A Synthesis Report of Vulnerability Assessment for Increasing Livelihoods Resilience through Climate-Smart Agriculture in West Kalimantan

WORLD AGROFORESTRY (ICRAF)
SOLIDARIDAD
2020

A Synthesis Report of Vulnerability Assessment for Increasing Livelihoods Resilience through Climate-Smart Agriculture in West Kalimantan

WORLD AGROFORESTRY (ICRAF)
SOLIDARIDAD

2020

Citation:

World Agroforestry (ICRAF) and Solidaridad. 2020. *A Synthesis Report of Vulnerability Assessment for Increasing Livelihoods Resilience through Climate-Smart Agriculture in West Kalimantan.* Bogor, Indonesia: World Agroforestry (ICRAF) Southeast Asia Regional Program.

World Agroforestry (ICRAF) Southeast Asia Regional Program

Jl. CIFOR, Situ Gede, Sindang Barang,Bogor 16115 [PO Box 161 Bogor 16001] Indonesia
Tel: +(62) 251 8625 415 Fax: +(62) 251 8625416
Email: icraf-indonesia@cgiar.org
www.worldagroforestry.org/region/SEA
blog.worldagroforestry.org

2020

Table of Contents

Figures

Tables

EXECUTIVE SUMMARY

Over the past 30 years, West Kalimantan has experienced massive land-use changes from vast forested areas into agricultural landscapes with forest remnants in the upstream areas. The major driver of land use-changes is the increasing demand for agricultural products locally and globally, and increasing population, therefore increasing demands for agriculture-based livelihoods. Changes in land-use and land cover have been widely known to the largest source of Green House Gas (GHG) emissions in most areas in Indonesia, including West Kalimantan. GHG emissions cause global warming and extreme weather. Locally, the direct influence of land use changes is experienced through increased temperature and reduced buffering capacity of the watershed, which in interaction with extreme events, will expose the landscape and the livelihood of people into negative impacts if resilience is lacking. As the West Kalimantan region belongs to two rainfall patterns, i.e., equatorial and monsoonal, the subregion is exposed to different challenges, and therefore needs to respond differently to the changing climate.

Prior to this project, the impacts of climate change on the local livelihoods, commodities, and the landscapes in West Kalimantan have not yet been studied. This project aims to fill the gap by assessing the vulnerability of agriculture-based livelihood to changing climate in the seven districts, namely: Bengkayang, Mempawah, Landak, Sekadau, Sanggau, Sintang, and Kapuas Hulu, through a combination of methods for data collection and analysis, from a participatory approach by conducting Focus Group Discussions (FGDs) with the local communities and governments to spatial analyses of hotspots, fire risks, deforestation potentials, and changes in land-use over the past five years. Besides, secondary data was also collected through literature reviews and discussions with key stakeholders in West Kalimantan.

The primary and secondary data were combined, mapped, and analyzed to produce a vulnerability class, of which villages are grouped based on characteristics that are theoretically relevant, according to literature, in determining the vulnerability of agriculture-based livelihoods to climate change. The set of characteristics used to develop the vulnerability class encompasses the contexts and trends of a set of spatially explicit variables that serve as a proxy of potential climate hazards and capacities to adapt, which together define their potential vulnerability to climate change. In this vulnerability class, villages under similar characteristics are grouped under the same vulnerability class. In total, five village vulnerability classes are constructed under the typology of agriculture-based livelihood vulnerability. The five vulnerability classes represent the villages that are: most vulnerable, highly vulnerable, moderately vulnerable, less vulnerable, and least vulnerable. The typology serves two purposes, ie. (i) providing the basis of village sampling for a detail participatory data collection; and (ii) allowing the extrapolation of results from the sampled villages to the rest of the group under the same cluster with regards to their vulnerabilities and potential interventions to increase their livelihood resilience to climate change.

We conducted the vulnerability assessments of communities' agricultural-based livelihoods to extreme climate events in three stages: (i) study the extreme events' exposure to and impacts on the agricultural-based livelihoods; (ii) document the responses of local communities to such exposures and impacts; (iii) identify the climate risk and adaptation potentials, along with their enabling factors. The assessment is conducted for each village vulnerability class. In this assessment, we particularly look at three main dimensions: water resources, farming systems, and marketing of dominant agricultural commodities. The choice was made based on our understanding that these three factors are key livelihood factors to be impacted by extreme events and, at the same time, the most potential areas to intervene in responding to extreme climate events.

From this study, we identified two major extreme events that impact agriculture-based livelihoods in West Kalimantan, i.e., climate events (prolonged drought and heavy rainfalls) and market shocks. Prolonged drought is of higher impacts on the agricultural-based livelihood compared to heavy rains. Prolonged drought-induced pest outbreak and extreme temperature dried the crops that caused harvest failures. The effect of prolonged drought on rubber-based farming systems and oil palm farming systems is mostly in the decreasing production. Severe drought also induced forest and land fire, which brought devastating impacts socially, economically and environmentally. The level of exposure and impacts, and the type of local communities' responses are variable across village clusters.

Based on the assessments, we formulated strategies to increase the resilience of livelihoods to extreme climate events at the village vulnerability Class level and district level. In the strategies, the development of capacities for local farmers to manage climate-smart agriculture systems and the existence of enabling factors are the primary strategy for increasing the resilience of agricultural-based livelihood to extreme events. Specifically, recommendation on climate-smart agriculture intervention should adhere to the three principles: having sustainable production; locally suitable and in synergy with climate change mitigation, i.e., climate-neutral at the very least.

1 INTRODUCTION

Climate change has undeniably started to take its toll. It is anticipated that the poor will be impacted more than the rest. Rural people or farmers, who depend on agricultural production for their livelihoods, are exposed to the risks of the large potential negative impacts. Buffering systems and adaptive capacities are imperative for livelihood resilience to climate change. Other external socio-economic-political aspects, which may or may not be interlinked with climate change, at the same time, may expose people to similar risks and need similar or interlinked capacities to address.

Under a changing climate, farmers, particularly poor farmers, are susceptible. They need alternative options in managing their landscape to achieve socio-economic benefits while also maintaining or improving ecological benefits. A Climate Vulnerability Assessment (CVA) can assist the identification of existing and potential shocks or extreme events, causes of extreme events as well as current and potential actions to cope and to reduce risks. The results of the vulnerability assessment are instrumental in developing strategies to increase farmers' resilience to climate change. The strategies have to prioritize interventions that need to be urgently implemented at livelihood, key commodities, and landscape levels.

Climate change brought an additional overarching layer of challenges to commodities and local societies and currently has significant implications for the future of commodity production and community livelihoods in many parts of Indonesia. In Indonesia, the agriculture sector contributes around 13.5% to the Indonesian Gross Domestic Products; 26.4% of which comes from plantation crops as the highest contributor to the agricultural sector. Additionally, the commodity sectors are sensitive to price fluctuations and inefficient supply chain, hence influencing the farmers income. Farmers who rely on a single commodity experience the worst impact so does the regional economy of the district.

Opportunities exist to reduce the impacts of climate change and other socio-economic-political stressors by building the resilience of farmers to withstand the adverse impacts of climate change, with the expectation that the agricultural productivity and farmers' livelihood will remain socially, economically, and environmentally stable. To achieve that, a climate vulnerability assessment delves into three interacting factors: exposure to climate stressors, sensitivity to those stressors, and adaptive capacity to manage stressors. Increasing the resilience of farmers through climate-smart agriculture as part of a broader green growth from the renewable land-based sector at the landscape level is the way to go in adapting and mitigating climate change in rural areas.

West Kalimantan, the third largest province in Indonesia, has an area of around 14.73 million hectares and a population of over 5.3 million in 2018. Agriculture, forestry, and fisheries are the largest contributors to the Provincial Gross Regional Domestic Product (GRDP). The Gross Regional Product per capita of West Kalimantan in 2018 was IDR 38.8 million, below the national average of IDR 56.0 million. The Human Development Index of West Kalimantan is 0.66, below the national average of 0.71, with a poverty rate of 8% and an unemployment rate of 4.23 (West Kalimantan Province in Figure, 2019).

