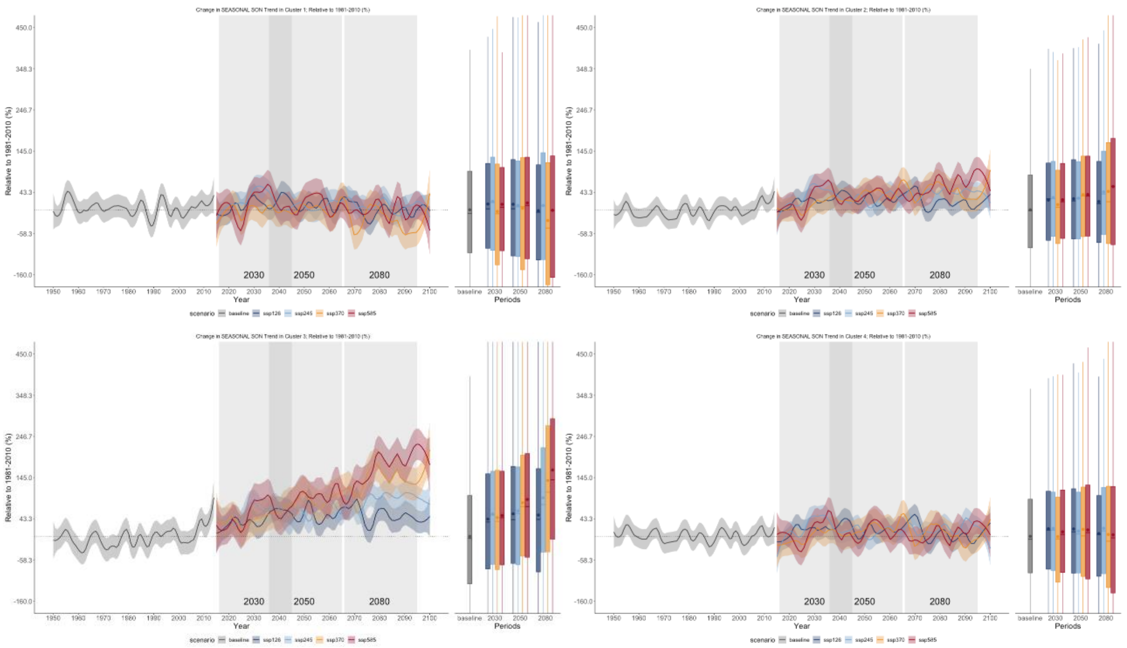


Figure 63: Trend of SON rainfall in West Kalimantan for 4 Clusters



5.2.1.2. Projection of Onset and Cessation

The benefits of onset information for the agriculture and forestry sectors have been described in the historical climate study. In this projection study, changes in onset conditions in the future are analysed. Two onsets are analysed: the rainy season onset and the dry season onset.

The analytical results reveal that the dry season onset will be delayed by roughly 20% in most regions of West Kalimantan. In some regions, the dry season onset in West Kalimantan would be delayed by up to 60% compared to the historical condition. Furthermore, some regions in the Kapuas Hulu District show that the dry season would begin roughly 20% earlier than usual.

This condition is most common in the 2030s. Dry season cessation advances and retreats in lockstep with the onset of the dry season. In general, the end of the dry season in West Kalimantan will result in a 25% retreat from current conditions (Figure 64). This causes the duration of the dry season to be longer. The analysis shows that the duration of the dry season will increase by up to 50% from the current condition (Figure 65).

Future wet season onset conditions will also change. The wet season onset is expected to be delayed by roughly 20% compared to the historical condition. This pattern occurs almost in all areas of West Kalimantan, except in Kubu Raya district which will advance about 12% from historical conditions. The wet season cessation condition is expected to decline by roughly 20% from historical levels. Kapuas Hulu District, which is roughly 15% of historical conditions, will advance the wet season cessation time (Figure 66). The duration of the wet season in West Kalimantan is expected to be variable. There will be locations with a longer wet season length due to an increase in wet season duration, but there will also be areas with a shorter wet season duration. Mempawah Regency, Kubu Raya, Sambas, Landak, Bengkayang, Ketapang, and Pontianak City will have a longer wet season duration. The length of the wet season is expected to be around 20% longer than it is now. The areas surrounding Sintang and Kapuas Hulu regencies are projected to have a 16% shorter wet season duration than in the past (Figure 67).

Figure 64: Projected changes of dry season onset (left) and cessation (right) in West Kalimantan

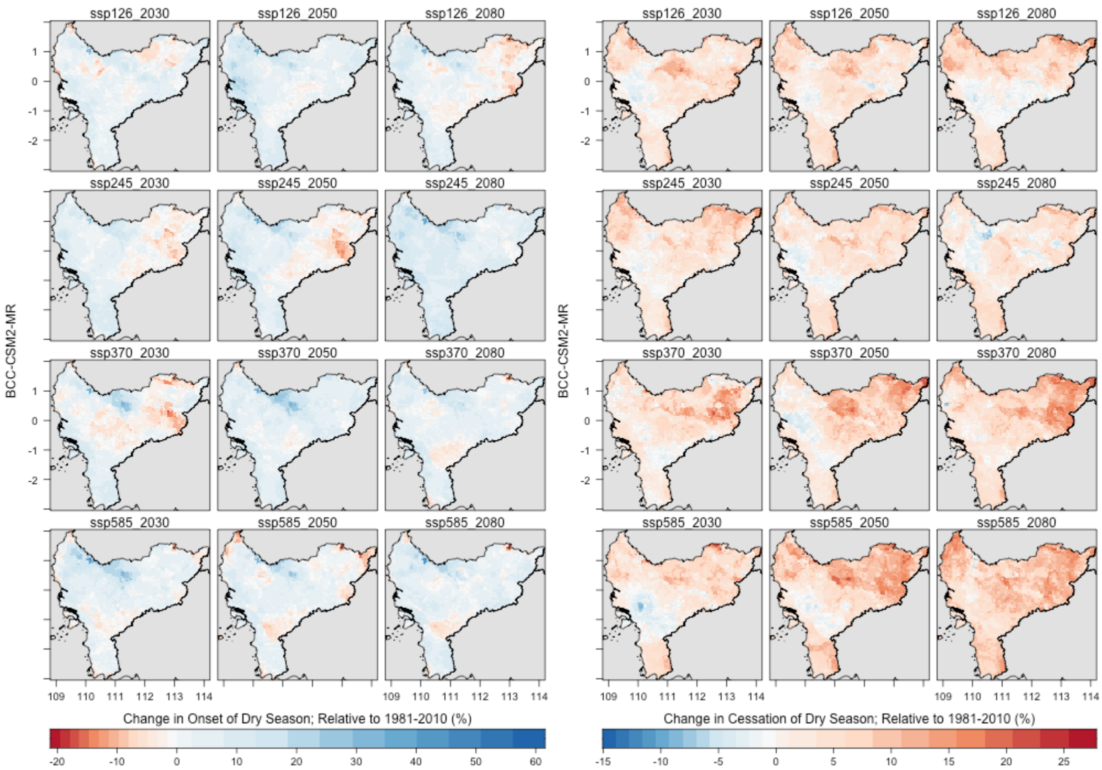


Figure 65: Projected changes of dry season duration in West Kalimantan

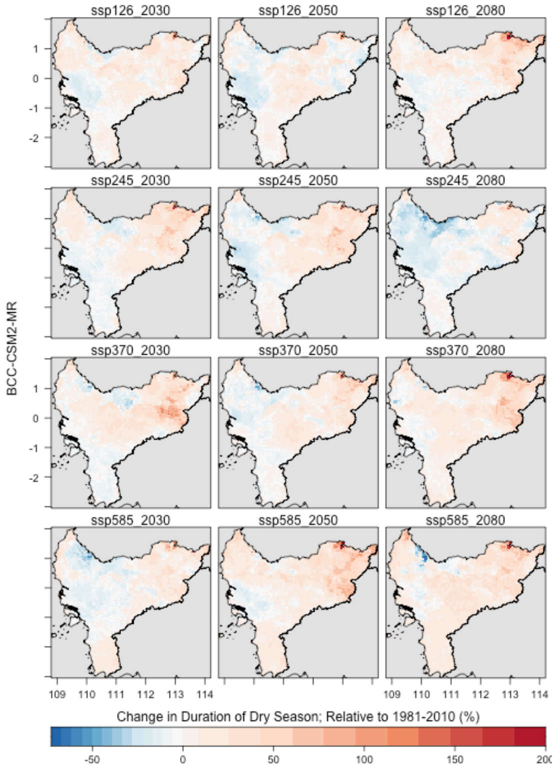


Figure 66: Projected changes of wet season onset (left) and cessation (right) in West Kalimantan

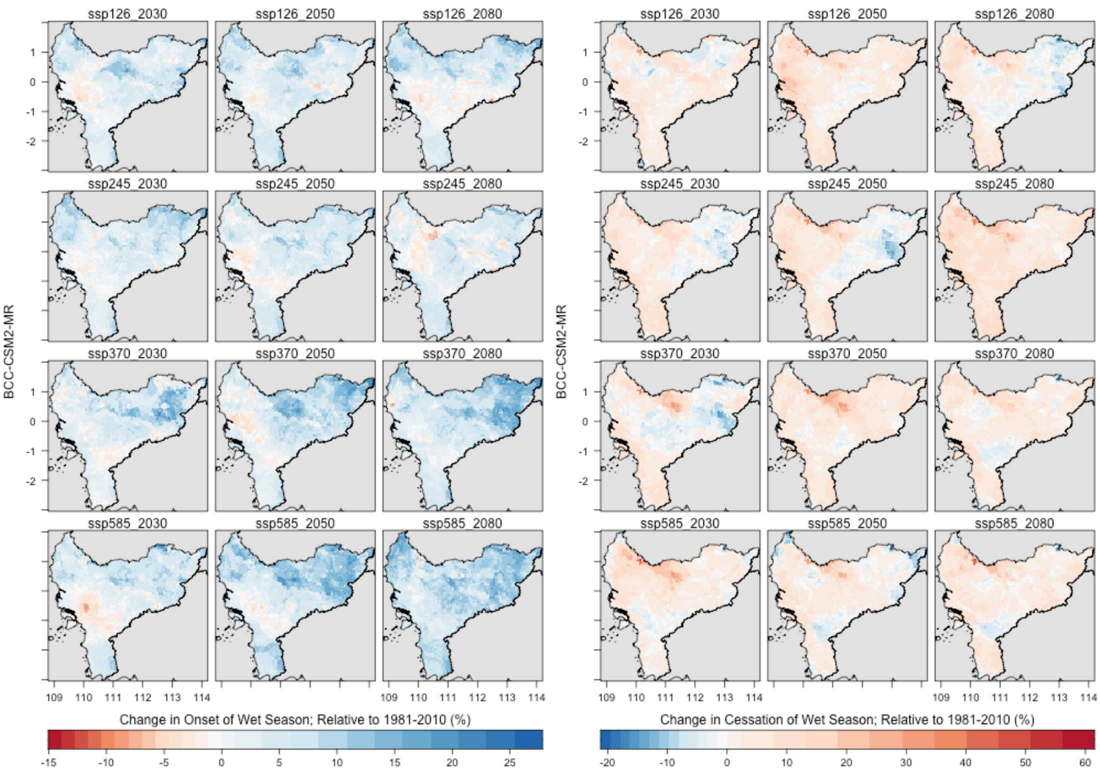
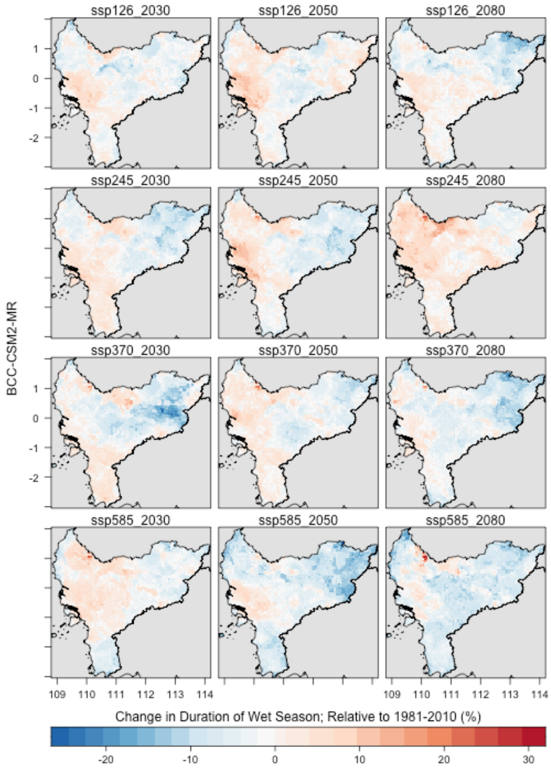


Figure 67: Projected changes of wet season duration in West Kalimantan



5.2.1.3. Extreme Rainfall Projection

Projections of future CDD (consecutive dry days) using nine GCMs show that most of the central part of West Kalimantan is projected to experience a decrease in CDD length, such as in Kapuas Hulu, Sintang, Sanggau, and Sekadau districts. CDD length is projected to increase in the Ketapang Regency. A decrease in CDD length occurs in almost all climate scenarios and projection time periods, except for the SSP85 scenario where in the 2080s all models are concurrent that CDD is projected to increase throughout West Kalimantan (Figure 68). The decrease in CDD length is projected to reach 25% of the baseline condition. The historical climate assessment shows that currently, the length of dry days in the central part of West Kalimantan ranges from 20-30 days, in the future this is projected to become shorter. The increase in CDD length is projected to reach 60% of the baseline condition (Figure 69). Currently, the length of CDD in Ketapang District ranges from 80-100 days. An increase in CDD length in this region will increase the risk of climate disasters, such as forest fires and droughts. The study by Jadmiko et al. (2017b) shows that the future risk of forest and land fires in West Kalimantan will increase. The trend of future changes in CDD length can be seen in **Error! Reference source not found.**. The trend analysis is divided into four cluster regions as shown in **Error! Reference source not found.**. In general, cluster 1 is the region with the highest increasing trend compared to other clusters. Cluster 2 and Cluster 3 show a mixed pattern, where there is an increasing trend in the SSP585 scenario, but a decreasing trend in SSP245.

Projections of future CWD (consecutive wet days) using nine GCMs show that most areas in West Kalimantan are projected to experience a decrease in CWD length. An increase in CWD length is projected to occur when using the SSP585 climate scenario (Figure 71). The reduction in CWD length is projected to reach 20% of the baseline condition. The historical climate assessment shows that the wet day sequence in West Kalimantan currently ranges from 30-50 days, in the future this is projected to become shorter. The increase in CWD length is projected to reach 30% of the baseline condition, mainly around the Mempawah, Kubu

Raya, Kayong Utara, and parts of the Ketapang districts (**Error! Reference source not found.**). Currently, the length of CWD in Ketapang District ranges from 20-30 days. An increase in the length of CWD in this region will increase the risk of disasters, especially floods, in the future. The trend of future changes in CWD length can be seen in **Error! Reference source not found.**. The trend analysis is divided into 4 cluster regions, as shown in **Error! Reference source not found.**. In general, cluster region 3 is an area that tends to remain stable in the future. The increasing trend of CWD occurs in Cluster 1, Cluster 2, and Cluster 4 for all scenarios and periods.