Over the past 20-30 years, there has been a growing trend of changing climate patterns in West Kalimantan through increased temperature from 0.3 to 1˚C; a slight increase in precipitation rate; and a slight decrease in precipitation frequency (Sipayung et al., 2018; unpublished data from Badan Meteorologi dan Klimatologi Kalimantan Barat in 2019). However, the changing climate patterns are slightly different from place to place, depending on the land cover and other landscape characteristics of the area. There is also a trend of more frequent incidences of prolonged drought due to the El Nino phenomenon that has impacted the production of crops in West Kalimantan and Indonesia. The worst El Nino over the past 30 years happened in 1997-1998 and 2014-2015, which has caused environmental and economic losses. Smallholder farmers are susceptible to climate change as it will cause food insecurity and reduce their income due to crop failure. More than 50% of the population in West Kalimantan are smallholder farmers. With the goal is to mitigate the impacts of climate change to the local livelihood, a Climate Vulnerability Assessment (CVA) need to be conducted to identify existing and potential shocks or extreme events, causes of the extreme events as well as the current and potential actions to cope with the risks and to reduce the risks. The results of the vulnerability assessment are expected to contribute to developing strategies to increase farmers' resilience to climate change in West Kalimantan.

Objectives and expected outputs

Vulnerability assessment of agricultural-based livelihoods to climate change was conducted in seven districts of West Kalimantan (Bengkayang, Mempawah, Sekadau, Sanggau, Landak, Sintang, and Kapuas Hulu District), with three main objectives, i.e.:

- Identify risks and exposure of key commodities and beneficiaries, including farmers, to climate change;
- Assess the impact of climate change on the key commodities and beneficiaries;
- Develop strategies to increase the resilience of key agricultural systems and beneficiaries to climate change.

Considering the variability of the local contexts, and therefore no one size fits all regarding vulnerability levels, causes, impacts and options to increase resilience. We developed a typology of village-level vulnerability using secondary socio-economic and biophysical data. For the community-level vulnerability assessment, we sampled villages based on the typology. The community-level vulnerability assessment was conducted in two focal areas per district. In total, there were 14 focal areas assessed in this study. The expected outputs from this assessment:

- Characterization of vulnerability class at the village level for all villages in seven districts;
- Hotspot data analysis, deforestation risks, and forest and land fire risks due to land uses and land-use changes;
- Data and analysis of Shocks, Exposures, Responses, and Impacts experienced by communities of focal areas to climate change;
- Strategies to increase resilience and adaptation potential at the village and district level.

Report structure

The report is divided into five chapters. The first chapter gives the background for the vulnerability assessment, the objectives and expected output of this vulnerability study. Chapter 2 describes the study area, including characteristics of the people, demographic statistics, and the source of livelihoods. It also provides information on the land-use change trajectories for 2012-2017, the climatic variabilities in West Kalimantan, and the risk of fire and deforestation across the seven districts. This information, combined with existing governmental programs on climate change adaptation and mitigation, provides the situation and condition of the community and landscape that form the sensitivity and potential exposure of the study areas to climate change. Chapter 3 presents the detailed result of the vulnerability assessment. We developed vulnerability class from the secondary data that is relevant in determining the vulnerability of the agricultural-based livelihoods to climate change. The typology serves as the basis to sample in-depth assessment of community-level agricultural-based vulnerability to climate change across villages with various village-level vulnerability classes. The land-use changes and their drivers are pivotal points between agricultural-based livelihoods and ecosystem health that buffers livelihoods and landscapes from exposure and impacts of extreme events. The extreme events that occurred in the study area are identified, along with the existing coping mechanisms and responses. The effects of such extreme events on people's livelihoods and key agricultural commodities are studied. The potential enabling factors to support the adaptation of the agricultural-based livelihood to climate change are discussed. Chapter 4 explains potential strategic interventions to increase agricultural-based livelihood resilience to extreme events through climate-smart agriculture. The strategies are identified at the village cluster and district level. Chapter 5 describes the general conclusion of the study.

2 SITE DESCRIPTION

The understanding of the broader contexts surrounding the villages where the communities live is necessary for assessing the communities' agricultural-based livelihoods vulnerability to climate change and identifying options or strategies to increase their resilience. The extent of this study is seven districts in West Kalimantan. This chapter describes the study area, from the general description of the geography, demography, sources of livelihoods, issues in natural resource management, land-use changes and government programs in mitigating and adapting climate change, which is central to agricultural-based livelihoods. Then we discuss climate variability during the past years. It is widely known that forest and land fire risks are high in these areas, and it has enormous socio-economic and environmental costs. Fire risk is shaped by climate change, forest degradation and deforestation and also land clearing practices for agriculture. Therefore, the last section in this chapter is devoted to discussing fire and deforestation risks.

We use several sources of data and information, such as secondary, statistical data, spatial data and local knowledge. We employ a range of methods in the data collection of analysis from statistical analysis, spatial analysis, modelling and FGD. This information, combined with existing governmental programs on climate change adaptation and mitigation, provides the contexts that affect the sensitivity and potential exposure, and therefore vulnerability, of the communities and villages to climate change.

2.1. General description

West Kalimantan Province consisted of 12 districts and two cities that spread from coastal areas to inland (Figure 1.). In this climate vulnerability assessment, seven districts were selected as studied sites, i.e., Mempawah, Bengkayang, Landak, Sanggau, Sekadau, Sintang and Kapuas Hulu. These seven districts, which cover more than 60% of West Kalimantan total area, have different land cover composition that can be grouped into three, i.e., (i) districts dominated by shrublands (Mempawah, Bengkayang, Landak); (ii) districts dominated by agroforestry (Sanggau and Sekadau); (iii) districts dominated by forested area (Kapuas Hulu and Sintang). Different domination of land cover may affect landscape responses to extreme climate events.

Five of seven studied districts, except Bengkayang and Mempawah, are located within Kapuas Watershed. Bengkayang is part of Sambas and Selakau Watershed, while Mempawah is part of several watersheds as this district has coastal areas.

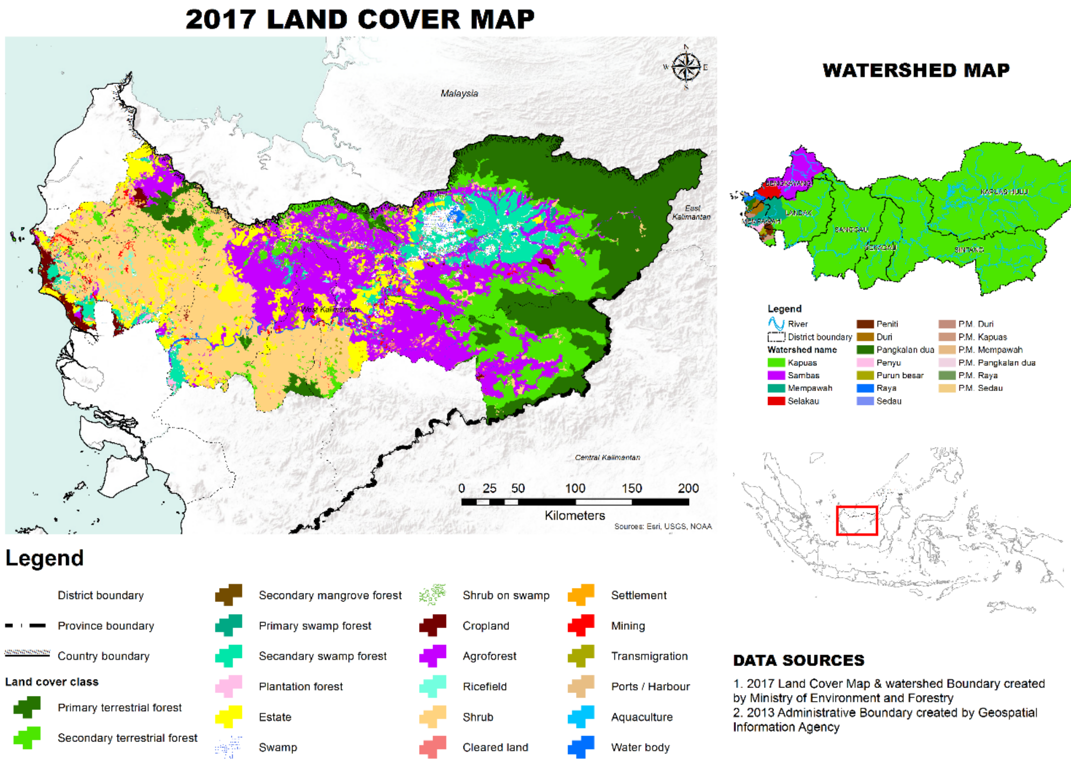


Figure 1. Landcover map of the 7 studied districts in West Kalimantan Province in 2017 from Indonesia Ministry of Environment and Forestry.

2.1.1. Sources of livelihoods in the studied districts

Agriculture is the main livelihood options across the seven districts, with rubber and oil palm as the primary tree commodities, managed by estate plantations and smallholders[1]. In Landak, both commodities contribute to 60% of agricultural production. Coconut is also commonly produced in Mempawah and Bengkayang, with the addition of pepper and cacao emerging in Bengkayang. Rice is the primary crop commodities across the district except in Landak and Sintang. Other crop commodities such as vegetables and maize are also commonly produced in Bengkayang, Mepawah and Kapuas Hulu. As a coastal district, the fishery is also a source of livelihood in Mempawah. Below are the detailed information on the condition in each studied district.

Landak District covers an area of 990,910 ha and consists of 151 villages with a population density of 37 persons/km^2. The dominant ethnic groups in Landak District are Dayak, Malay, and Javanese. The main sources of livelihood of the people in Landak District are farming and the extraction of natural resources. As of 2018, 60% of people are dependent on oil palm and rubber commodities, managed both by smallholders and companies. Natural resources exploitation includes mining of gold, diamond, and sand by the villagers and bauxite mining managed by PT. Antam Tbk.

---

[1] This session relies on secondary data from Statistics Indonesia (BPS) in 2019.

Mempawah District covers an area of 279,788 ha and consists of 67 villages. The people are dominantly from the Dayak and Malay ethnic groups, with a population density of 205 persons/km^2. The main sources of livelihood for the majority of the people in Mempawah District are agriculture. Varieties of agricultural commodities are planted such as bananas, pineapples, paddy, and estate crops consisting of rubber, coconut, and oil palm. Mempawah has coastal areas, and therefore fisheries are also a source of income for the community.

Bengkayang District is a relatively new district located in West Kalimantan Province. It was only developed in 1999 and now has 124 villages. In general, the population of Bengkayang District is dominated by the Dayak and Malay ethnic groups. The population density in Bengkayang District is approximately 47 persons/km^2. The main source of livelihood for its communities is agriculture, both for annual and perennial crops, managed either by the communities or companies. The most common annual crops are paddy, both in irrigated and non-irrigated fields, maize and vegetables. The perennial crops include rubber, pepper, and oil palm. Some farmers also grow coconut and cacao.

Sanggau District has an area of 1,285,570 ha with 169 villages and a population density of 35 persons/km^2. The main source of livelihood of the community living in this district is agriculture, mainly for food crops and estate crops commodities, both managed by smallholders and companies. Rubber, oil palm, and paddy are the three major commodities grown in Sanggau District. In addition to agriculture, mining is also a source of community income, particularly bauxite mining, which is managed by PT. Antam. Many people also conduct gold mining in the river.

Sekadau District covers an area of 544,430 ha and consists of 87 villages with a population density of 37 persons/km^2. The population is predominantly from of Malay, Dayak, and Javanese ethnic groups. The local sources of livelihood in Sekadau District are agriculture and trading. Farmers mostly cultivate oil palm and rubber. Reduced price of rubber causes some rubber traders (*tauke*) to shift professions and become grocery vendors. Likewise, those who cannot meet their daily needs by working in rubber plantation become migrant workers or other non-farm workers in other towns.

Sintang District has an area of 2,163,500 ha with 391 villages and a population density of 19 persons/km^2. The majority of its population consists of the Dayak, Malay, and Javanese ethnic groups. The main local livelihood in Sintang District is farming, with rubber and oil palm as the major agricultural commodities. Most people in Sintang also make a living by collecting non-timber forest products, such as *illipe nut (Shorea sp.)*, candlenut, fish, rattan, and honey. Mining is also a source of livelihoods for the community in Sintang. This is found, particularly in the upstream of the Melawi River, where gold mining activities are still widely conducted by the community, mostly in the dry season.

Kapuas Hulu District covers an area of 2,984,200 ha consisted of 278 villages with a population density of nine persons/km^2. In general, its population is dominated by the Dayak and Malay ethnic groups and migrants from Java. Compared to other districts in West Kalimantan, the forested areas in Kapuas Hulu are relatively large, i.e., 71% of the total district area. The livelihood of the people in Kapuas Hulu District is agriculture and non-timber forest product extraction. Most common NTFPs are fish, honey, and rattan. The community mostly grows rubber and annual crops, such as paddy and vegetables, using the shifting cultivation practices. After land burning was prohibited, the community limited the practice of shifting cultivation, which was commonly used for lad clearing to grow food crops to meet basic needs, such as paddy and vegetables.

2.1.2. Natural resources management issues

We held a workshop on "Climate Change and Its Impact on Agriculture and Forestry-Based Livelihoods in West Kalimantan" on 18 September 2019. Representatives from the seven studied districts attended the workshop and contributed actively to the participatory sessions and share their local knowledge. The stakeholder highlighted that natural resources management issues in the districts are mainly related to the intensification of land-use and land-use conversions over the past 20-30 years. The changes are particularly marked in shrubland-dominated districts and agroforestry-dominated districts. In forested districts, issues of fire and illegal mining were brought up frequently. Frequent floods, particularly in the riverbank areas, were also discussed.

Forest and land fires occur due to land clearing activities by plantation concessions and the slash-and-burn system implemented by the communities as part of their shifting cultivation practices. Forest and land fire more frequently take place in shrubland and agroforestry-dominated districts, such as Mempawah, Landak, Bengkayang, Sanggau, and Sekadau. Fires that occur in Mempawah are usually more severe due to the peatland areas in the district. Besides Mempawah, Kapuas Hulu also has a large area of peatlands.

Floods occur more frequently in districts that are located in the downstream areas such as Mempawah and Bengkayang. From the discussion with stakeholders in Mempawah and Bengkayang, floods happen regularly every year, and they get more severe during heavy rainfall as the effect of the La Nina phenomenon.

Massive land-use changes for agriculture and mining in the seven studied districts have transformed the landscapes. They have caused river sedimentation and disrupted the water balance system. Where significant tree cover turned into shrublands, people experience the decreases in the water level of their wells. The water level of the river fluctuates quite highly, i.e., decreases in a short period without rain and rapidly increases during heavy rains.

Mining is not directly related to climate change. However, gold and bauxite mining by companies and the community have been massive. Mining activities mostly take place in the riverine area, and it has been polluting the river water. This effect in water quality poses health problems since many communities in West Kalimantan still rely on river water as a source of drinking water, especially during the prolonged drought seasons.

2.1.3. Land-use changes

Based on the discussion with local stakeholders in the seven districts, over the past 20-30 years, expansions of oil palm, rubber, timber, and mining concessions in West Kalimantan have been significant. Communities change their lands, e.g., from rubber and fruit agroforestry to other farming systems to gain higher profit. Before the regulation on zero burning for land clearing was implemented in 2015, most land clearing activities used the slash-and-burn method that would likely cause forest and land fires, leading to negative impacts on the livelihood of the surrounding community. The frequency and magnitude of forest and land fire are exacerbated by climate change and forest degradation in the surrounding areas.

From the analysis of land cover change from 2012 to 2017[2], most dominant land-use changes occurred from dryland and shrubs to newly vegetated lands, which can become new plantations or shrubland. From the seven studied districts, Sanggau has the highest land conversion rate over the past five years. The highest land conversion is due to the new plantation concessions operated in the area, and the community has also started to change their old agroforestry system into more productive land-use systems (Table 1). Landak has the second-largest land conversion rate, followed by Sekadau, Bengkayang, Mempawah, Sintang and Kapuas Hulu, respectively. Kapuas Hulu District experienced much less land-use changes compared to the other studied districts. The low rate of land-use change in Kapuas Hulu is due to the status of the forested areas as state forest, which covers about 75% of the total district area. Kapuas Hulu is in the upstream areas, with the lowest population density and least access. Therefore the pattern observed is not surprising.