The projection of RX1DAY in West Kalimantan using nine GCM models shows that most of West Kalimantan is projected to experience an increase in RX1DAY. This is evidenced by more than 60% of the models agreeing that the value of RX1DAY is projected to increase in the future. Only a small portion of the region is projected to experience a decrease in RX1DAY. The increase in RX1DAY occurs in almost all climate scenarios and projection periods (Figure 72). The increase in RX1DAY is projected to reach 35% of the baseline condition. The increase mainly occurs in the 2080s with the SSP585 scenario. The historical climate assessment shows that currently the value of RX1DAY in West Kalimantan ranges from 100-130 mm, in the future is projected to increase further. The decrease of RX1DAY in a small part of the region is projected to be no more than 5% from the baseline condition (Figure 70). The trend of future changes in RX1DAY can be seen in Figure 73. The trend analysis is divided into four regional clusters, as shown in **Error! Reference source not found.**. Almost all clusters have an increasing trend in RX1DAY values until 2100. The highest trend of RX1DAY increase occurs in cluster 3, around Kapuas Hulu Regency. The increase of RX1DAY in West Kalimantan will increase the risk of floods and landslides in the future.

The projection of RX5DAY in West Kalimantan using nine GCM models shows the same pattern as the projection of RX1DAY, where most of West Kalimantan is projected to experience an increase in RX5DAY. This is evidenced by more than 60% of the models used, are concurrent that in the future, the value of RX5DAY will increase, especially in the 2050s and 2080s projection periods. Only a small portion of the region is projected to experience a decrease in RX5DAY, such as in the 2030s (Figure 74). The increase in RX5DAY is projected to reach 25% from the baseline condition. The increase mainly occurs in the 2080s under the SSP370 and SSP585 scenarios. The historical climate assessment shows that currently the value of RX1DAY in West Kalimantan ranges from 200-260 mm, in the future this is projected to increase further. The decrease of RX5DAY in a small area is projected to be no more than 5% from the baseline condition (Figure 71). The trend of future changes in RX5DAY can be seen in Figure 72. The trend analysis is divided into four regional clusters, as shown in Figure 73. Almost all clusters have an increasing trend in RX1DAY values until 2100. The highest increasing trend RX1DAY occurs in cluster 3, around Kapuas Hulu Regency. The increase of RX5DAY in West Kalimantan will increase the risk of floods and landslides in the future.

Figure 68: Model agreement for projection of CDD (upper left), CWD (upper right), RX1DAY (below left) and RX5DAY (below right). The red colour means that all models agree to an increase compared to the baseline

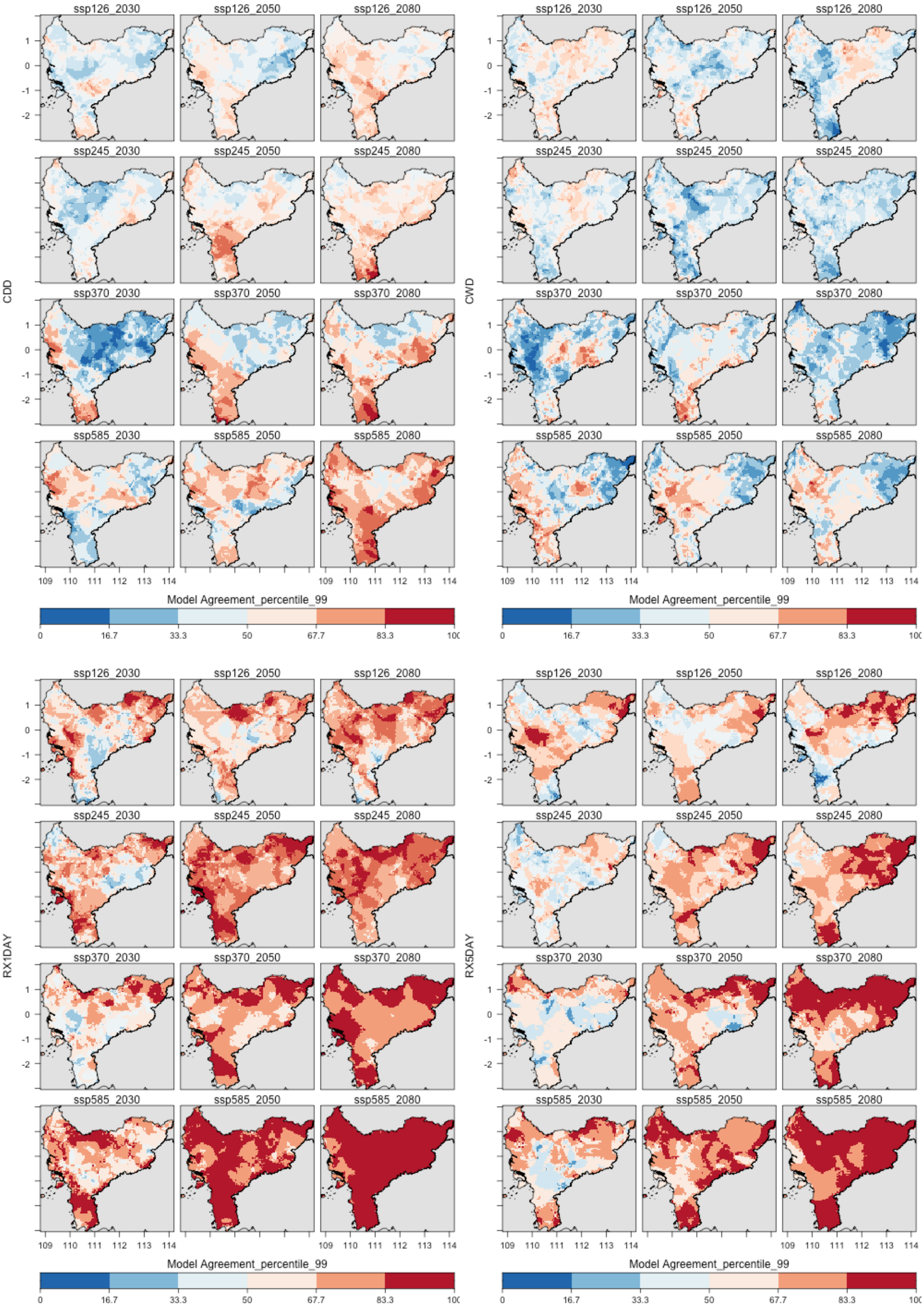


Figure 69: Projected changes in CDD (upper left), CWD (upper right), RX1DAY (below left) and RX5DAY (below right). The map shows the median value of the multi-model ensemble (MME) for 9 models.

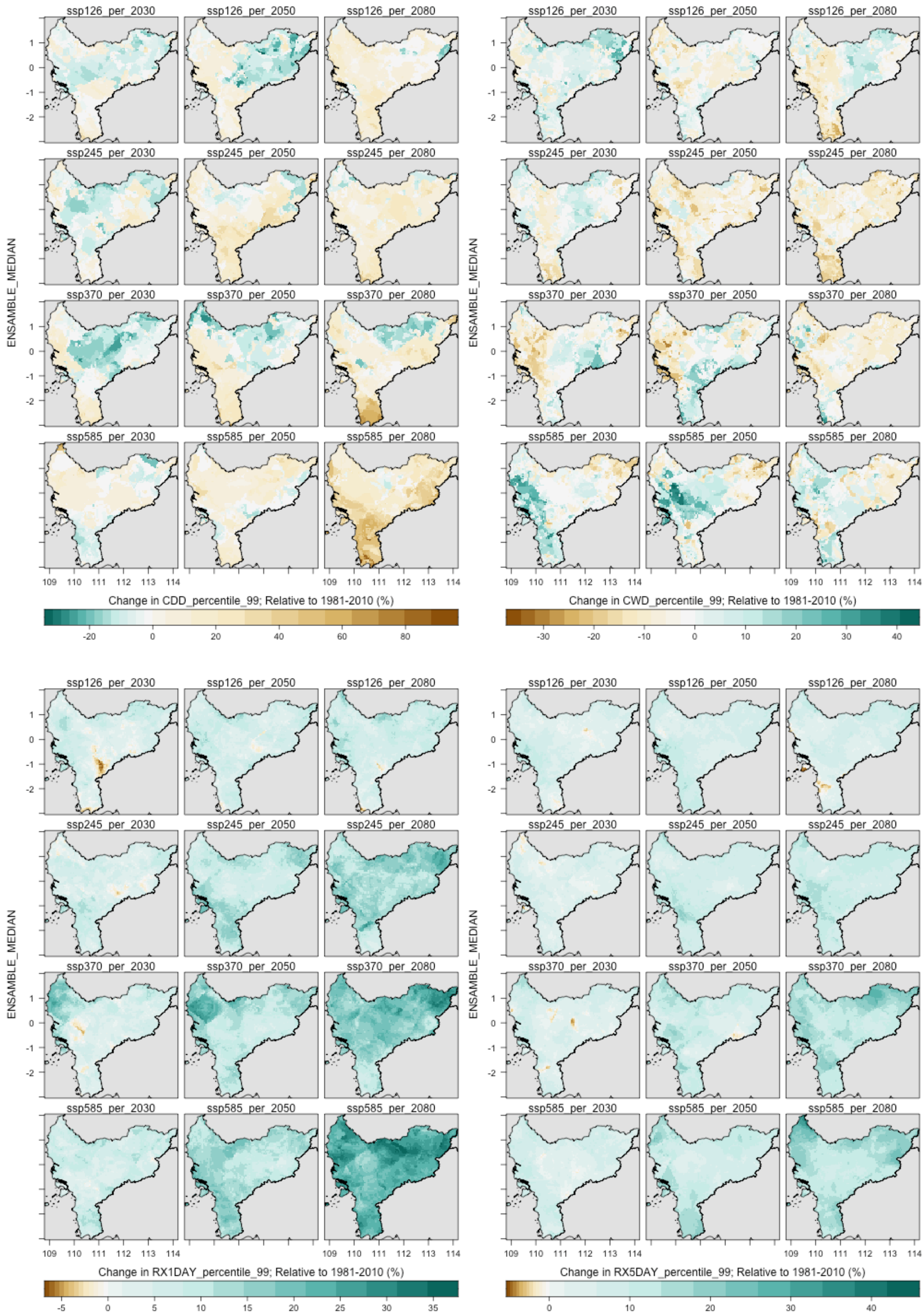


Figure 70: Trend of CDD in West Kalimantan for 4 Cluster

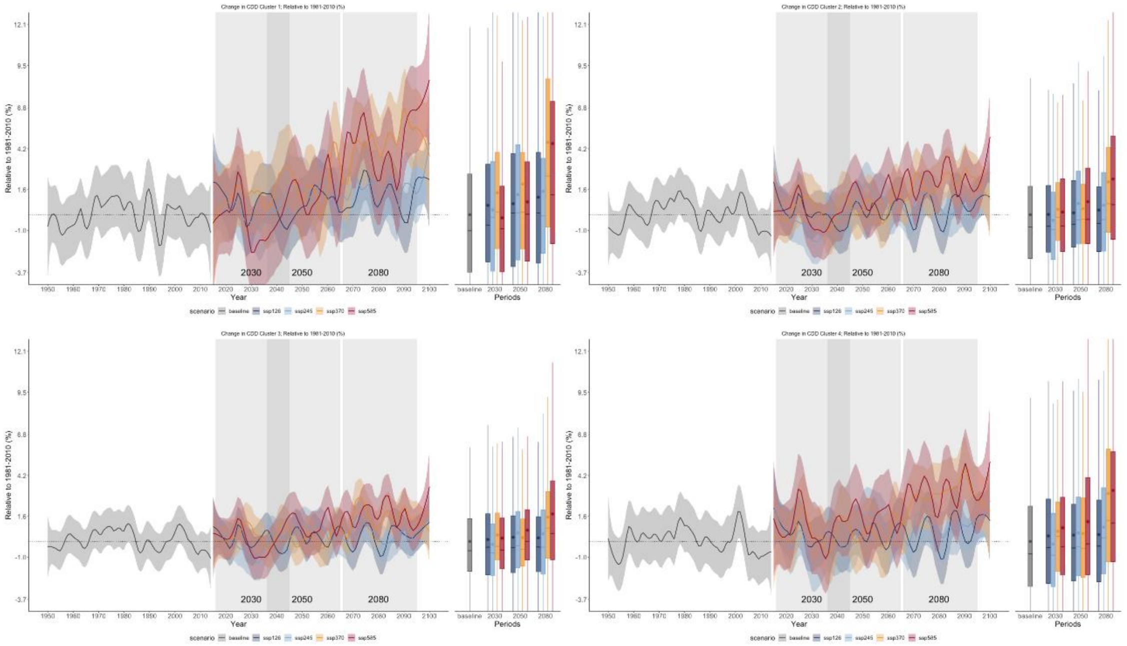


Figure 71: Trend of CWD in West Kalimantan for 4 Clusters

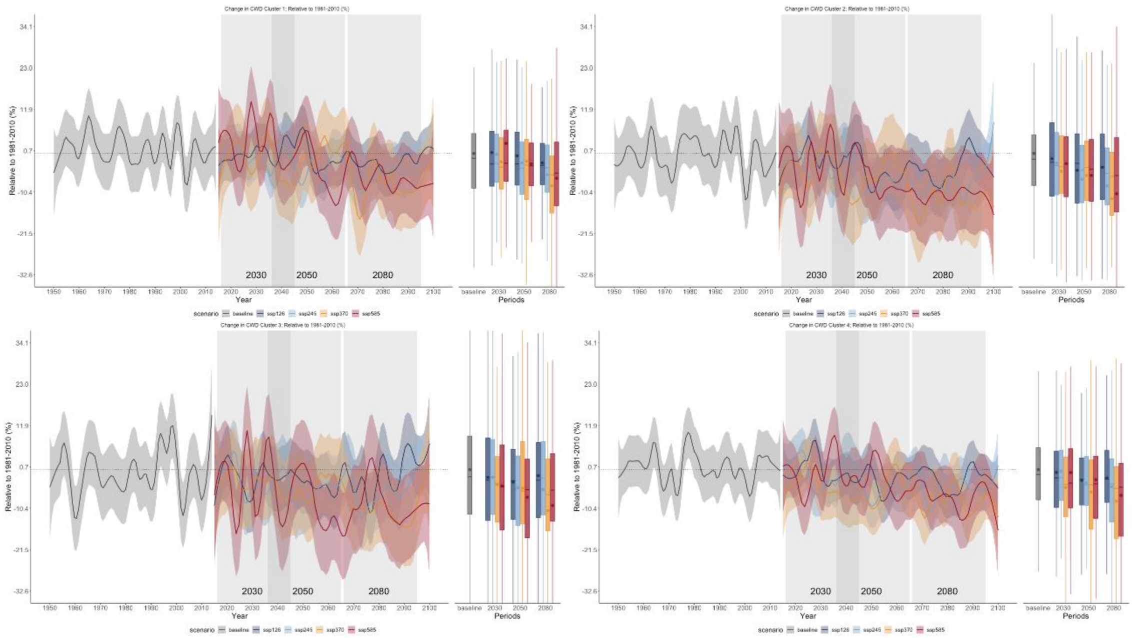


Figure 72: Trend of RX1DAY in West Kalimantan for 4 Clusters

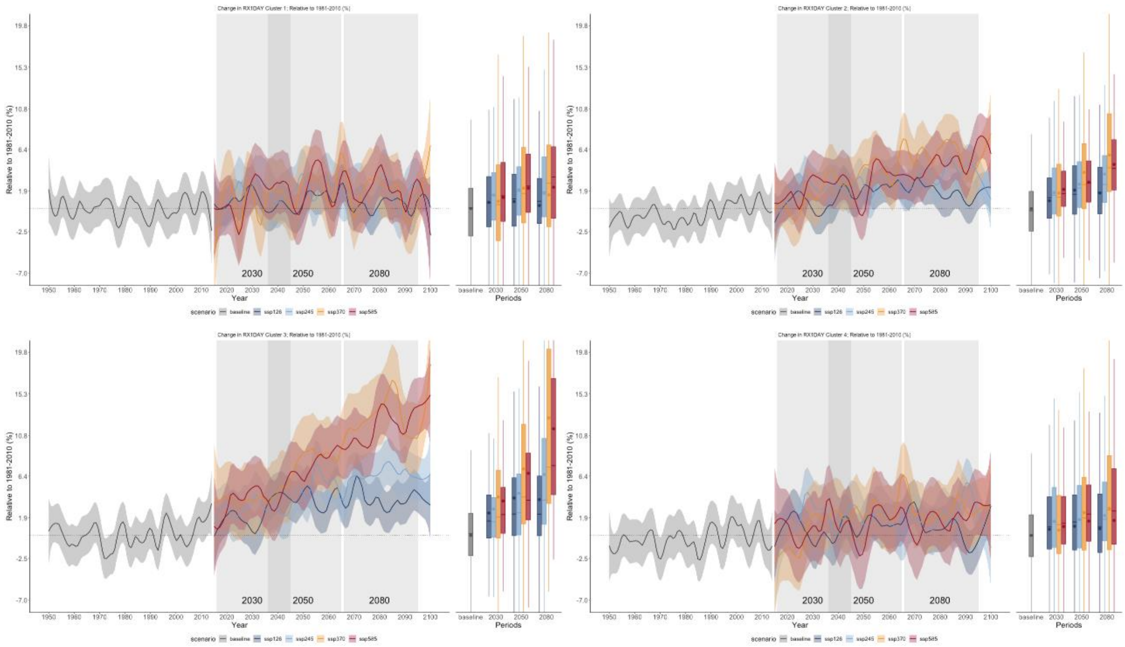
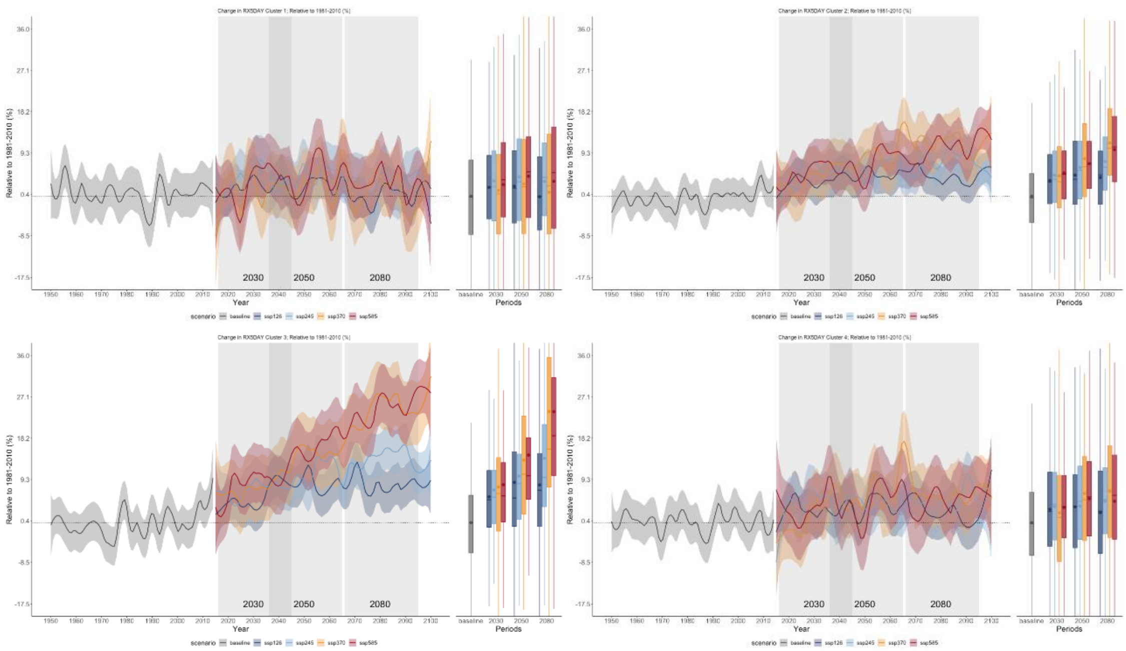


Figure 73: Trend of RX5DAY in West Kalimantan for 4 Clusters



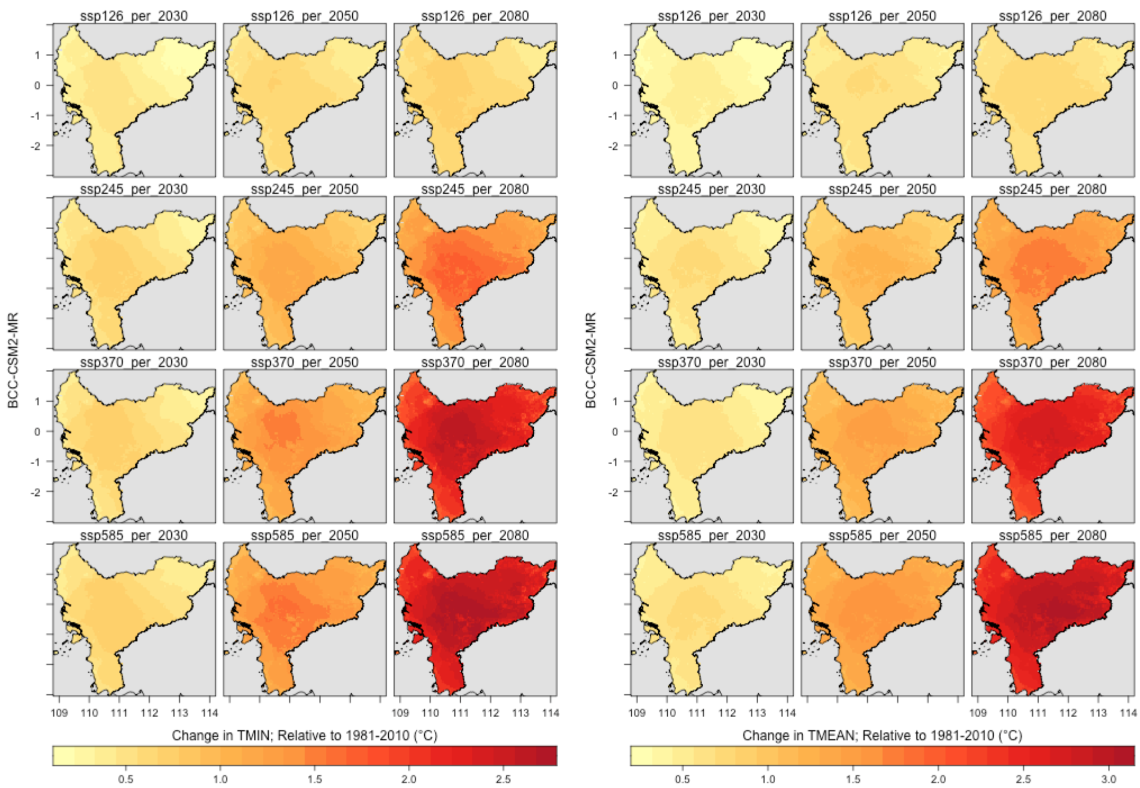
5.2.2. Temperature

5.2.2.1. Projection of Temperature

Temperatures are projected to increase significantly in the future, as a result of increased greenhouse gas emissions. In the IPCC AR6 report, it is stated that global temperatures will increase by up to 5℃, with variable area-specific increases. The tropics will generally experience a lower temperature increase than the arctic regions, reaching up to 4℃ (IPCC

2023). However, this increase would render most of the tropics unhospitable for humans.[4] Specifically, this West Kalimantan region study predicts a minimum air temperature increase of 2.8 ℃ and a maximum temperature increase of 3.4 ℃ until 2080. The mean temperature will increase by up to 3.2 ℃ (Figure 74).

Figure 74: Projection of Minimum Temperature (upper-left), Mean Temperature (upper-right) and Maximum Temperature (below) Change in West Kalimantan



[4] https://www.nature.com/articles/d41586-019-03595-0

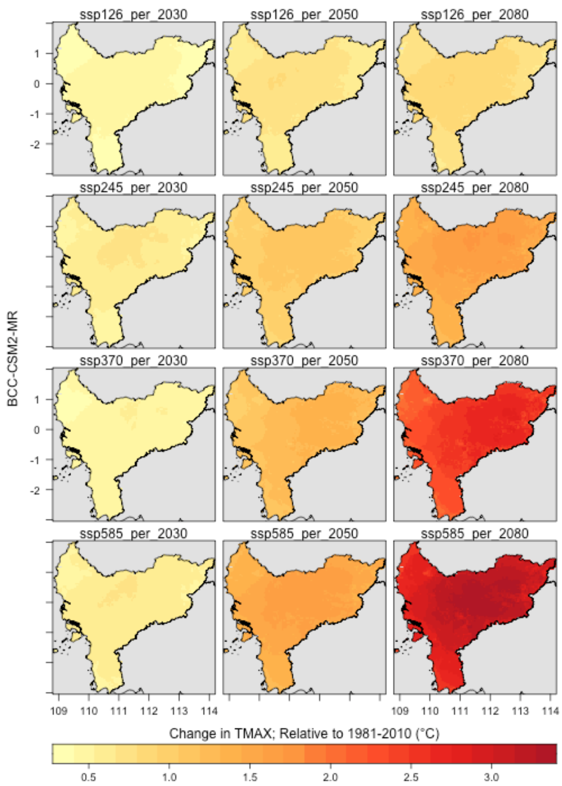
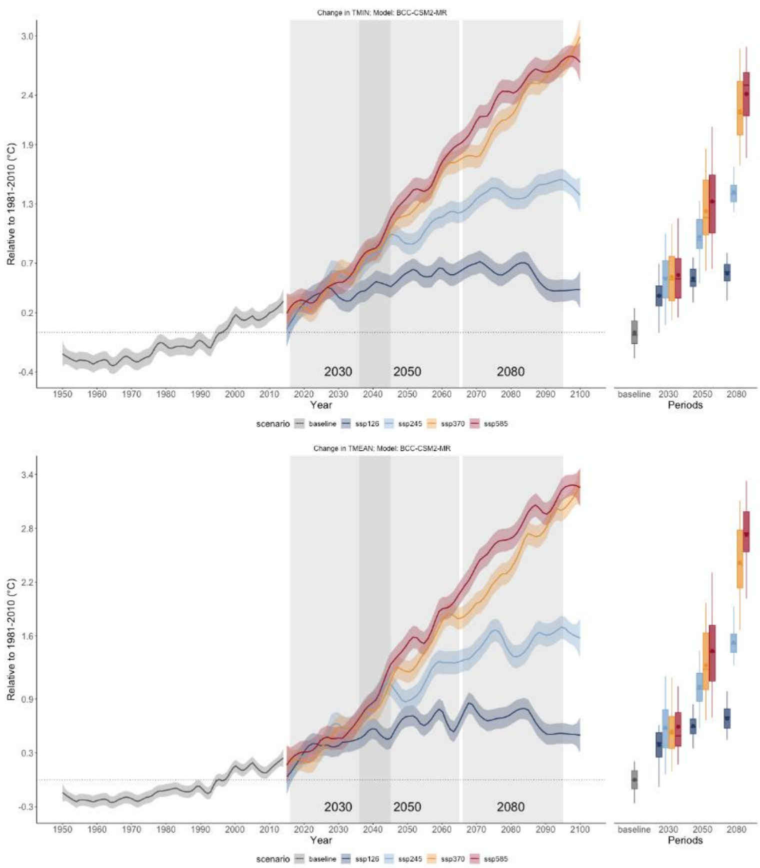
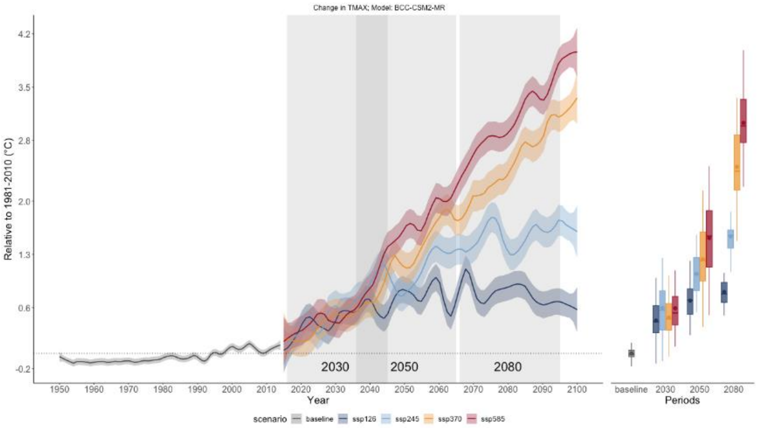


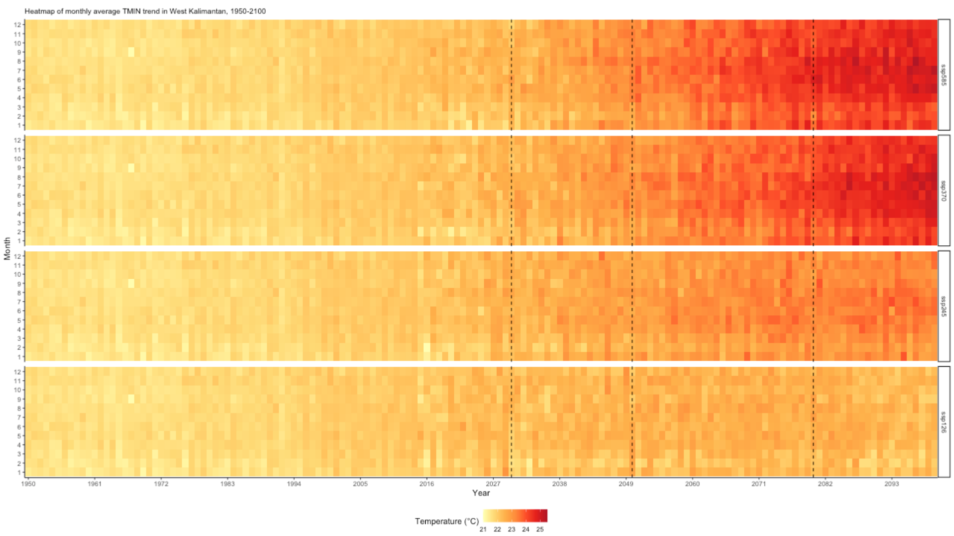
Figure 75: The projected trend of Minimum Temperature (upper), Mean Temperature (middle) and Maximum Temperature (below) in West Kalimantan