Table 1. Dominant land-use change in the seven studied districts of West Kalimantan Province in 2012-2017

Districts	Dominant land-use change	Total land conversion area
Sanggau	Dryland farming and shrubs (mixed gardens/*tembawang* or agroforestry) were converted into shrubland cover (newly vegetated land or non-irrigated paddy fields)	600,000 ha or equal to 47% of the total Sanggau area
Landak	Dryland and shrubs (mixed gardens or agroforestry) to shrubland (newly vegetated land)	561,000 ha or equal to 67% of the total Landak area
Sekadau	Mixed dryland farming with shrubs (mixed garden or agroforestry) to shrubland (newly vegetated land or field)	260,000 ha or equal to 48% of the total Sekadau area
Bengkayang	Dryland farming and shrubs (agroforestry) to shrubland (possibly young rubber/oil palm plantations or non-irrigated paddy fields)	180,000 ha or equal to 34% of the total Bengkayang area
Mempawah	Agroforestry to shrubs, cropland, plantation and irrigated paddy fields	75,000 ha or equal to 27% of the total Mempawah area.
Sintang	Dryland farming and shrubs (mixed gardens or agroforestry) to shrublands (newly vegetated land)	151,448 ha or equal to 7% of the total Sintang area
Kapuas Hulu	Shrublands to plantations (oil palm and rubber)	60,000 ha or equal to 2% of the total Kapuas Hulu area

2 The analysis was conducted by ICRAF by using land cover maps produced by Ministry of Environment and Forestry Indonesia

2.1.4. Government programs on climate change mitigation and adaptation

Environmental Departments at Provincial and District level are the major government institutions that have direct programs related to climate change mitigation and adaptation. Some of the program implemented in West Kalimantan are part of the national-level climate change mitigation and adaptation programs. One of those is Program Kampung Iklim (ProKlim) launched by the Ministry of Environment and Forestry. ProKlim aims to increase community participation in reducing the impacts of climate change and reducing emission from greenhouse gases.

Stakeholders in the seven studied districts also conveyed that there has been a government policy with regards to the moratorium for new oil palm plantations as part of climate change mitigation and adaptation strategy. Other than that, several other measures are reducing massive land conversion rate and risks of land fires; climate-smart village program; rehabilitation or replanting of critical areas; and implementation of social forestry schemes. There are also programs to mitigate the impacts of extreme climate events (drought, heavy rainfall, and pests and disease incidences), such as those related to watershed management, irrigation and drainage infrastructure development, increasing food security, and enforcement of zero burning for land clearing.

Regarding climate-smart agriculture, outreach and extension services to improve farmers' knowledge and capacity have been planned and implemented. However, the program has not reached as many farmers as expected. There are challenges related to the limited government budget allocation for extension services and outreach activities. Thus, based on the discussions with government agencies in the seven studied districts, the participation of other non-governmental agencies is expected to also contribute to enhancing community awareness and capacity to cope with the impacts of extreme climate events.

2.2. Climate variabilities in West Kalimantan

Information on climate variabilities was obtained through discussion in a workshop attended by key government agencies from the seven districts. The workshop was held by the Niscops project on 18 September 2019. Moreover, we also gathered information at the provincial level and the Centre for Meteorology, Climatology and Geophysics (BMKG, Badan Meteorologi, Klimatologi dan Geofisika) in Pontianak. We learned that there had been a changing pattern of climate in West Kalimantan over the past 30 years. However, the trend varies across different parts of West Kalimantan. The region of West Kalimantan differentiated by two rainfall patterns, i.e., equatorial and monsoonal. Depending on these patterns, areas experience different effects of changing climate. Based on the analysis of rainfall data BMKG for the period of 1980 to 2018, we see that there has been a slight increase in the monthly precipitation rate, an increase in temperature, and a decrease in precipitation frequency. The magnitude of changes varies across districts.

2.3. Fire and deforestation risks

Land and forest fire have been known to be impacted by climate events, especially during the prolonged drought in El Nino years. Fire risks are increased with fuel availability due to anthropogenic factors such as deforestation, forest degradation, drained peat, and land clearing with burning. In turn, fire contributes to a significant amount of GHG emissions that further induce global warming. This feedback should be addressed in integrated climate change adaptation and mitigation strategies. Therefore risks of fire and deforestation are quite relevant factors in understanding climate change vulnerability.

In this section, we analyzed hotpots data to understand the trend of fire probability in the areas over time. We then conducted fire risk modelling to identify the driving factors of fire and also to areas that are prone to fire. Lastly, we modelled deforestation and projected the deforestation risk in the future.

2.3.1. Hotspots analysis

A hotspot is defined as an area that has a higher temperature compared to its surrounding. Hotspots distribution data[3] shows fire potential but not fire existences. From the analysis of the time-series of hotspot data of West Kalimantan over the past 20 years, we found that the highest number of hotspots occurred in 2009. In total, 18,569 hotspots were identified. The second-highest number of hotspots occurred in 2015 with a total of 13,776 hotspots, while in 2019, there were 10,848 hotspots (Figure 2). In most years, the highest number of hotspots occur from July to September, i.e., the peak of the dry season. During the period, usually, land clearing for shifting cultivation takes place with the slash-and-burn method. In El Nino years, the slash-and-burn activities would cause massive fires. Other land clearing activities, such as the development of new plantations has also caused enormous forest and land fire. Attribution of who causes what has been a never-ending debate and it is beyond the scope of this report.

[3] Data was taken by MODIS sensor from TERRA and AQUA satellite, from global data that can be obtained every day and provided by NASA (https://firms.modaps.eosdis.nasa.gov/map/). Hotspot data is recorded by MODIS every 3 hours. Hotspot

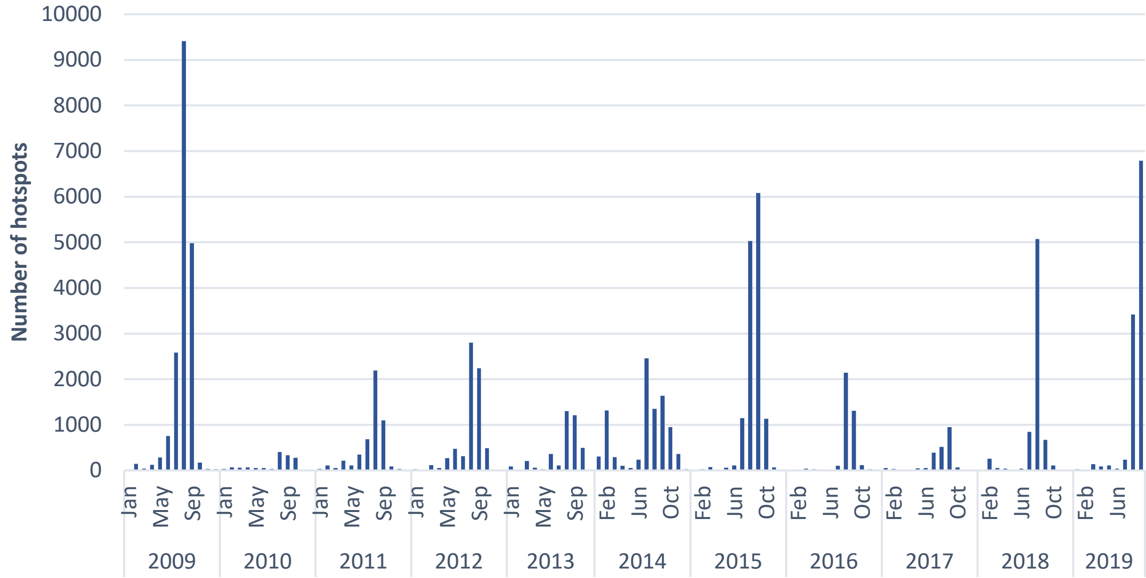


Figure 2. Temporal distribution of hotspots in West Kalimantan from 2009 to 2019

In the studied districts, the proportion of the number of hotspots per total area in each district showed in 2009 Bengkayang has the highest proportion, followed by Mempawah, Sanggau, with Kapuas Hulu as the least (Figure 3). On the other hand, in 2015, Sintang has the highest proportion, followed by Mempawah, Sanggau, Sekadau, Bengkayang, Kapuas Hulu and Landak as the least. In 2019, Mempawah had the highest proportion, with Kapuas Hulu as the least. The reason for the drastic changes in the number of hotspots per areas in 2009 and 2015 required further investigation.