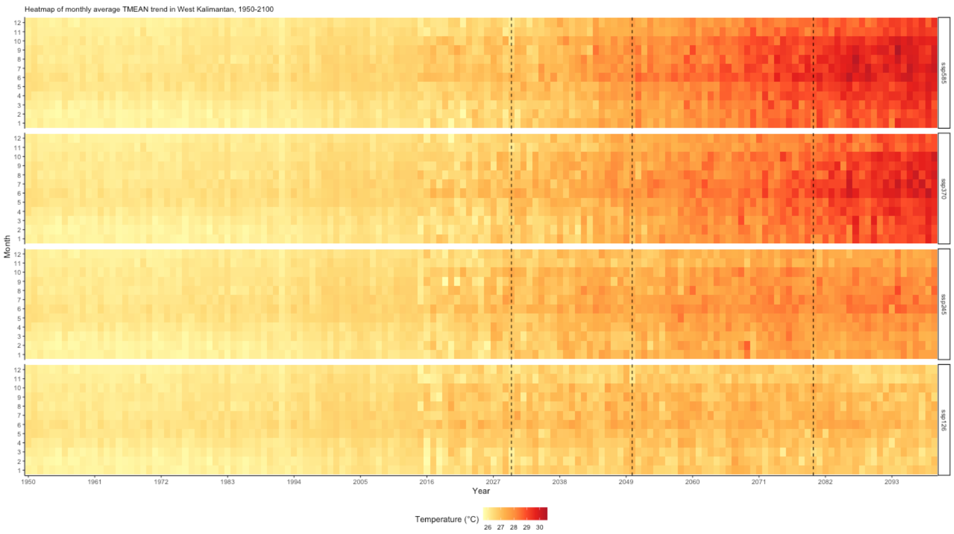


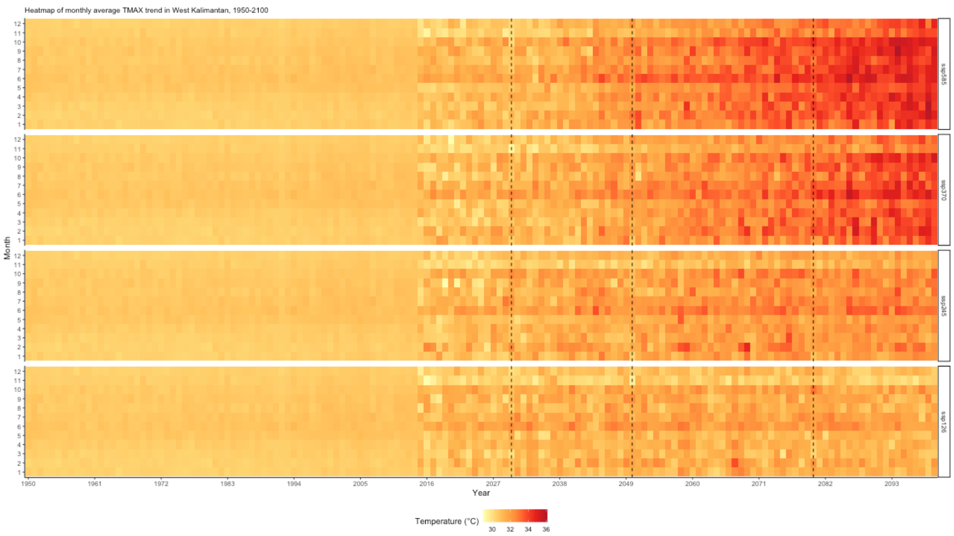


The spatial pattern of mean temperature increase suggests that regencies in the central part of West Kalimantan Province, such as Sanggau, Sekadau, and Malawi, have a higher temperature increase than other locations. The central area of West Kalimantan is expected to face an increase of its mean temperature by up to 3.2°C, whereas for the other regions an increase of about 2.8°C (Figure 75) is predicted. The mean temperature increase trend pattern demonstrates that the SSP370 and SSP585 scenarios have a linear trend until 2100, but the SSP126 and SSP245 scenarios have a linear trend until 2050, which becomes constant until 2100 (**Error! Reference source not found.**). Seasonally, the most significant increase in mean temperature will occur during the dry season, which lasts from May to September (Figure 76).

Figure 76: Projection of Monthly Minimum Temperature (upper), Mean Temperature (middle) and Maximum Temperature (below) in West Kalimantan







The increase in maximum temperature in West Kalimantan generally has a pattern like changes in rainfall. In general, the pattern of rise of maximum temperature can be separated into two regions: the southern and northern parts of West Kalimantan. The southern region will experience a smaller increase in maximum temperature compared to higher temperature increase in the northern area. The maximum temperature increase differential between the southern and northern sections of West Kalimantan Province is approximately 0.2 ℃.

The maximum air temperature of West Kalimantan is projected to increase by up to 3.4℃ in the 2080s under the SSP585 scenario. Under the SSP126 scenario, the maximum temperature will increase by 1.0℃. Meanwhile, using the SSP245 and SSP370 scenarios, it will increase by 1.8℃ and 2.4℃ respectively (Figure 76). The trend of temperature change shows that the SSP585 and SSP370 scenarios tend to increase consistently until 2100. Meanwhile, the SSP126 and SSP245 scenarios have an increasing pattern until 2050 then tends to stabilize until 2100 (Figure 76).

The monthly trend of maximum temperature change indicates that the dry season will see more significant temperature increases than the wet season. The highest temperature in the dry season is anticipated to reach 35°C by 2100 under the SSS585 scenario, while the maximum temperature in the rainy season is projected to reach 34°C. Other climatic scenarios show similar results (Figure 76).

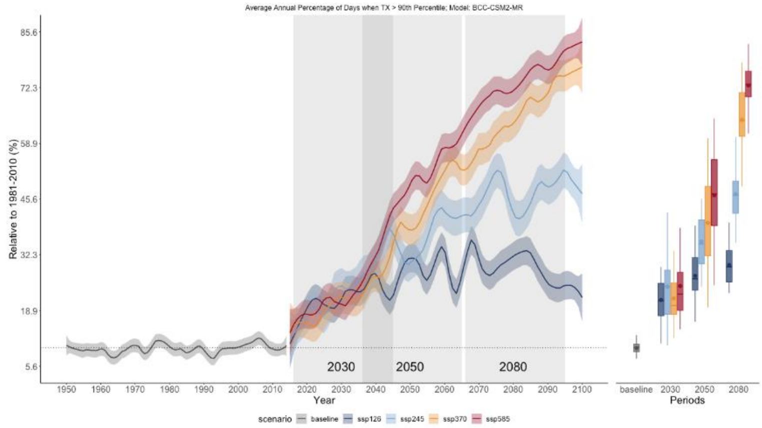
The increase in minimum temperature in West Kalimantan has a pattern of change that is similar to the increase in average temperature. The central region is the region with the highest increase in minimum temperature, compared to the other areas. In this part of the region, the temperature increase reaches 2.8℃ in the SSP585 scenario. The trend of temperature increase shows that the SSP585 and SSP370 scenarios continue to increase until 2100. Meanwhile, the SSP126 and SSP245 scenarios have an increasing pattern until 2050, which tends to be stable until 2100 (Figure 76). The highest monthly minimum temperatures occur during the dry season from May to September (Figure 76).

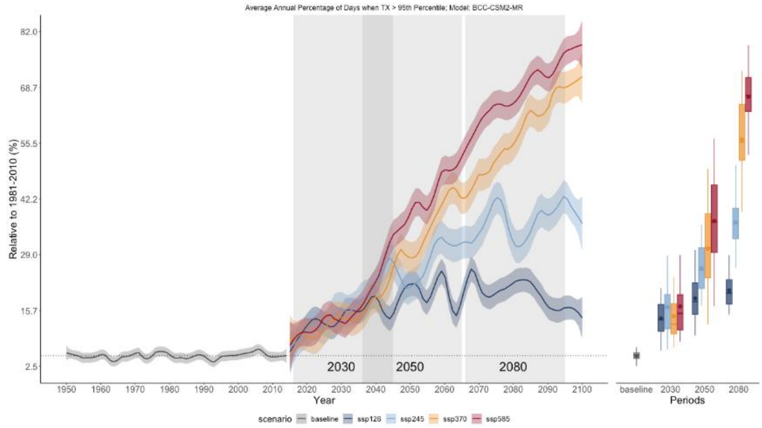
The temperature increase will impact various aspects, including the forestry and agriculture sectors. In the agricultural sector, the higher the air temperature, the higher the potential for pest attacks on agricultural/plantation crops (Boer et al. 2020). Likewise, high heat stress risks increasing the potential for disease and comfort in humans.

5.2.2.2. Projection of Extreme Temperatures

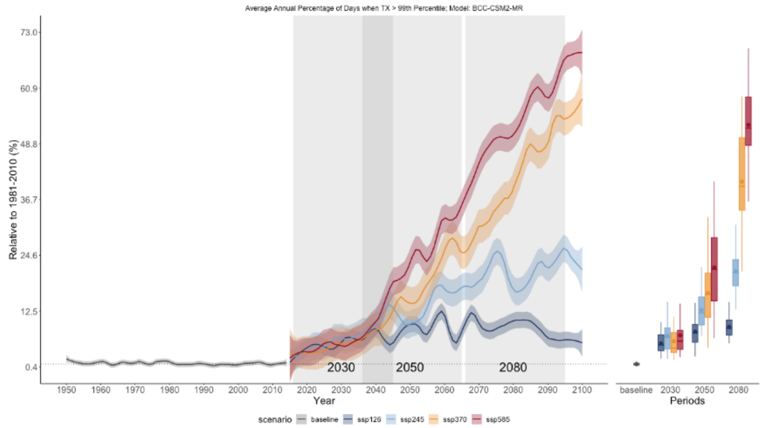
Future temperature increases will result in an increase in extreme temperatures. This analysis of the maximum temperature of hot extremes shows that the number of days with maximum temperatures above the 99th percentile will increase by 70% from the current condition. The increase in extreme temperatures will mainly occur in the southern region and on the west coast of West Kalimantan Province (Figure 77). This indicates that the increase in temperature in lowland areas tends to be higher than the increase in temperature in highland areas. In general, the pattern of increasing the number of days experiencing extreme temperatures is like the pattern of increasing maximum temperatures. In the SSP370 and SSP585 scenarios, it consistently increases until 2100, while in the SSP126 scenario, it will increase until the period of 2050 and will be constant until 2100 (Figure 77). The distribution at the 95th percentile and 90th percentile boundaries have a similar pattern to the 99th percentile boundary.

Figure 77: Projected trend of number of days with extreme hot Maximum Temperature of 90th (Above), 95th (middle) and 99th (bottom) percentiles in West Kalimantan



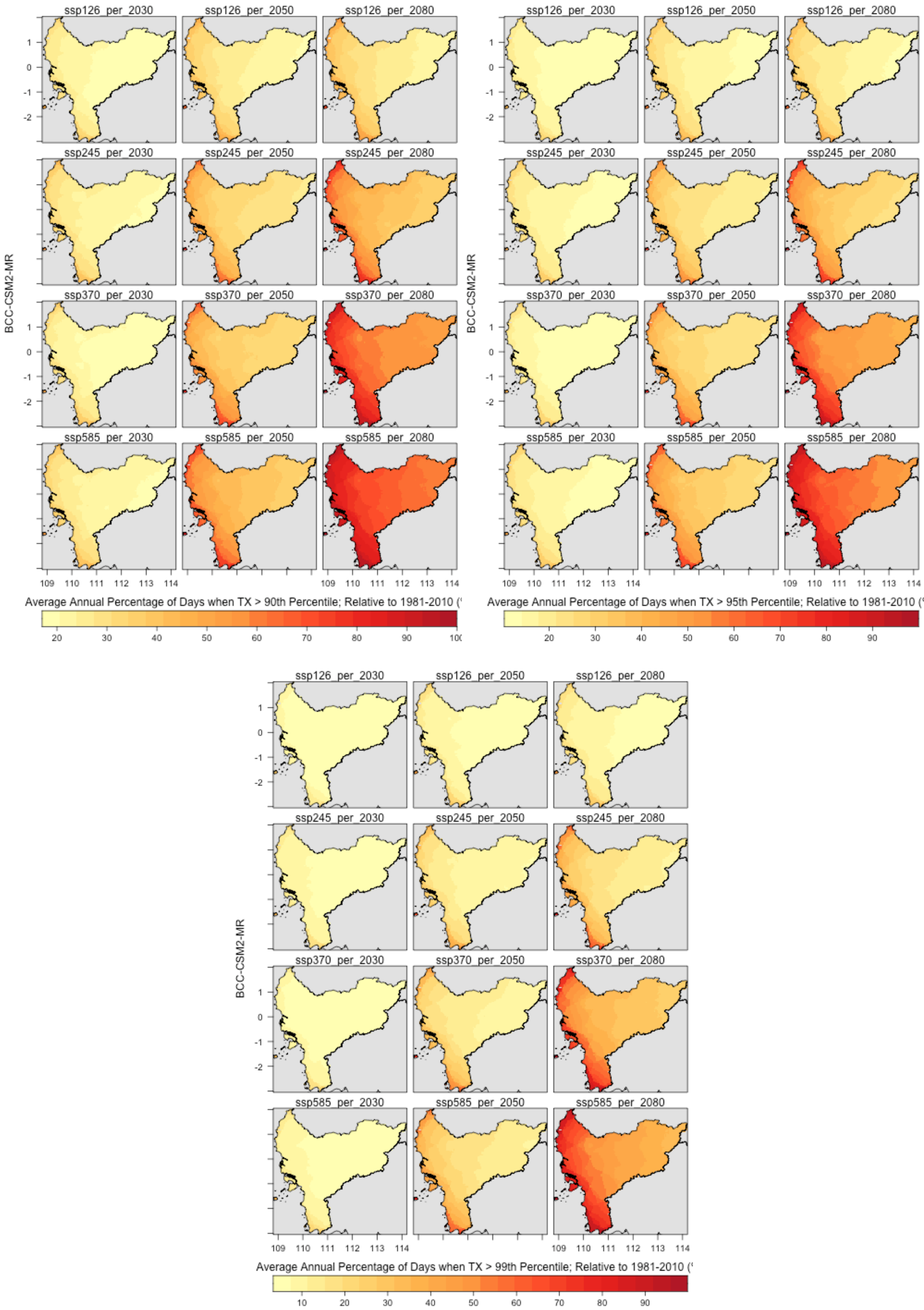


Average Annual Percentage of Days when TX > 95th Percentile; Model: BCC-CSM2-MR
Relative to 1981-2010 (%)
82.0
68.7
55.5
42.2
29.0
15.7
2.5
2030
2050
2080
1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Year
baseline 2030 2050 2080
Periods
scenario baseline ssp126 ssp245 ssp370 ssp585



Average Annual Percentage of Days when TX > 99th Percentile; Model: BCC-CSM2-MR
Relative to 1981-2010 (%)
73.0
60.9
48.8
36.7
24.6
12.5
0.4
2030
2050
2080
1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Year
baseline 2030 2050 2080
Periods
scenario baseline ssp126 ssp245 ssp370 ssp585

Figure 78: Projection of number of days with extreme hot Maximum Temperature of percentile 90th (upper-left), percentile 95th (upper-right) and percentile 99th (bellow) in West Kalimantan



5.3. Climate Summary

Global warming, due to the increase of greenhouse gas concentration in the atmosphere is causing climate change - the impacts of which are increasingly being felt. West Kalimantan is among the regions in Indonesia that is affected by climate change, particularly in the agriculture and forestry sectors. An increasing trend of extreme climates recently has increased the danger of forest and land fires.

West Kalimantan has two types of rain patterns, namely the equatorial pattern in the north and the monsoon type in the southern region. This condition causes most of the northern region not to be included in the BMGK seasonal zone for seasonal climate predictions. West Kalimantan has generally high annual rainfall with an average in the 1981-2010 period of around 3500 mm. The eastern region is an area with particularly high annual rainfall, reaching more than 4500 mm, while the lowest annual rainfall occurs in areas along the coast of West Kalimantan. The peaks of the rainy seasons occur in April and October while the height of the dry season occurs in August. The start of the dry season generally occurs at the beginning of July to the beginning of August, while the start of the rainy season occurs at the end of September to the beginning of November.

This report examines extreme rainfall conditions based on several climate indices defined by ETCCDI. There are four climate indices, namely CDD, CWD, RX1DAY and RX5DAY. The results of the analysis show that CDD conditions in West Kalimantan were highest for 22 days in Ketapang Regency, while other districts ranged between 10-12 days. The CWD condition shows a different pattern with the longest CWD condition occurring in the northern region (Sambas and Bengkayang Regencies) and the southern region (Ketapang Regency) for 22 days. Other areas show that CWD ranges from 12-14 days. The RX1DAY and RX5DAY indices have a similar spatial pattern where the eastern region (Kapuas Hulu Regency) is the region with the highest index value compared to other regions. The highest RX1DAY value in Kapuas Hulu on average is 50mm while the RX5DAY value is 130 mm. In addition to the index based on ETCCDI, a meteorological drought index was also calculated using SPEI and scPDSI. The analysis results show that the temporal patterns of SPEI and scPDSI follow the distribution of rainfall. Thus, drought patterns have a high correlation with rainfall events. The duration of the drought and the severity of the drought are influenced by the index time period used.

Historical temperature conditions in West Kalimantan generally show that the areas with the highest temperatures are in the western coastal region and the lowest temperatures occur in the mountainous regions in the eastern region. Apart from being influenced by altitude, temperature conditions in West Kalimantan are also greatly influenced by the latitude, with West Kalimantan being crossed by the equator. The minimum temperature ranges from 18℃ - 23℃ and the maximum temperature ranges from 29℃ - 32℃ with the average ranging from 24℃ to 28℃. The period from 1981 to 2015, all regions in West Kalimantan experienced an increasing trend of up to 0.6℃. The highest temperature increase trend occurs in the minimum temperature, while the maximum temperature tends to experience a lower increasing trend. The temperature anomaly in West Kalimantan shows that the temperature anomaly value since 1985 has experienced an increasing trend until now. This condition indicates that there has been an increase in temperature in the historical period. This condition has an impact on the extreme temperatures that occur in West Kalimantan, where an increasing trend in extreme temperatures also occurs in the same period.

The study of climate projections in West Kalimantan was carried out using output from 9 global climate models (GCMs). The 9 climate models used in this study are all confluent that annual rainfall will increase in the future. The annual rainfall rise in Kapuas Hulu District is 15% greater than the baseline condition. Only certain locations in the Ketapang and Sambas districts are expected to see a decrease in annual rainfall, with a decrease by 6% and 3% respectively. An increase in rainfall will occur during the peak of the rainy season (MAM) and a decrease in rainfall will occur during the dry season (JJA). In the MAM period, more than 70% of the models agree that there will be an increase in rainfall in the future. For the JJA period more than 70% of the models agree on a decrease in rainfall in the future. The increase in rainfall in the MAM period will reach 15%, while the decrease in rainfall in the JJA period will reach 20% of the baseline conditions.

The analytical results reveal that the dry season onset will be delayed by roughly 20% in most regions of West Kalimantan. In some regions, the dry season onset in West Kalimantan would be delayed by up to 60% compared to the historical condition. Furthermore, in Kapuas Hulu District the dry season will begin approximately 20% earlier than usual. The wet season onset is expected to be delayed by roughly 20%, compared to the historical condition. This pattern occurs in almost all areas of West Kalimantan, except in Kubu Raya district which will advance about 12% from the historical conditions. The wet season cessation condition is expected to retreat by roughly 20% from historical levels.

Projections of future CDD using 9 GCMs show that most of the central part of West Kalimantan is projected to experience a decrease in CDD length, such as in Kapuas Hulu, Sintang, Sanggau, and Sekadau districts. CDD length is projected to increase in the Ketapang Regency area. The decrease in CDD length is projected to reach 25% of the baseline condition. The projections of future CWD also show the similar condition with CDD, that the most areas in West Kalimantan are projected to experience a decrease in CWD length. The decrease in CWD length is projected to reach 20% of the baseline condition. The projection of RX1DAY in West Kalimantan using 9 GCMs models shows that most of West Kalimantan is projected to experience an increase in RX1DAYof 35% compared to the baseline condition. The increase will mainly occur in the 2080s with the SSP585 scenario. The projection of RX5DAY in West Kalimantan using 9 GCMs models shows a similar pattern as the projection of RX1DAY, with most of West Kalimantan experiencing an increase in RX5DAY, by 25% compared to the baseline condition.

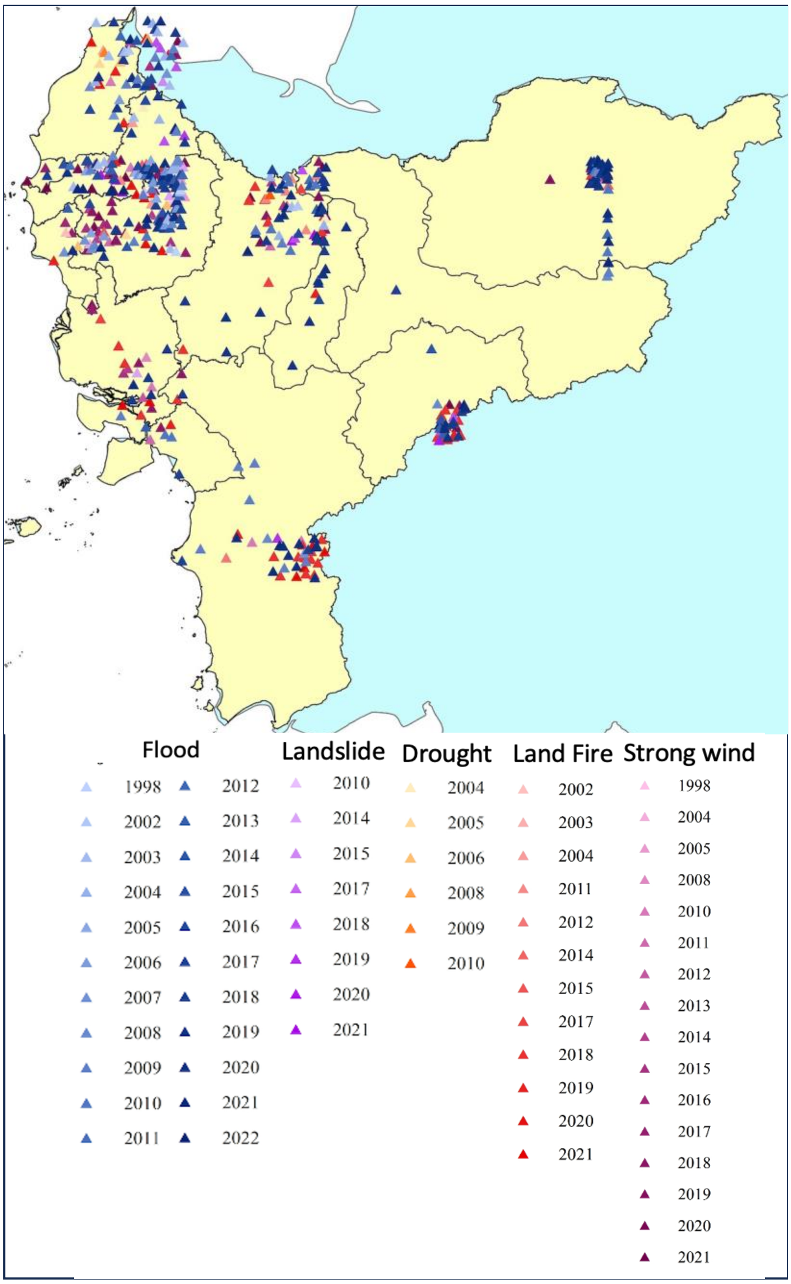
Temperatures are projected to increase significantly in the future, as a result of increased greenhouse gas concentrations. The analysis for West Kalimantan region shows the minimum air temperature is projected to increase up to 2.8 ℃ while the maximum temperature is projected to increase up to 3.4 ℃. The mean temperature will increase by up to 3.2 ℃ in extreme scenarios. Analysis of the maximum temperature of hot extremes shows that the number of days with maximum temperatures greater than the 99^{th} percentile will increase by 70% from current conditions. The increase in extreme temperatures will mainly occur in the southern region and around the west coast of West Kalimantan Province.

6. Climate risk assessment

6.1. Climate Hazard

The occurrence of extreme climate events has already caused hazards and affected the livelihoods of many people and sectors in West Kalimantan. The increase of temperature due to human activities that induced climate change would bring more frequent and intense extreme climate events. Records from the National Disaster Agency (BNPB) from 1998-2022 show that floods, strong winds, and land fires were the most common hazards that occurred across West Kalimantan (Figure 79). Landslides and droughts occurred on a lower scale.

Figure 79: Types of climate related hazards occurred in West Kalimantan (from Database of BNPB, 2023)



Extreme low rainfall and hot weather during dry season leads to drought. Unsustainable land practices and excessive water use result in the decrease of water quantity in the region, which will add to the drought risks. Drought can reduce agricultural productivity and slow plant growth, which can result in crop failure and economic losses for farmers, especially smallholder farmers. Drought also increases the risk of forest and land fires, which can cause significant damage to forests and the natural environment. Forest and land fires in West Kalimantan are influenced not only by extreme low rainfall but also by social, and economic factors. Social factors include human activities, such as land clearing, livestock grazing, hunting and illegal logging. These practices increase the risk of forest fires as they often involve the use of fire. Economic factors include economic pressures and the demand for natural resources, such as wood and agricultural land. The provision of wood and agricultural land often involves land clearing and deforestation, which can increase the risk of forest fires. In addition, difficulty in accessing markets and resources can hinder efforts to prevent and combat forest fires. Furthermore, Cahyono et al (2015) stated that such diverse factors such as export prices of crude palm oil, El Nino, forestry budget, and economic crisis can also contribute to forest fires. At the same time, social factors such as community awareness of forest fire hazards and their ability to mitigate them can also affect the risk of forest fires.

The analysis of extreme climate events causing drought and land fires shows that the occurrence of long consecutive dry days (CDD) contributes significantly to the increase of land and forest fire. Intensity of land and forest fire increases with an increase in CDD length (Figure 79). The fires occur mostly when the length of CDD exceeds 12 days. On average the area affected by fire per village is between 10 to 50 ha, the burnt area expands as the length of CDD increases. Villages affected by fires are mostly located in the eastern and southern part of West Kalimantan (Figure 80). The climate projection analysis indicates that CDD are expected to last longer in these areas (see Figure 81) suggesting an increased risk for land fires in the future. Without strategic adaptation planned from now, things will even get worse. Temperature in West Kalimantan will continue to increase in the future, irrespective of emission pathway scenarios. Present temperature has already increased by about 1oC compared to the average temperature between 1951-1980. In the next 10 years under the SSP126 and SSP245 (low emission scenarios), the temperature will increase further to about 0.2/0.3oC, but in the SSP370 and SSP585 it will increase more than 0.5oC. By the end of 2050, with the first two scenarios the temperature increase will be still less than 1oC, but with the last two scenarios, it will be above 1oC.

Figure 80: Relationship between burnt area and length of consecutive dry days in West Kalimantan in the period 2015-2020

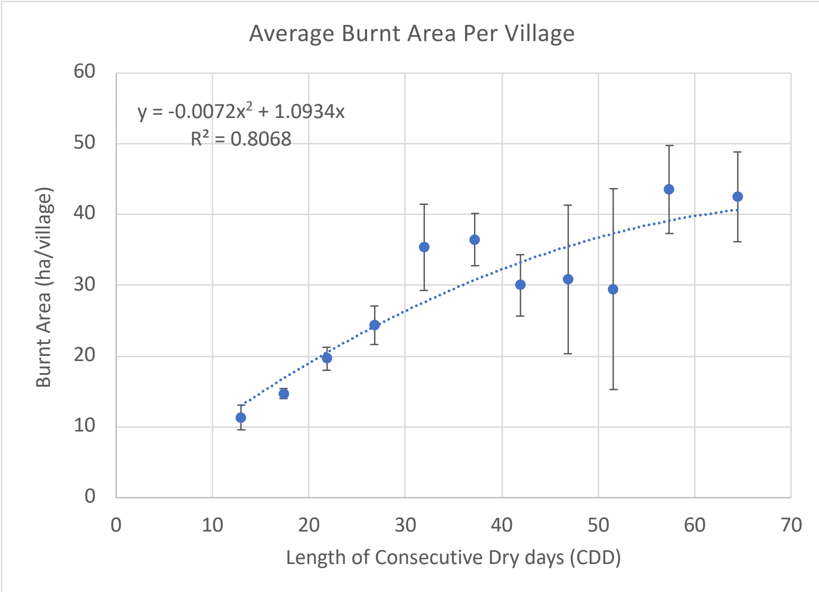
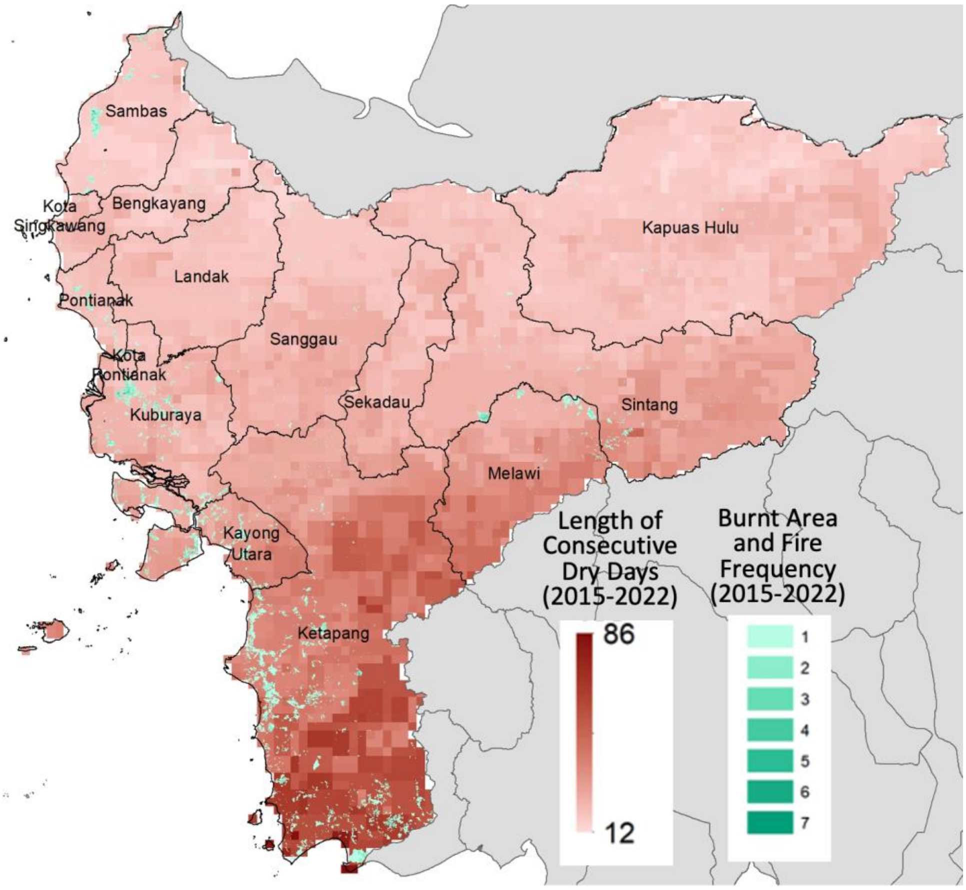


Figure 81: Length of Consecutive Dry Days (CDD), Burnt Area and Fire Frequency in West Kalimantan over the period of 2015-2022. Burnt Area data is from KLHK (2023)



Floods are the most prominent climate-related hazard in West Kalimantan. They are triggered by high rainfall intensity, lowland topography, and high river discharge. Changes in land use, deforestation, and infrastructure development that do not consider environmental impacts worsen the impact of floods. Like droughts, also floods damage crops and forests and reduce productivity, which can cause economic losses for farmers and landowners. In addition, floods also cause landslides and erosion, which can lead to environmental damages. The analysis of one day maximum rainfall (RX1DAY) and its relation to flood occurrence indicates that the probability of flood occurrence increases as the RX1DAY increases (Figure 82). In contrast to land and forest fires, floods mostly occur more frequently in the northern part of West Kalimantan (Figure 83). It is expected that in the future the intensity of RX1DAY and other extreme rainfall events in this area will increase further (see Figure 82). This will result in an increased frequency and intensity of floods. Without adaptation measures, the impact of floods will become more severe.