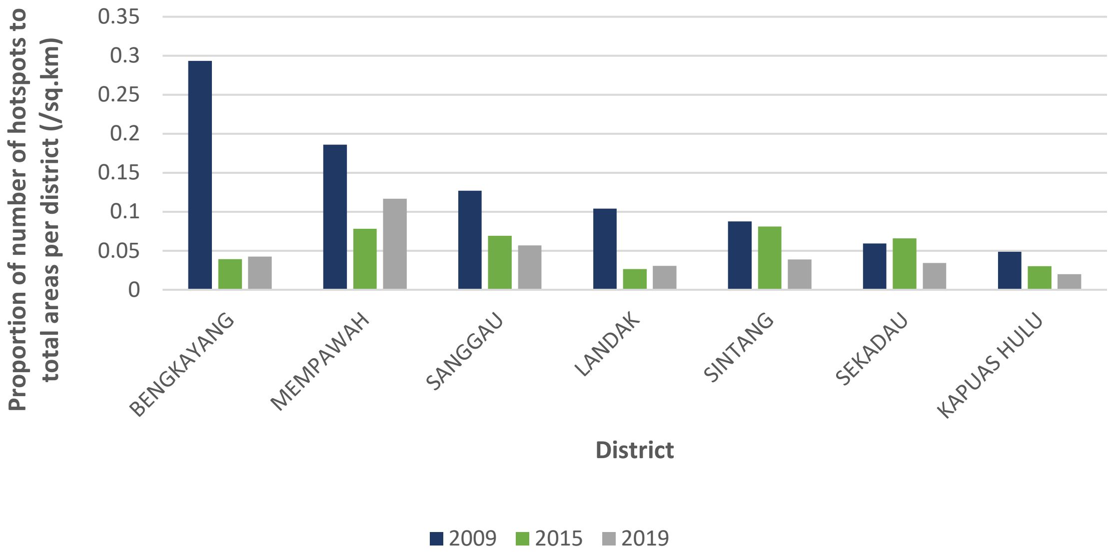


Figure 3. Spatial and temporal distribution of hotspots in the seven studied districts of West Kalimantan Province from 2009 to 2019

2.3.2. Fire risks

For fire risk analysis, the Maximum Entropy (MAXENT) modelling[4] was used to show fire-prone areas based on the hotspots and fire driving factors. Data that were used in the modelling are:

- Hotspots data from MODIS sensor Terra and Aqua in 2015 by using hotspots data from NASA;
- Land allocation (distance to plantation areas, distance to timber concession areas);
- Infrastructure map (distance to canals, roads);
- Proxy to tenure, land management, and other human activities (distance to settlements, population density);
- Proxy to policy-related with demography areas (distance to transmigration areas);
- Land cover and land-use maps;
- Biophysical characteristics of the landscape (DEM, distance to the river, ecoregion, distance to peatland areas, temperature, and rainfall);
- Statistical analysis to understand main driving factors that may contribute to the fire risk threats.

Based on the MAXENT model analysis, a driving factor that has the highest correlation with fire risk threats is dry air temperature that contributes to 25% determination of potential threats compared to the other 18 driving factors data used in the analysis. Other important driving factors are elevation (19%), distance from fire-prone areas to peatlands (14%), and land-use systems (14%).

In West Kalimantan province, high fire risks occur in the southern part of the province where there are peatlands, and fires frequently happen near the peatland areas. Our study sites are located mostly in the central and northern parts of the province. Of the seven studied districts, the projected fire risks for the next 30 years in descending order of medium to high fire risk are Mempawah, Sanggau, Sekadau, Landak, Sintang, Bengkayang and Kapuas Hulu (Figure 4). In Mempawah, approximately 95% of its area has medium to high risk of fire, and in Kapuas Hulu 45% of its area has medium to high risk of fire in the next 30 years.

4 Maximum entropy modeling is modeling from a set of environmental (e.g., climatic) grids and georeferenced occurrence localities. The model expresses a probability distribution where each grid cell has a predicted

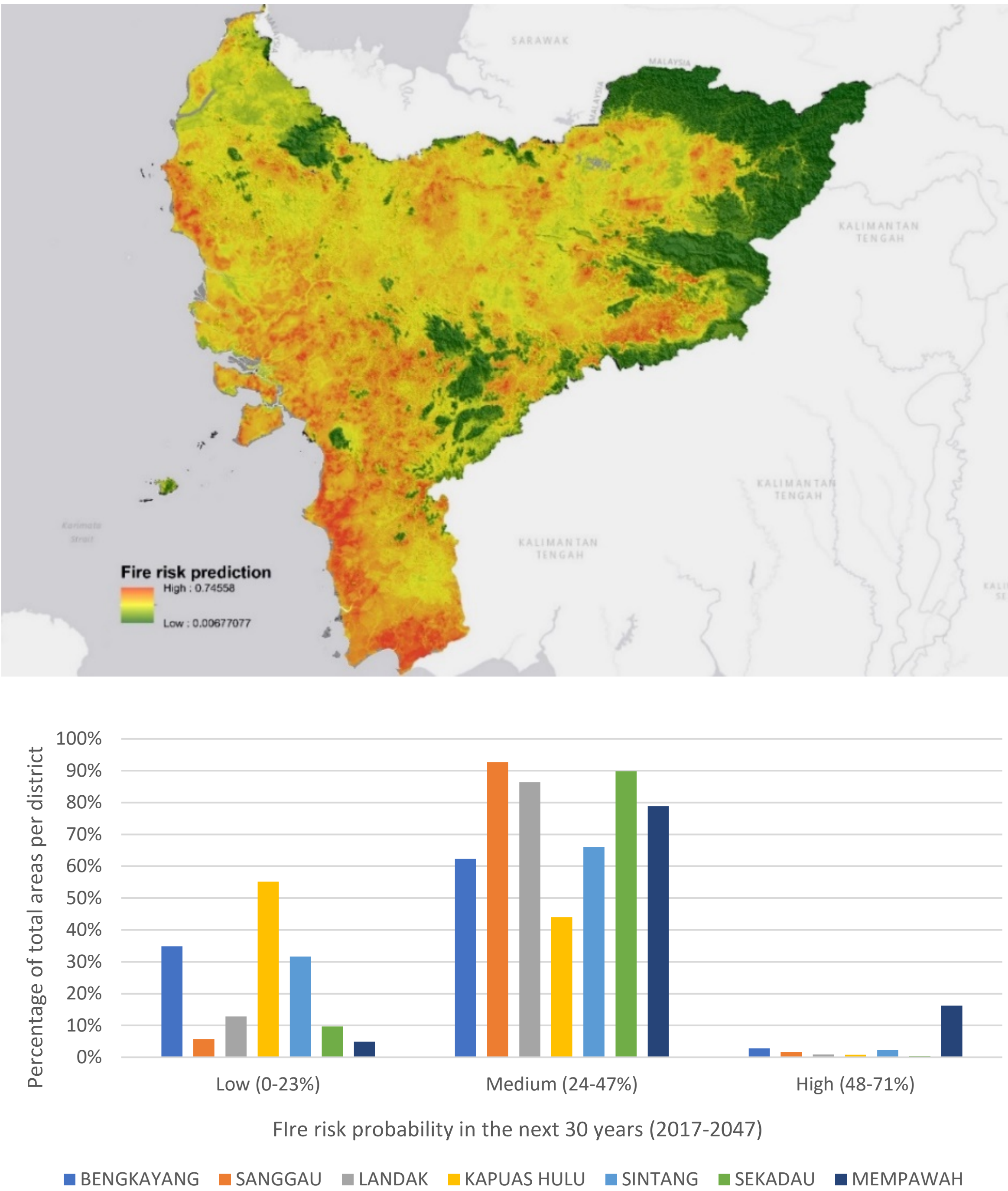


Figure 4. Fire risks threat map and graph based on a prediction from the year 2017 to 2047 in West Kalimantan Province

2.3.3. Deforestation risks

Deforestation risk was analyzed through mapping future land cover analysis by using Land-Use Planning for Multiple Environmental Services (LUMENS) produced by ICRAF. The modelling uses a land cover map as the main source of data, with additional biophysical maps and other related maps. Changes in land cover between 2012 and 2017 are projected to 30 years from

2017 to 2047. Under this study, we assumed the past driving factors remain relevant in the future. In reality, we know that this will not be the case. This study does not focus on land-use change modelling per se, and we do not intend to capture the impacts of any policy scenarios and other trends on land uses and land-use changes. We are merely interested in identifying areas with high deforestation risks, and therefore we think the approach suffices.

Based on the simulation, Sintang shows the highest potential risk of deforestation compared to the other districts (Figure 5). After Sintang, Sekadau placed as the district with the second-highest probability for deforestation, followed by Sanggau, Kapuas Hulu, Mempawah, Bengkayang and Landak, respectively. This, of course, is almost a tautology, since many districts have much less forest to be deforested. However, the location of the threatened forest is quite interesting, and therefore, prevention strategies can be implanted in the spatial land use planning and development planning at the district level.

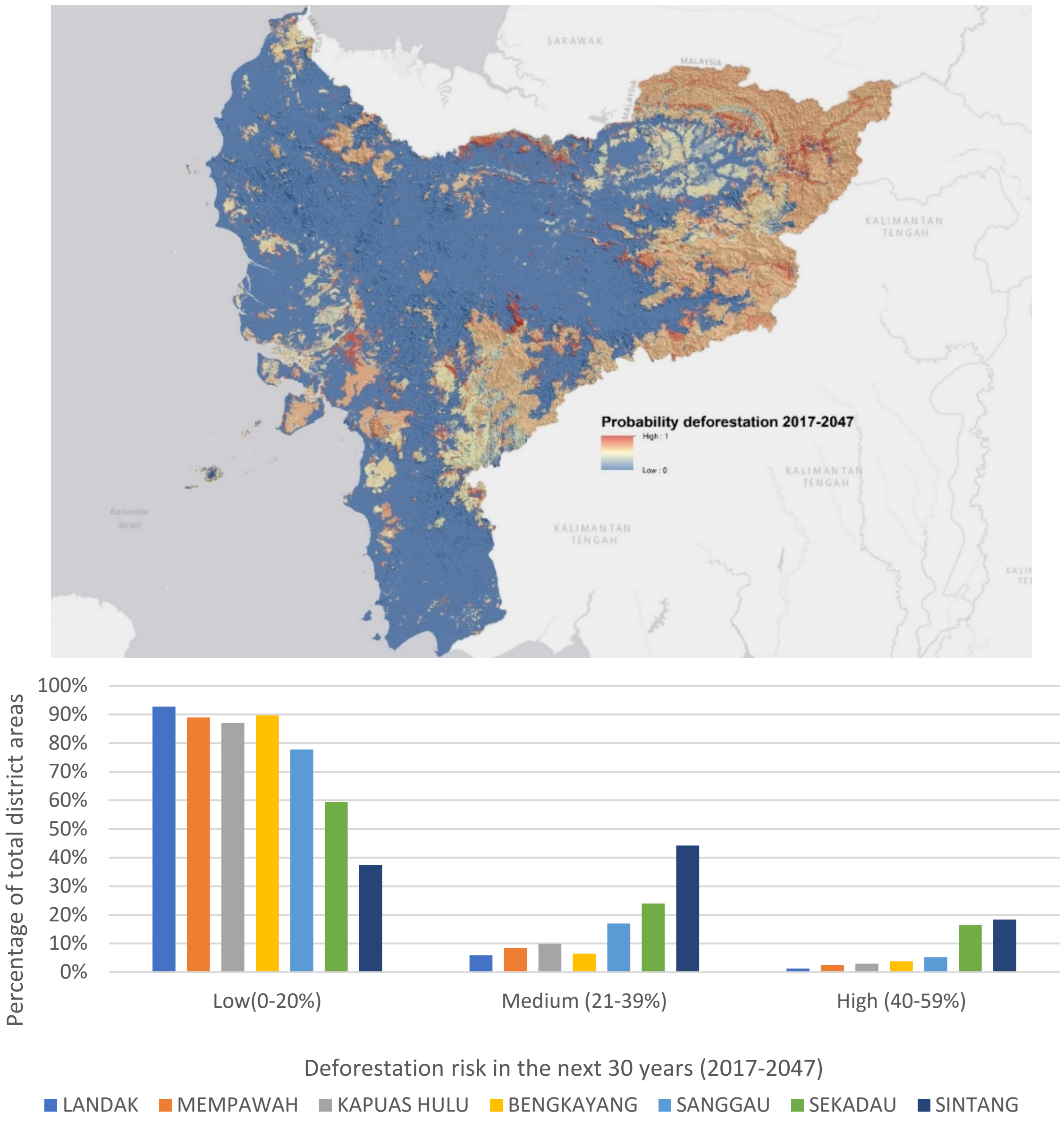


Figure 5. Projected deforestation risk map and graph during 2017 to 2047 in West Kalimantan Province

3 VULNERABILITY OF AGRICULTURAL-BASED LIVELIHOOD TO CLIMATE CHANGE

This chapter will start with the conceptual framework and approach of our vulnerability assessment. Then the chapter will present and discuss three main topics: (i) the results of the village vulnerability class; (ii) the findings of the community vulnerability assessment; and (iii) the risk and adaptation potential. We developed vulnerability class from the secondary data that is relevant in determining the vulnerability of the agricultural-based livelihoods to climate change. The vulnerability class serves as the basis to sample in-depth assessment of community-level agricultural-based vulnerability to climate change across villages with various village-level vulnerability classes. The land-use changes and their drivers are pivotal points between agricultural-based livelihoods and ecosystem health that buffers livelihoods and landscapes from exposure and impacts of extreme events. The extreme events that occurred in the study area are identified, along with the existing coping mechanisms and responses. The effects of such extreme events on people's livelihoods and key agricultural commodities are studied. Then we will discuss the potential enabling factors to support the adaptation of the agricultural-based livelihood to climate change.

First, we will briefly describe our conceptual framework and approach of the assessment. The units of analysis of the assessment are village and community. The extent is seven districts in West Kalimantan as stated earlier. The landscape, watershed, district and provincial contexts are taken as the contexts where village and community vulnerability are assessed. Communities are composed of households, but in this study, we are not to address variabilities among households, and therefore resilience strategy will not household-specific. The approach we use is adapted from the Capacity Strengthening Approach to Vulnerability Assessment (CaSAVA) developed by ICRAF (http://bit.ly/CaSAVA). CaSAVA has been applied in three provinces in Indonesia, one province in Vietnam and in the Philippines. In this study, we use an abridged version of CaSAVA.

Figure 6 shows the framework of our assessment. While we put villages and communities at the centre of our assessment, we take into account the broader contexts that shape the vulnerability at the village and community level. We acknowledge that drivers of land-use change will be manifested at the landscape and village level that bring to certain land-use compositions and land conversion, including deforestations. The unsustainable land conversion and expansion of intensified agriculture can lead to degradation of ecosystem services and reduce the buffering capacity of the landscapes. Combination of stressors in the form of extreme events due to climate changes, such as prolonged droughts and heavy rains, the landscape with low buffering capacity may result in the exposure of villages to flood and fire. Another Class of stressor which may or may not have any direct link to climate change is a market shock. The market shock may cause price drops or non-marketable commodities. This also presents another Class of exposure. Depending on the village-level resource endowment and five livelihood capitals, the exposures and the impacts on the community-level may vary. In our study, we focus on three main factors at the community level that shape agricultural-based livelihoods: water resources, farming systems and commodity market. In turn, the impacts of shocks or stressors on the community will determine the household-level livelihood strategies and outcomes. However, this study will not go deeper into a household-level assessment.

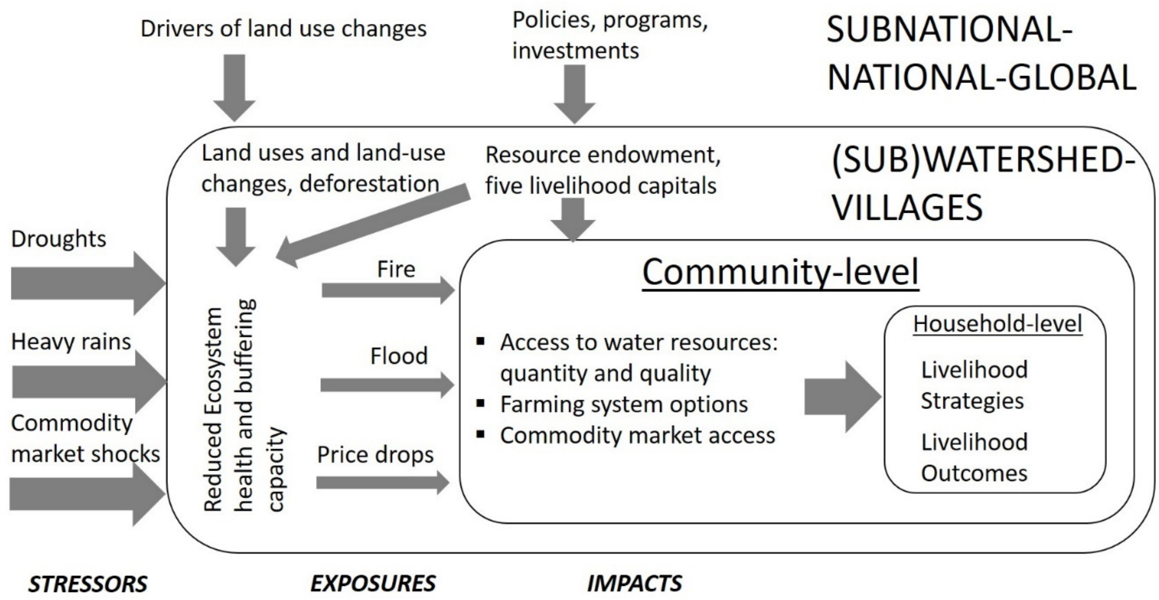


Figure 6. Village and community-level vulnerability assessment framework of agricultural-based livelihoods to climate change in West Kalimantan Province