Figure 82: Relationship between probability of daily maximum rainfall and floods in West Kalimantan in the period 1998-2022

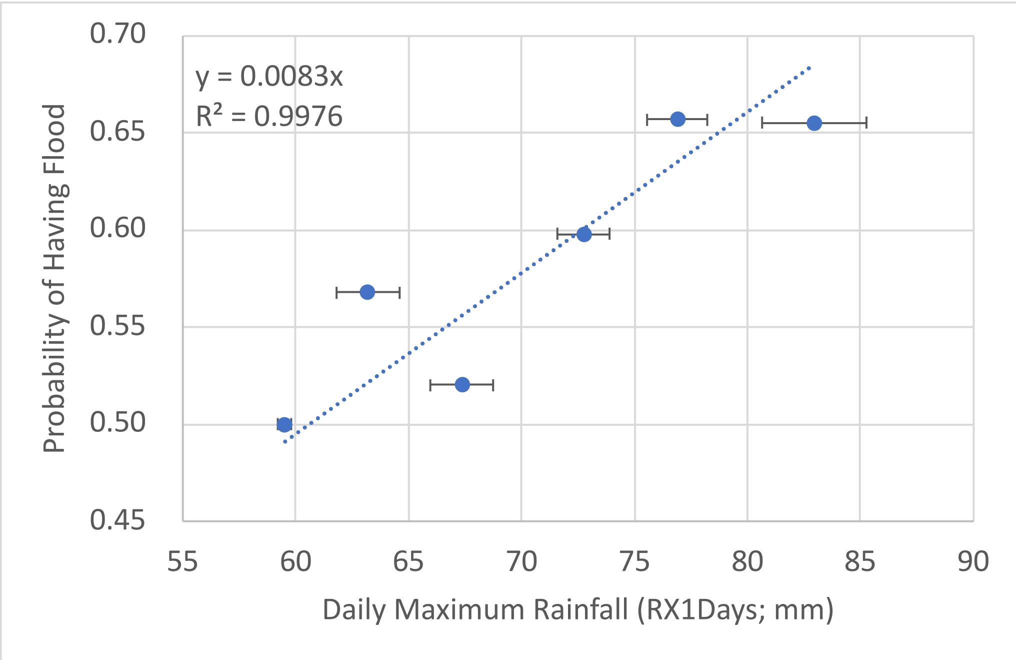
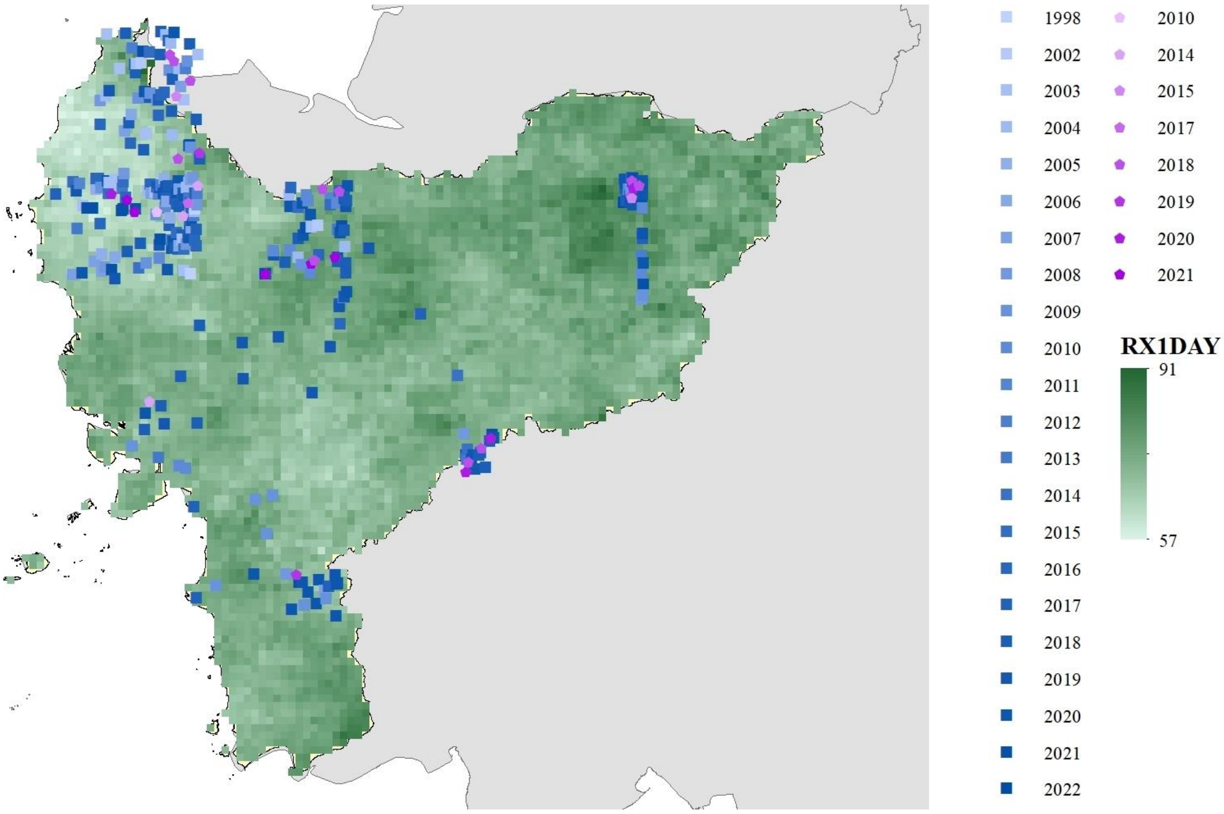


Figure 83: Map of Maximum daily rainfall (RX1Days) and flood events in the period of 1998-2022 in West Kalimantan



Climate change poses significant risks to various sectors and regions around the world, including West Kalimantan, Indonesia. West Kalimantan is exposed to a range of climate hazards, including increased temperatures, changes in precipitation patterns, sea-level rise, as well as increased frequency and intensity of extreme weather events such as floods, droughts, and forest fires. These climate hazards have the potential to negatively impact various sectors, ecosystems, and communities in the region.

6.2. Potential Impacts on Climate Change in the AFOLU sector

Most villages in the five target districts of West Kalimantan Province face high climate risks. According to current assessments, approximately 199 villages are at a high risk of climate-related disasters, 167 villages face a medium risk, and only 12 villages have a low risk level. As the likelihood of extreme climate events is expected to rise across West Kalimantan, the frequency and severity of disasters are bound to increase.

The occurrence of fires is closely correlated to prolonged dry spells (CDD) and high temperatures. Fires appear particularly frequently during years with dry spells lasting more than 15 days (15-CDD). The severity of fire outbreaks correlates with the duration of CDD; as CDD extends, the affected area by fires increases. On average, when exposed to 15-CDD and a fire breaks out, approximately 10% of a village's area is affected by fire. This percentage escalates to 19% with 20-CDD, to 27% with 30-CDD, to 32% with 40-CDD, and to 36% with 50-CDD.

Projections indicate a higher probability of longer CDD occurrences in the future, irrespective of emission scenarios. Notably, the likelihood of experiencing 20-CDD is expected to rise significantly in most villages, especially in Ketapang and Kubu Raya districts. The SSP585 scenario, which reflects a failure in global emissions reduction efforts, forecasts the highest increase. Presently, the probability of 20-CDD ranges from 3% to 14%, but in the future, it could reach between 5% and 32%, varying per districts, emission scenarios, and periods.

The likelihood of 40-CDD is nearly zero in all villages across the five targeted districts. However, this may change dramatically, with a projected likelihood of up to 20%. Without effective adaptation measures, the area affected by village fires is anticipated to increase significantly. In Ketapang and Kubu Raya districts, fires affecting at least 20% of village areas occur on average every 7 to 8 years. However, by the 2080s, such fire events will occur once every 2-3 years. Additionally, larger fires that could impact over 30% of the village area are expected once every ten years in Kubu Raya and once every 5 to 6 years in Ketapang. These projections underscore the need for comprehensive adaptation strategies to mitigate the region's escalating climate change risks.

In their research, Nuzul Hijri Darlan et al. (2016) inferred that the El Niño phenomenon of 2015 considerably influenced the productivity of oil palm cultivation across the Sumatra region. The repercussions of El Niño-induced drought, notably water deficits and extended dry spells, were observed to induce stress within oil palm plantations, consequently precipitating diminished productivity levels. The research findings indicated a reduction in oil palm productivity in the first half of 2016 compared to the same period in 2015. The documented reductions in oil palm productivity within the surveyed regions were as follows: 14.96% in Riau, 6.80% in West Sumatra, 33.79% in Jambi, 43.98% in South Sumatra, and 60.00% in Lampung.

Table 5: Probability of having 20-CDD and 40-CDD in villages of the five districts under low and high-emission scenarios

	PERIOD	KAPUAS HULU	KETAPANG	KUBU RAYA	SANGGAU	SINTANG
		P(20-CDD)				
Baseline	1995s	3.4%	13.1%	13.5%	7.1%	3.8%
SSP126	2030s	5.2%	16.4%	18.0%	8.3%	5.0%
	2050s	5.5%	16.6%	17.1%	8.1%	6.0%
	2080s	3.7%	18.6%	17.5%	8.0%	4.6%
SSP585	2030s	3.8%	15.2%	15.4%	7.7%	5.7%
	2050s	5.4%	20.1%	19.0%	10.3%	7.2%
	2080s	8.0%	31.3%	31.4%	16.6%	11.8%
		P(40-CDD)				
Baseline	1995s	0%	0%	0%	0%	0%
SSP126	2030s	0%	3.9%	2. 8%	2.0%	0%
	2050s	3.6%	5.9%	3.1%	1.9%	0%
	2080s	0%	1.1%	0%	0.%	0%
SSP585	2030s	0%	7.5%	13.6%	0.3%	0%
	2050s	0%	7.1%	14.0%	0.3%	0%
	2080s	0 %	19.3%	10.0%	9.3%	0%

Fires in West Kalimantan have resulted in significant damage across various sectors. The notable 2019 fires, predominantly affecting peat swamp forests, caused damage to approximately 151,000 hectares of forest land. Over the past five years, wildfires have led to a combined loss of around 330,000 hectares of forest. The consequences of these fires extend beyond environmental damages alone. They encompass economic losses ranging from USD 50 to USD 1200 per hectare of burned area. Moreover, fires have indirect impacts, such as health issues and transportation disruptions due to the release of smog, which leads to long-term air pollution and decreased visibility. The reduction in photosynthetic active radiation (PAR) levels due to smog also adversely affects crop production.

West Kalimantan has also recently experienced more frequent and severe drought events, leading to a heightened risk of devastating forest fires. The study found a strong negative correlation between monthly rainfall and hotspot occurrences in Indonesia, with lower rainfall during the dry season from July to October associated with a higher number of hotspots, indicating the significant influence of climate factors on forest and land fires in regions like Kalimantan and Sumatra (Suharjo et al. 2018). The other study also found that changes in rainfall intensity due to climate change have significantly impacted the environment in West Kalimantan, with lower rainfall leading to increased forest fires and deforestation, while higher rainfall is associated with decreased forest fires and potential reforestation or expansion of plantations. (Anggraini, N., and Trisakti, B., 2011).

Forest fires accompanied by dense smoke haze cause economic and social (health) losses for the surrounding communities, including palm oil plantations and those involved in the palm oil industry. Forest fires reduce the dry weight production of fresh fruit bunches (FFB) by approximately 4-12 percent (Harahap and Rahutomo, 1999). The resulting smoke haze also impacts palm oil yield, which tends to decrease (Hasibuan and Pradiko, 2018). This smoke haze causes stress to palm oil plants and hinders the process of photosynthesis and the formation and growth of palm fruits, thereby reducing productivity by about 0.2-5.5 percent. The potential losses per hectare due to productivity declines caused by nearby forest fires can reach 12-15 million IDR per hectare (PASPI, 2023).

The effects of climate change have become increasingly apparent in the palm oil-producing regions of West Kalimantan. Studies have shown that reduced rainfall levels and higher temperatures in the area have led to decreased palm fruit yields and poorer oil quality in many plantations (Ardiyanto et al., 2021). The changing climate has also made the palm trees more susceptible to pests and diseases, further exacerbating production challenges for local farmers (Setiowati et al., 2023).

The temperature rises and the intensification of the dry season, driven by climate change as evidenced by the increased duration of consecutive dry days (CDD), is prone to significantly impact agriculture. Through rising temperatures alone, the region's suitability for many crops will become threatened. Studies indicate that as climate change worsens, crops' climatic suitability shifts and may move to higher altitudes and latitudes. For instance, an increase of one °C in temperature could lead to a 10% reduction in oil palm production. Additionally, the prolonged duration of consecutive dry days during the growing phases of crops can induce drought stress, resulting in reduced yields for - among other crops - oil palm and rubber trees.

As climate change advances, the frequency and intensity of strong rainfall events during the wet season are expected to increase. Villages in the five districts have already begun experiencing flooding when extreme rainfall exceeds 60 mm (60-Rx1Day). The probability of villages being affected by floods during such events is approximately 50%, rising to 65% for rainfall events exceeding 80 mm (80-Rx1Day). Floods resulting from extreme rainfall events at 60-Rx1Days are categorized as small, while those at 80-Rx1Days are considered large - due to their significant impact on people and biophysical infrastructure. Currently there is a return period for large floods of about 7-10 years. It is anticipated that in the future, this cycle will shorten to once in every 5-6 years. This highlights the escalating risk posed by extreme weather events in the region.

Table 6. Return period for small and extensive floods in villages of the five districts under low and high emission scenarios

	PERIOD	KAPUAS HULU	KETAPANG	KUBU RAYA	SANGGAU	SINTANG
		Small floods (flood cycle in a year)				
Baseline	1995s	4	4	4	4	4
SSP126	2030s	4	4	4	4	4
	2050s	3	4	4	4	4
	2080s	3	4	4	4	4
SSP585	2030s	4	4	4	4	4
	2050s	4	4	4	4	4
	2080s	3	3	4	4	3
		Extensive floods (flood cycle in a year)				
Baseline	1995s	7	7	8	8	10
SSP126	2030s	7	6	7	7	8
	2050s	6	6	7	6	8
	2080s	6	6	7	7	8
SSP585	2030s	7	7	6	6	8
	2050s	6	6	6	6	7
	2080s	5	5	6	5	6

Floods have been inflicting extensive damage to communities, resulting in significant economic losses and severe damages to infrastructure. A case study conducted in Sikawang City highlighted the aftermath of a major flood in 2016, which led to financial losses of 15.8 billion IDR. In agricultural areas, floods have posed numerous challenges, including destroying valuable farmlands, reducing crop yields, and difficulties accessing food due to disrupted transportation systems.

The detrimental effects of floods and waterlogging on crop yields have been extensively documented. On average, the reduction in crop yields due to waterlogging typically reaches 32.9%, with variations depending on the crop type. Notably, waterlogging during the reproductive growth stage results in a more significant yield reduction, averaging at 41.90%, compared to during the vegetative growth stage, when the average decrease is 35%.

The impact of waterlogging on oil palms is particularly noteworthy because when their roots become submerged, oil palms experience disturbances in their normal respiration process. This leads to impaired water and nutrient uptake, delayed frond opening, and reduced availability of carbohydrates, all of which negatively affect the palms' overall health and productivity. This detailed insight underscores the multifaceted challenges posed by floods and waterlogging in agricultural contexts, necessitating comprehensive strategies for mitigation and adaptation.

The rubber industry in West Kalimantan has also faced significant challenges due to the impacts of climate change. Rubber cultivation in the region relies on consistent rainfall patterns and moderate temperatures, but the increasing variability in these environmental conditions has disrupted optimal growing conditions (Junaidi, 2019). The study also found that rainfall has a significant 78.6% influence on rubber productivity, while other unaccounted factors contribute the remaining 21.4%, indicating a strong relationship between rainfall and rubber production.

6.3. Climate Risk

The Risk and Vulnerability Assessment conducted in West Kalimantan identifies three primary hazards: extremely high Precipitation, increasing temperature, and long dry spells. The three indicators are identified as hazards because they are natural conditions that can increase risks if their indicator values are high, and vice versa. However, these conditions cannot be changed, as they are natural occurrences. Increased precipitation impacts the rising frequency and magnitude of floods in an area. While increased temperatures and prolonged dry spells result in a growing risk for droughts, as well as land- and forest fires.

If a hazard appears in an area with a high level of vulnerability, the resulting impact will also be high. In such a setting a hazard will result in a disaster. In contrary, if a hazard arises in an area with a low level of vulnerability, the resultant effect will be low. Such a system has the ability to absorb shocks and can be considered resilient.

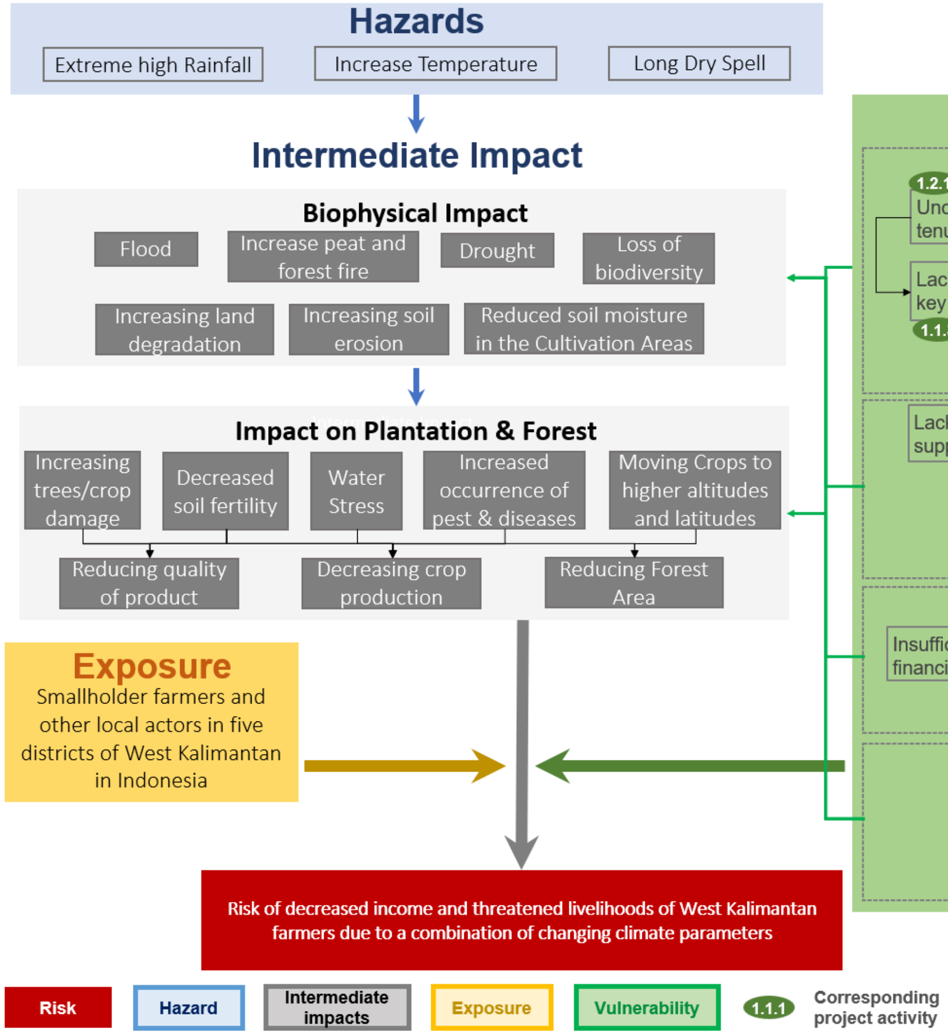
In this analysis, intermediate impacts are divided into two stages: The first is biophysical impact, followed by the second, which is the impact on plantations and forests. The hazards are extreme temperatures, precipitation, and dry spells. The biophysical impact is related to the potential of hazards such as floods, forest and peat fires, droughts, and loss of biodiversity. Under these conditions, another potential impact is the loss of soil moisture, leading to increased land degradation and soil erosion.

The identification of impacts on crops and forests is the next step after the identification of biophysical implications. The occurrences of droughts and floods, including forest and peat fires, have a damaging impact on crops. Plants endure water stress due to drought, or disrupted growth due to reduced soil fertility caused by soil erosion, which erodes of organic matter in fertile soil. On the other hand, prolonged drought conditions also lead to an increase in plant pests and diseases, resulting in a decreased overall crop production. The combined impacts of these conditions result in a reduction in both quantity and quality of crop production. The onset of frequent droughts and/or floods in a particular region will render it eventually unsuitable for plant growth. This would necessitate the acquisition of new land for production, since the demand for crop production persists and even increases. Consequently, this leads to new land openings, which in most cases – due to the given limitation of the production factor land – leads to encroachment of valuable forest areas.

The conditions that can increase or decrease intermediate impacts in a certain location are defined as vulnerability factors, which are subsequently derived into vulnerability indicators. The identification of vulnerability conditions is obtained through an analysis of barriers that can increase the potential for such impacts. These barriers pose challenges and are influenced by physical, social, and institutional factors.

A comprehensive sustainability assessment of West Kalimantan has led to the identification of several vulnerability indicators. The initial step was the establishment of causal linkages components that are influenced by barriers. Four barriers have been identified: 1. governance, 2. Institutional and technical capacities, 3. Financial constraints, and 4. Market-related challenges.

Figure 84: Impact chain of CRVA in West Kalimantan



The next chapter will analyse the vulnerabilities factors in each barrier and describe the outlined the planned adaptation measures through the GCF project.

7. Adaption Measures

Adaptation measures refer to specific actions, strategies, and policies implemented to reduce the negative impacts of climate change and enhance the resilience of systems and communities. As the impacts of global climate change intensify, the need for effective adaptation measures in West Kalimantan becomes increasingly urgent. While the mitigation measures outlined in the previous chapter aim to reduce greenhouse gas emissions, adaptation strategies focus on building resilience to the unavoidable changes already underway. This chapter explores how the four identified vulnerability barriers for West Kalimantan: 1. Governance, 2. Institutional and Technical Capacities, 3. Financial, and 4. Markets are effectively addressed with GCF support to facilitate adaptation to climate change.

The approaches used to identify adaptation measures closely followed the methods employed by Indonesia's Ministry of Environment and Forestry (MoEF) in the *Sistem Data dan Indeks Kerentanan (SIDIK)* system. The process began by identifying the barriers and challenges faced in the national development process and vulnerability barriers. After this initial step, a sectoral analysis was conducted based on vulnerability indicators, with a particular focus on the adaptive capacity component.

The identification of adaptation measures was generally structured into programs at the national scale, which were then tailored for implementation at the local government level. This was based on the indicators found to have the highest contribution to vulnerability. The visualization of these indicators was presented in a spider diagram, which illustrated the relative contribution of each factor to the overall vulnerability assessment. In the case of West Kalimantan, the same approach was applied, ensuring that regions with specific conditions and high vulnerability supporting indicators received tailored adaptation measures for the specific location.

By using this approach, specific regions will receive adaptation measures that are aligned with the specific conditions of that area, which collectively contribute to reducing vulnerability on a broader scale.

Governance Barrier:

Effective governance is essential for coordinating adaptation efforts across various sectors and levels of government. National and sub-national governments play key roles in developing policies, regulations, and strategies to address climate risks. This involves integrating climate adaptation into broader development plans and establishing mechanisms for coordination and collaboration among relevant stakeholders.

A major identified component of vulnerability in West Kalimantan is the lack of coordination between critical ministries and agencies. Inconsistent or conflicting policies and regulations across different ministries and agencies can undermine efforts to address climate change holistically.

Climate change intersects with various sectors, including agriculture, forestry and conservation. Without coordination, ministries and agencies may miss opportunities to leverage synergies between different sectors and to develop integrated solutions. Without appropriate coordination, ministries and agencies may duplicate efforts or work at cross-purposes, leading to inefficient use of resources. Fragmented policy implementation may result in disjointed strategies that fail to effectively reduce greenhouse gas emissions, enhance climate resilience, or promote sustainable development.

Inadequate coordination can also undermine enforcement mechanisms and compliance with climate-related regulations and standards. Without clear roles and responsibilities among relevant ministries and agencies, there may be gaps in monitoring, reporting, and enforcement activities, allowing non-compliance to go unchecked and undermining the effectiveness of climate policies. To address the outlined vulnerability factors, the project will support the strengthening of the institutional framework for the coordination of mitigation and adaptation activities across relevant stakeholders.

Due to poor inter-sectoral coordination in West Kalimantan spatial and other regional development plans are often misaligned and lack a clear direction on climate change issues. Inadequate land use planning may result in developments being situated in areas prone to flooding, wildfires, or other climate-related hazards. This can lead to increased vulnerability of communities and infrastructure to extreme weather events, resulting in property damage, loss of life, and economic disruption. Inadequate land use planning can furthermore impose significant economic costs on communities in the future. These may include expenses related to disaster response and recovery, decreased property values due to climate risks, and lost opportunities for sustainable economic development. Climate change impacts often disproportionately affect marginalized communities, exacerbating existing social inequities. Inadequate land use planning can perpetuate these disparities by concentrating environmental risks and limiting access to resources and opportunities for vulnerable populations.

To address these vulnerability factors, the GCF project will promote and support the inclusion of climate change adaptation in mid-term, spatial, and regional development plans in West Kalimantan. In particular, REDD+ and Ecosystem-based Adaptation (EbA), are still not fully mainstreamed and integrated into the long and mid-term Regional Development Plans at the provincial and regency levels. The alignment of the provincial REDD+ policies with the national mitigation policies and regulations will be strengthened.

Where lack of coordination between critical ministries and agencies becomes particularly evident is in the gap between forest and land governance on the sub-national level. Agriculture and forestry often compete for land and resources, leading to conflicts over land use priorities. Expansion of agricultural land can result in deforestation and forest degradation, which can undermine ecosystem services provided by forests. Forests provide important ecosystem services that enhance resilience to climate change impacts, such as regulating water flows, reducing soil erosion, and protecting against natural hazards like floods and landslides. Forests are home to a significant portion of the world's biodiversity, providing habitat for countless plant and animal species. Forests play a crucial role in sequestering carbon dioxide from the atmosphere, helping to mitigate climate change. Inadequate forest and land governance can compromise these ecosystem services, leaving regions of West Kalimantan more vulnerable to climate risks and disasters.

Forests and agricultural lands are both susceptible to wildfires, which can have devastating ecological, economic, and social consequences. Uncontrolled fires in forests can spread to adjacent agricultural areas, destroying crops, livestock, and infrastructure. Collaborative efforts between forest and agricultural stakeholders are essential for fire prevention, early detection, and suppression.

Many communities in West Kalimantan rely on forests and natural resources for their livelihoods, including through activities such as agriculture, forestry, and ecotourism. Lack of clarity and consistency in forest and land governance can fuel conflicts over land tenure, resource rights, and access to natural resources. Competing interests among different stakeholders, including local communities, indigenous peoples, government agencies, and private companies, may lead to land disputes, social tensions, and even violence, further undermining efforts to address climate change.

In the absence of integrated forest and land governance, sub-national regions may experience higher rates of deforestation and forest degradation, risking failure at the achievement of sub-national FOLU Net Sink 2030 targets. Weak enforcement of land use regulations, unclear land tenure, and conflicting policies among different government agencies can lead to unplanned land conversion for agriculture and infrastructure, resulting in forest degradation and deforestation, as well as biodiversity loss. The project will strengthen mitigation actions through improved REDD+ implementation towards achieving sub-national FOLU (Forestry and Other Land Use) Net Sink 2030 targets. Furthermore, the project will support the restoration and rehabilitation of mangrove and peat forest ecosystems (3.2.1.4.).

Overall, recognizing and managing the interdependencies between agriculture and forests is critical for promoting sustainable development, conservation of natural resources, and resilience to environmental changes. Integrated land use planning and sustainable land management practices are needed to reconcile competing land uses and minimize conflicts. A concrete example is the requirement to strengthen the regulatory framework and implementation of High Conservation Value and High Carbon Stock (i.e., HCV, HCS) areas on non-state forest land (1.2.1.). The project will support the development and strengthening of regulations at provincial and regency levels, to govern the protection and sustainable management of the high biodiversity and carbon areas (1.2.1.2.).

Summarizing, to address the gap between forest and land governance at the sub-national level integrated approaches that promote coordination among different government agencies, stakeholders, and sectors are required to strengthen climate change adaption capacities in West Kalimantan. This will be approached through enhancing institutional arrangement (1.1.3.1) and supporting activities of the provincial body for climate change (1.1.3.2).

The outlined gaps in forest- and land governance are determining an insufficient integration between local and indigenous communities in sustainable land and forest management. Recognition and protection of customary land rights, and ensuring meaningful participation of affected communities in decision-making processes are crucial steps toward achieving improved climate change adaptation. Indigenous and local communities rely heavily on natural resources for their livelihoods.

The exclusion of local and indigenous communities from decision-making processes can lead to conflicts over land and resource use. When these communities' rights to land and natural resources are not recognized or respected, they may face encroachment by external actors, such as commercial interests or government agencies, leading to tensions and disputes over resource access and control. An approach to improve the role of indigenous and local communities in conserving forests, biodiversity, and maintaining ecosystem services is through the implementation of various social forestry schemes. Overall, ensuring the meaningful participation and inclusion of indigenous and local communities in sustainable land and forest management is essential for promoting social justice, achieving sustainable development, and addressing climate change adaptation effectively.

Decision-making processes related to land use planning, natural resource management, and climate adaptation often exclude local/indigenous communities with unclear land tenure rights. Unclear land tenure results in insecurity especially for marginalized communities and indigenous peoples who rely heavily on land for their livelihoods. Without secure rights to their land, these communities may face displacement, loss of access to natural resources, and increased vulnerability to climate-related shocks, such as extreme weather events. Unclear land tenure can discourage investments in sustainable land management practices and climate adaptation strategies. Without secure land rights, landholders may be reluctant to make long-term investments in climate change adaptation activities.