The diagram underlines the importance of the broader contexts in shaping the vulnerability of communities' agricultural-based livelihoods to climate change. Considering the heterogeneity of resource endowment and capitals as well as land use and land-use changes of villages across the seven districts in West Kalimantan, we develop a typology to characterize these variations. We then design the sampling based on the typology so that the findings of vulnerability assessment are not biased, and the strategies identified to increase resilience can be extrapolated to areas broader than the samples.

3.1. Vulnerability class of agricultural-based livelihood vulnerability to climate change in West Kalimantan Province

This section discusses the development of vulnerability class of all villages in seven studied districts. We present the methodology and the results of the vulnerability class. We then analyze the spatial distribution of the vulnerability class according to the vulnerability classes. Further, we will describe some relevant stressors and risks to vulnerability based on the class.

3.1.1. Description of village-based vulnerability class

A village, as the smallest administrative unit in Indonesia, is taken in this vulnerability assessment as the appropriate level of intervention in increasing resilience of agricultural-based livelihoods to shocks and hazard, especially those induced by climate change. Village level is also considered by the Indonesian Government to acquire information on vulnerability to climate change through Information System on Index data of Vulnerability to Climate Change or Sistem Informasi Data Indeks Kerentanan Perubahan Iklim, released by Directorate of Adaptation to Climate Change, General Directorate of Climate Change, Ministry of Environment and Forestry of Republic of Indonesia every three years since 2014 (http://ditjenppi.menlhk.go.id/reddplus/images/resources/buku_sidik/BUKU_SIDIK_FINAL.pdf). While SIDIK aims to assess the general vulnerability of a village, this study focuses on the vulnerability of agricultural-based livelihood to climate change. Thus, this study used different approaches and variables in assessing village vulnerability to climate change.

A vulnerability assessment to climate change is used to identify effective responses to climate changes and other shocks and hazards, including the capacities to mitigate, absorb, adapt, and transform within the existing contexts and trends. In our study, the contexts and trends were captured by a set of spatially-explicit variables that serve as a proxy of potential climate hazards and capacities to adapt, which together define the vulnerability potentials to climate change. Based on these variables, the vulnerability class is characterized. This typology of vulnerability classes aims to: (i) capture the diverse contexts and trends of the village agricultural-based livelihoods in the study areas; and (ii) group villages with similar characteristics into the same classes. The classification is then being used to stratify the sampling of village-level assessment of vulnerability also village-level identification of interventions to increase resilience to climate change.

To characterize the village-level vulnerability of agricultural-based livelihoods to climate change, we use the following variables: the composition of land use and land cover (LU/LC), land-use changes, distance to natural resources, distance to infrastructure, distance to hazard areas (fire), hazards and human population (Table 2). We hypothesize that these variables provide relevant contexts and trends that determine potentials threats, buffers and filter extreme events of climate change in the areas. These variables were collected from secondary data in the forms of maps. They were verified through the field visits to the seven districts and the discussions with key stakeholders, including farmers, traders, district government officers, and village government officers in each district. Villages with peatlands are not included in the grouping as these peatland villages are more prone to climate change than the mineral soil villages, and therefore lumping them into the same analysis will lead to biased results. Due to the objectives and the extent of this study, we cannot opt for more in-depth data collections. Therefore, the choices of the variables have consulted the literature and have considered the best available and accessible dataset.

Table 2. Spatially explicit variables to develop village vulnerability typologies of agricultural-based livelihoods to climate change

No	Category	Spatially explicit variables	References
1	Distance to infrastructure	Distance to oil palm plantation	Landcover map 2017 from MoEF
2	Distance to infrastructure	Distance to roads	BIG
3	Distance to infrastructure	Distance to a rubber factory	ICRAF
4	Distance to infrastructure	Distance to oil palm factory	ICRAF
5	Distance to natural resources	Distance to forest	Landcover map 2017 from MoEF
6	Distance to natural resources	Distance to river	BIG
7	Distance to natural resources	Distance to mining areas	BIG
8	Distance to hazards area (fire)	Distance to burnt areas	KLHK 2015
9	Land use and land cover	% area of oil palm per village	Landcover map 2017 from MoEF
10	Land use and land cover	% of forested areas per village	Landcover map 2017 from MoEF
11	Land use and land cover	% of shrubs areas per village	Landcover map 2017 from MoEF
12	Land use and land cover	% forested areas per district compared to district areas	Landcover map 2017 from MoEF
13	Land use and land cover	% oil palm areas at district level compare to district areas	Landcover map 2017 from MoEF
14	Land use and land cover	% water body compared to district areas	Badan Informasi Geospatial (BIG), Geospatial Information Agency of Indonesia
15	Land use and land cover	Distance to deforestation	Landcover map 2017 from MoEF
16	Land use and land cover	Deforestation area	Landcover map 2017 from MoEF
17	Hazards	Flood incidence	Village Potentials, Statistics Indonesia 2018
18	Hazards	Heavy flood incidence	Village Potentials, Statistics Indonesia 2018
19	Hazards	Fire incidences	Village Potentials, Statistics Indonesia 2018
20	Hazards	Drought incidences	Village Potentials, Statistics Indonesia 2018
21	Demography	Village population	Village Potentials, Statistics Indonesia 2018
22	Distance to infrastructure	Distance to oil palm concession areas	Department of Estate Crops, West Kalimantan Province

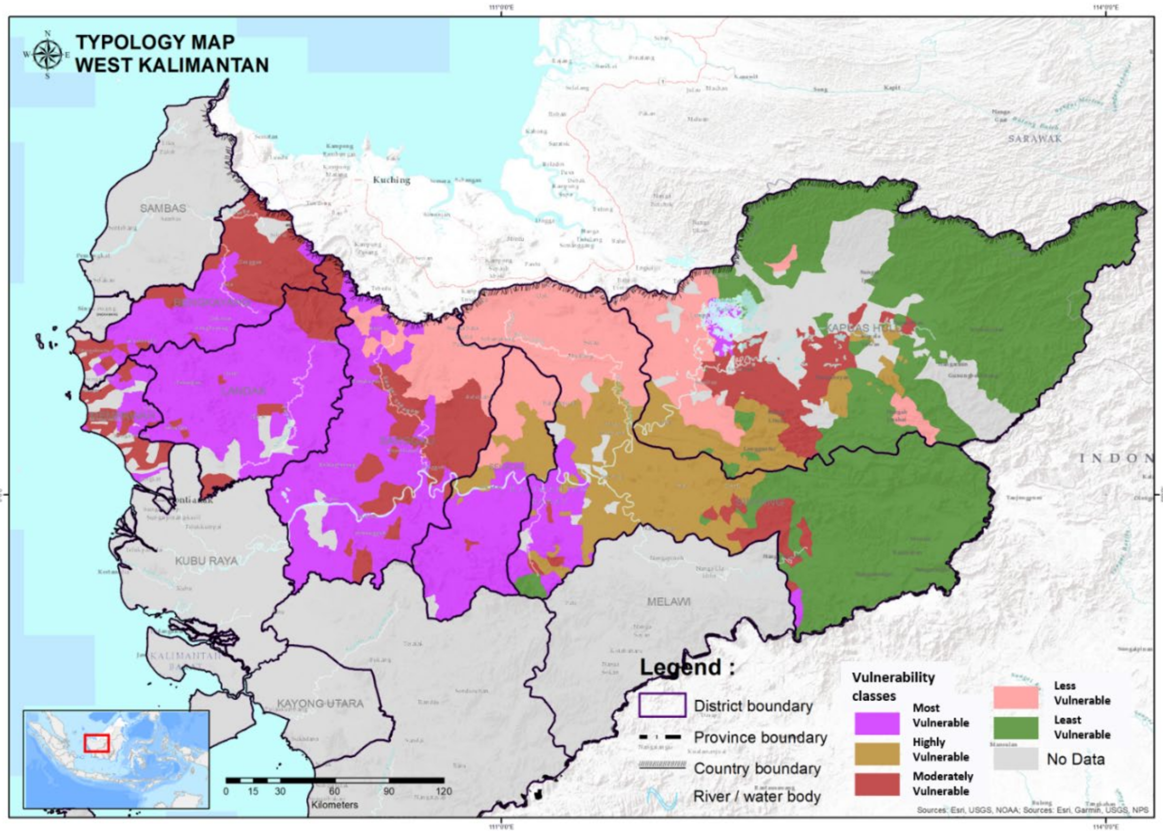


Figure 7. Village-level vulnerability classes of agricultural-based livelihoods to climate change in the studied districts in West Kalimantan Province