Climate change-induced environmental degradation, such as sea-level rise, desertification, and loss of agricultural productivity, can exacerbate existing land tenure disputes and lead to forced displacement and migration. This will add to land tenure disputes, exacerbated by climate change impacts, such as competition for scarce resources and changing land use patterns. Contested or unclear land rights may escalate into conflicts over access to land and natural resources, leading to social instability.

The Indonesian government is aware about the importance of secure land tenure and has initiated measures to accelerate land registration. E.g. the Indonesian Sustainable Palm Oil (ISPO) standard calls for mandatory land registration.

Addressing the challenges posed by unclear land tenure and rights is essential for building resilience to climate change and promoting sustainable development. Thus, the GCF project will support the clearing up and simplification of land tenure issues in West Kalimantan.

Effective climate action relies on robust data monitoring and reporting among relevant stakeholders. However, the described lack of coordination between ministries and agencies hinders comprehensive data sharing and collaboration, leading to fragmented information systems and incomplete understanding of climate change impacts, vulnerabilities, and mitigation opportunities.

Consequently, lack of coordination can lead to delays in decision-making processes related to climate change, as inter-sectoral conflicts or bureaucratic hurdles may impede progress. Delayed decision-making can prolong the implementation of urgently needed climate policies and measures, exacerbating the impacts of climate change and increasing the costs of mitigation and adaptation efforts in the long run.

Addressing the challenges of coordination requires strong leadership, effective governance structures, and institutional mechanisms for inter-sectoral, as well as inter-regional collaboration and coordination. Establishing clear mandates, communication channels, and decision-making processes can help overcome silos and ensure that ministries and agencies work together cohesively to tackle the complex challenges posed by climate change.

The implementation of these activities is expected to reduce GHG emissions from deforestation and degradation, enhance forest carbon stocks through reforestation and forest land rehabilitation, improve good agriculture practices and ultimately strengthen the resilience of forest and peat landscapes in West Kalimantan. The combined result is a reduced vulnerability to climate change hazards, leading to a decreased risk of income losses and threatened livelihoods for West Kalimantan.

Institutional & Technical Capacities Barrier:

Building institutional capacity is critical for implementing adaptation measures effectively. This includes enhancing the capacity of government agencies, civil society organizations and research institutions to assess climate risks, develop adaptation plans, and implement relevant measures.

Weak institutional capacities hinder the development and implementation of comprehensive climate change adaptation strategies, as reflected in mid-term, spatial, and other regional development plans. Without adequate technical expertise and adaptation capacities, local governments and communities are insufficiently prepared for climate-related hazards such as extreme weather events, sea-level rise, and changing precipitation patterns. This can result in ad-hoc or reactive measures that fail to address long-term adaptation needs. Weak institutional capacities may also undermine coordination and collaboration among relevant stakeholders, including government agencies, local communities, and civil society organizations. This can lead to fragmented efforts, duplication of activities, and missed opportunities for synergies in climate change adaptation initiatives. To address the vulnerabilities outlined above the project will strengthen the capacities for climate change adaptation of government institutions (agricultural agencies, FMUs). as well as for stakeholders at provincial, regency and village levels to implement and scale up sustainable AFOLU (Agriculture, Forestry, and Other Land Use) practices.

Jurisdictional Approaches (JA) are deemed an appropriate tool for improved coordination and collaboration among relevant institutions and stakeholders in West Kalimantan. This will include the establishment of a commodity-based platform at the regency level and engagement with provincial, national and international Multi-Stakeholder-Platforms (MSPs) to promote dialogue on sustainable forestry & agriculture practices, investment into sustainable supply chains and sustainable sourcing practices (2.1.3.1.). Enabling Jurisdictional Approach certification for Ketapang Regency as a replicable model of REDD+ implementation to other regencies in West Kalimantan Province (1.2.1.5).

Limited financial and human resources allocated to institutions responsible for land use and forestry can constrain adaptation efforts. Thus, the project will strengthen the institutional framework for peatland and biodiversity conservation and develop a multi-stakeholder partnership framework to provide underlying sustainable financing.

Insufficient technical support by local governments may limit local communities' ability to adapt their livelihood practices to changing environmental conditions. This can result in decreased productivity, income loss, and increased food insecurity, particularly for communities dependent on climate-sensitive sectors such as agriculture, forestry and fisheries. To counteract these vulnerabilities the project will strengthen community-based management and conservation of peatland systems in targeted landscapes.

Addressing these challenges requires investments in capacity-building, knowledge transfer, technology transfer, and institutional support tailored to the identified needs and priorities of West Kalimantan. The advancement of social forestry schemes is particularly of particular interest in this regard.

Overall, addressing institutional capacity barriers is essential for enhancing the resilience of land use and forestry systems to climate change. Strengthening capacities through investment in training, advancement of social forestry implementation, technology transfer, policy support, and stakeholder engagement can improve governance, foster innovation, and promote sustainable practices that contribute to climate change adaptation and mitigation goals.

Financial Mechanisms Barrier:

Financing climate adaptation efforts is a major challenge, particularly for developing countries and vulnerable communities with limited resources. Insufficient financial resources can undermine efforts to build resilience and protect communities from climate-related hazards. This leaves communities more exposed to the impacts of extreme weather events, leading to loss of life, property damage, and economic disruptions.

Inadequate funding for adaptation can exacerbate existing inequalities and disproportionately affect marginalized groups, including women, people living in poverty and indigenous people. These groups often have limited resources and capacities to cope with climate change impacts, making them more vulnerable to its adverse effects.

Without adequate funding, governments, communities, and organizations may struggle to implement adaptation projects and initiatives. This can result in delays or cancellations of planned activities, leaving vulnerable communities ill-prepared to cope with climate change impacts. The failure to invest in climate change adaptation can result in higher long-term economic costs associated with disaster response, recovery, and reconstruction. Delaying adaptation measures may lead to increased damages, insurance premiums, and public expenditures related to climate-related disasters, placing a greater burden on governments, businesses, and communities in the future.

Addressing the consequences of insufficient financial support for climate change adaptation requires increased investment from governments, international organizations, and other stakeholders. In addition to public finance, leveraging private sector investment is crucial for scaling up adaptation efforts. The Green Climate Fund (GCF), an international climate fund, provides financial support to developing countries for climate adaptation and mitigation projects for mobilization of adequate funding, leveraging innovative financing mechanisms, and prioritizing adaptation in development planning. These are all essential steps toward building resilience and safeguarding communities from the impacts of climate change.

In West Kalimantan financial mechanisms for climate-resilient and low-emission forest and landscape management are insufficient. This leads to a lack of finance to advance the implementation of social forestry schemes, which particularly benefit Indigenous People (IP). Thus, the project will develop and implement social forestry management plans and support new social forestry permit proposals for local communities (3.2.1.1.). The support will encompass the development of sustainable financial mechanisms that ensure meaningful engagement of IP, as well as accelerate and enable access to potential financial streams for social forestry for climate change mitigation and adaptation strategy (3.2.1.6.).

Financing mechanisms potentially include sustainable financing models, such as payments for ecosystem services or climate finance. Payments for ecosystem services schemes, such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation), provide financial incentives to conserve and sustainably manage natural resources. However insufficient institutional budget allocations for Forest Management Units (FMU) are preventing the development and implementation of climate-informed forest- and peat management plans, including fire management. FMUs, who are in charge of managing and protecting vital forest and peat ecosystems are plagued by human capacity deficits and chronic underfunding, which prevents them from effectively filling their role.

Thus, the project will support FMUs in developing and implementing climate-informed forest management plans (1.3.1.). Crucially this involves provision of training, technical assistance, and resources to FMUs to enhance their capacity in climate-informed management practices. Thereby FMUs will become capacitated to integrate climate change considerations into forest management planning, such as the effectively identifying and implementing of measures to manage and prevent forest fires. This will include the elaboration of strategies, policies, and procedures for one or several financing mechanisms for climate-resilient agriculture and forestry (1.3.1.2.).

Implementing those adaptation measures will result in capacitated FMUs and private sector actors incentivized to engage in implementing climate-informed protection and sustainable management of forest and peat ecosystems.

On the whole, this will improve the management, security, and rehabilitation of forest and peatland ecosystems, as well as the conservation of biodiversity and water resources. These successfully proven sustainable land and forest-based investment business models will then be scaled up to other regions of West Kalimantan (2.1.1.).

Markets Barrier:

Market mechanisms can complement regulatory and financial approaches to climate adaptation by harnessing market forces to incentivize adaptive behaviour and investments. Building linkages within market value chains can enhance supply chain resilience to climate change impacts. Diversification of suppliers, geographic sourcing, and investment in climate-smart logistics and infrastructure can improve resilience to shocks such as extreme weather events, natural disasters, and other climate-related risks.

Integration into market value chains can incentivize sustainable production practices throughout the supply chain. This includes promoting eco-friendly production methods, reducing contamination, and adhering to social and environmental standards, all of which contribute to climate change adaptation and mitigation efforts.

Linking local producers to market value chains can also promote inclusive development by creating opportunities for smallholders and marginalized groups to participate in economic activities. This can empower vulnerable communities to build resilience and reduce poverty through productive and sustainable livelihoods. Integration into market value chains can enable communities to diversify their livelihoods beyond climate-sensitive sectors. This diversification can reduce dependence on sectors vulnerable to climate change impacts and provide alternative income sources that are less susceptible to climatic variability.

To address the challenges outlined above the project will support activities for reducing emission reductions and enhancing sustainability as well as climate resilience of smallholders in crucial commodity supply chains (2.1.2.2). One concrete approach for such an integration is agroforestry. These are systems that integrate trees and shrubs with agricultural crops or livestock, providing multiple benefits such as improved soil fertility, increased biodiversity, and diversified income sources while lowering the requirement for external inputs. Agroforestry practices blur the traditional boundaries between agriculture and forestry, demonstrating the potential for synergies between the two sectors in sustainable land management. The implementation of GRASS (Greening Agricultural Smallholder Supply Chain) constitutes a co-financing activity, through which such approaches are piloted, and market access channels are explored and established.

Furthermore, market value chain linkage can contribute to improved food security and nutrition outcomes by increasing the availability, accessibility, and affordability of diverse and nutritious foods. This can help communities cope with climate-related challenges, such as crop failures, price volatility, and food shortages.

Linking local producers to broader market value chains can provide them with access to larger markets for their goods and services. This can lead to increased income opportunities for producers, thereby enhancing their ability to invest in climate-resilient practices and technologies. Accordingly, the project will improve capacities to implement resilient and sustainable smallholder farming (2.1.2.1.).

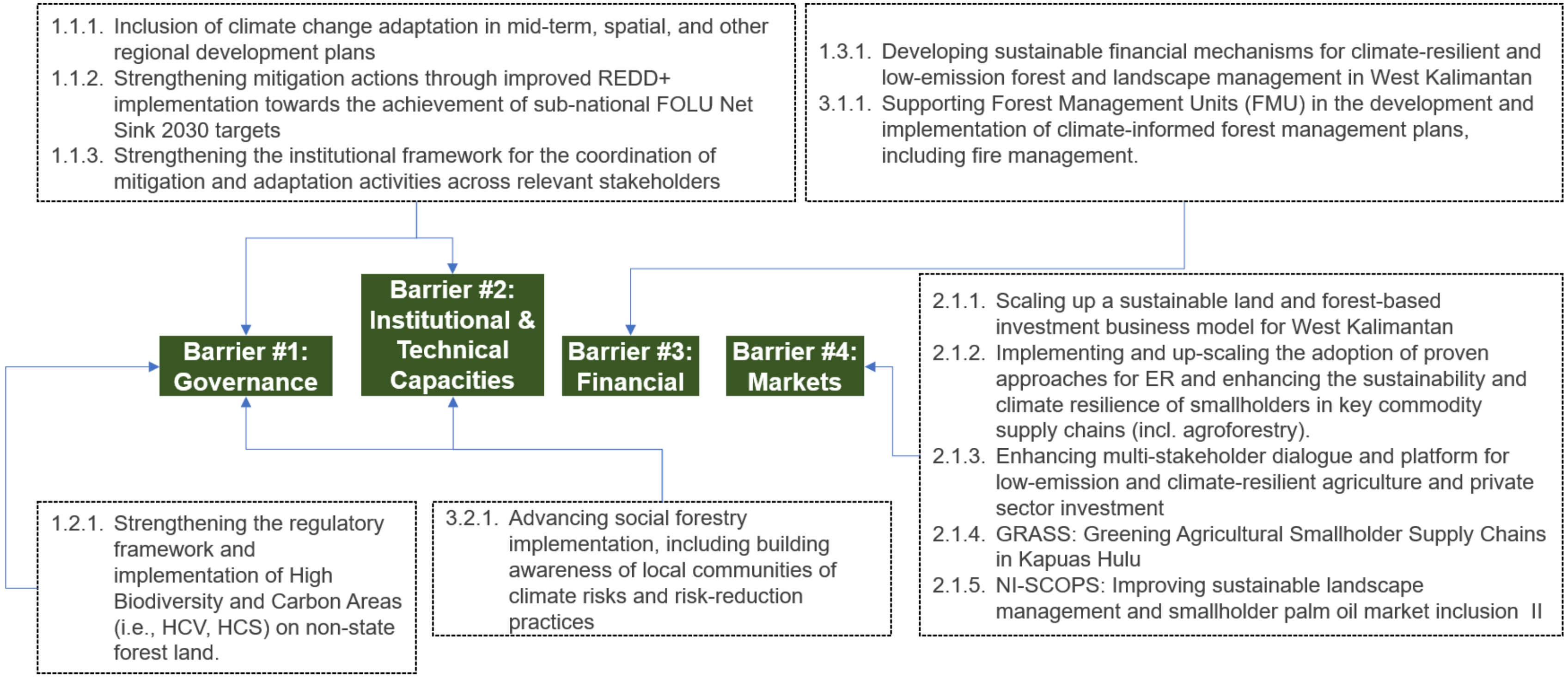
Participation in market value chains can also improve access to financial resources, including credit, loans, and investment capital. This can enable producers to make investments in climate adaptation measures. In West Kalimantan, the absence of effective multi-stakeholder dialogues and platforms to foster low-emission and climate-resilient agriculture and private-sector investment is limiting access to financial resources. There is a lack of sustainable business models for farmers and local communities and only limited functioning value chain linkages to markets. Thus, the project will support the scaling up of a sustainable land- and forest-based investment business model for West Kalimantan. The implementation of NI-SCOPS constitutes a co-financing activity and piloting the improvement of sustainable landscape management and smallholder palm oil market inclusion. The lessons learned will be incorporated in GCF project activities.

Engagement in market value chains often facilitates the transfer of technology, knowledge, and innovation from buyers and investors to local producers. This can enable the adoption of climate-resilient practices and sustainable land management practices. The private sector off-takers are increasingly required by market forces to adopt sustainability principles in their supply chains. An example is the NDPE (No Deforestation, Peat, or Exploitation) commitment by many companies. With specific international sustainability requirements, the requirements to place deforestation-risk commodities on the European Market are becoming much more stringent. The project will join forces with these private sector priorities and support measures for compliance. This includes digital systems for value chain traceability and certification, and improved access to services (2.1.2.3).

Overall, market value chain linkage can play a crucial role in enhancing climate change adaptation by promoting economic development, fostering innovation, and strengthening resilience at the local and global levels.

Concludingly, addressing the challenges of climate change requires a multi-faceted approach that encompasses governance, institutional capacity building, financial mechanisms, and market interventions. By integrating adaptation considerations into policy and planning processes, strengthening institutional capacity, mobilizing financial resources, and harnessing market forces, West Kalimantan can enhance its resilience to climate risks to build a more sustainable future.

Figure 85: Identified adaptation options for addressing the barriers in West Kalimantan



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