One thousand one hundred and eighty-eight villages of seven districts in West Kalimantan were grouped into five vulnerability classes of agricultural-based livelihoods to climate change, i.e., most vulnerable, highly vulnerable, moderately vulnerable, less vulnerable, and least vulnerable (Figure 7). Characteristics of villages within each village vulnerability class to climate change are as follows:

- **Vulnerability class 1 – most vulnerable**: In total, 439 villages have the characteristics of being located closest to oil palm plantations, oil palm concession areas, mining areas, roads, palm oil factories; have the largest shrubs area per village; furthest from deforestation and have the lowest deforestation rate; has the smallest percentage of forested areas per village; have the smallest percentage of the water body; have the highest village population.

- **Vulnerability class 2 –highly vulnerable:** In total, 224 villages have the characteristics of being located closest to burnt areas; have the largest percentage of oil palm area per village; located closer to oil palm concession areas; closest to rubber factory; have the largest percentage of water body (lake, river); have lower deforestation rate but located closer to deforestation areas; have higher village population.

- **Vulnerability class 3 – moderately vulnerable:** In total, 189 villages have the characteristics of being located closest to the river; have a larger percentage of oil palm area per village; located slightly farther from oil palm companies and mining areas; have a larger percentage of forested areas and shrub areas per village; have medium-sized village population.

- **Vulnerability class 4 – less vulnerable:** In total, 128 villages have the characteristics of being closest to deforestation areas and have the highest deforestation rate; located furthest from the river; most distant from burnt areas; slightly closer to forested areas; slightly farther from oil palm concession areas; have lower village population.
- **Vulnerability class 5 – least vulnerable:** In total, 93 villages have the characteristics of having the largest percentage of forested areas per village; located furthest from roads, rubber factory, oil palm factory, mining, and oil palm concession areas; have the smallest percentage of shrubs area per village and percentage of oil palm per village; located closer to the river; closest to forested areas; have the lowest village population.

3.1.2. Distribution of village vulnerability classes across districts

The distribution of each village vulnerability of agricultural-based livelihoods class to climate change was analyzed based on the current conditions on the ground-based on the information collected in 2012-2017. Using a bottom-up approach, we further classify districts into vulnerability classes based on the composition of village vulnerabilities. We found four district groups (Figure 8): 1) districts that are most vulnerable to highly vulnerable, i.e., Landak, Bengkayang, and Mempawah; 2) districts that are most vulnerable to less vulnerable, i.e., Sanggau; 3) districts that have a wide range of vulnerability, i.e., from the most to the least vulnerable, i.e., Sintang and Kapuas Hulu. From the seven districts, Landak has the highest number of villages that are classified as most vulnerable in terms of their agricultural-based livelihoods to climate change. Sanggau has the second-highest number of villages that are potentially most vulnerable, followed by Bengkayang, Sekadau, Sintang, Mempawah, and Kapuas Hulu.

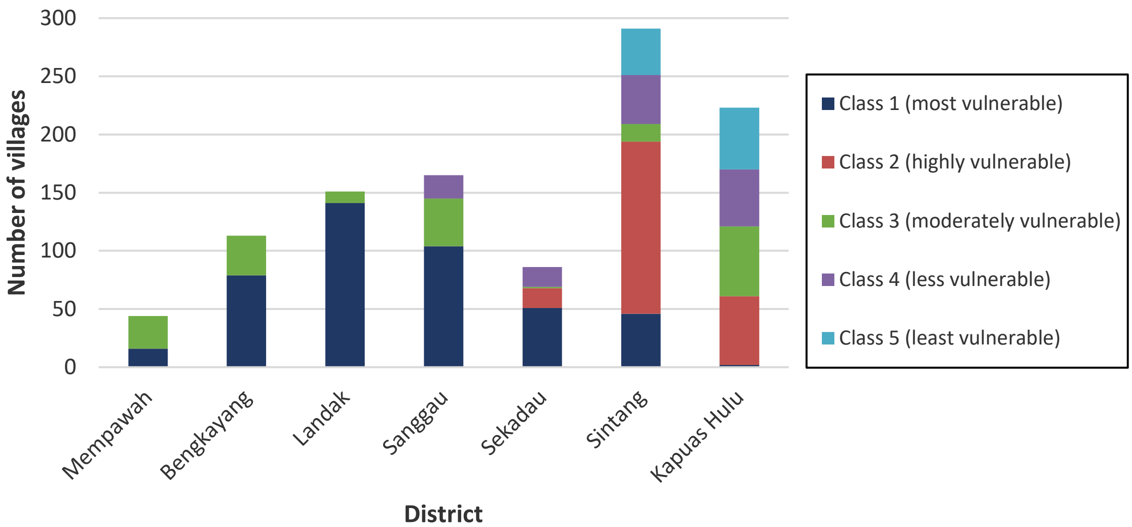


Figure 8. Number of villages per vulnerability class of potential vulnerability to climate change of seven districts in West Kalimantan Province

Interventions and strategies to mitigate impacts of extreme climate events of these districts may be different based on the vulnerability of the villages within the districts. Districts with a high number of vulnerable villages, such as Landak, may have different strategies to mitigate and adapt to climate change from districts that are least vulnerable, such as, Kapuas Hulu.

3.1.3. Vulnerability factor characterization

In this section, we will look further at how the village level agricultural-based livelihood vulnerability to climate change correlates with six main factors: the number of poor people at subdistrict level, hazards due to extreme climate events experienced by the community in each village with data from Statistics Indonesia (2018), the number of hotspots per vulnerability class with data from NASA, fire risk analysis from 2017 to 2047, deforestation risks from 2017 to 2047, and land use and land-use changes

Poverty

Distribution of the poor people[5] across the village-level vulnerability class depends on the population density in each village vulnerability class. Villages with vulnerability class 1 have the highest population density, while those of vulnerability class 5 has the lowest population density. Out of the 428,682 poor people in the seven studied districts, 47% reside in villages of vulnerability class 1, 15% of vulnerability class 2, 19% of vulnerability class 3, 8% of vulnerability class 4, and 10% of vulnerability class 5. In general, the total number of poor people is not strongly correlated with the vulnerability class to climate change (Figure 9). Rather than causality, what more important is the fact that the highest percentage of poor people reside in most vulnerable villages. With the general understanding that poor people are the most vulnerable people to climate change, priorities and precautions need to be taken to prevent the crashes of livelihoods of farmers. In this case, since the largest percentage of most vulnerable concentrate in vulnerable villages, programs and policies can be geographically targeted.

[5] Percentage of poor people in all studied districts was taken from the number of people below the national average welfare based on the Integrated Data of the Intervention Program for the Poor (*Program Penanganan Fakir Miskin* / PPFM) from the National Team for the Acceleration of Poverty Reduction (*Tim Nasional Percepatan Penanggulangan Kemiskinan* / TNP2K) that was published in 2017. This data recorded the 40% lowest welfare status of total population in an area. For the purpose of our study, we are only using data of the 20% lowest welfare status, which in the TNP2K is categorized as Desil 1 and Desil 2. More detailed information on the sources of data and classification of poor people can be obtained in this link below. http://www.tnp2k.go.id/images/uploads/downloads/Buku%20Tanya%20Jawab%20BDT_25102013-1.pdf.

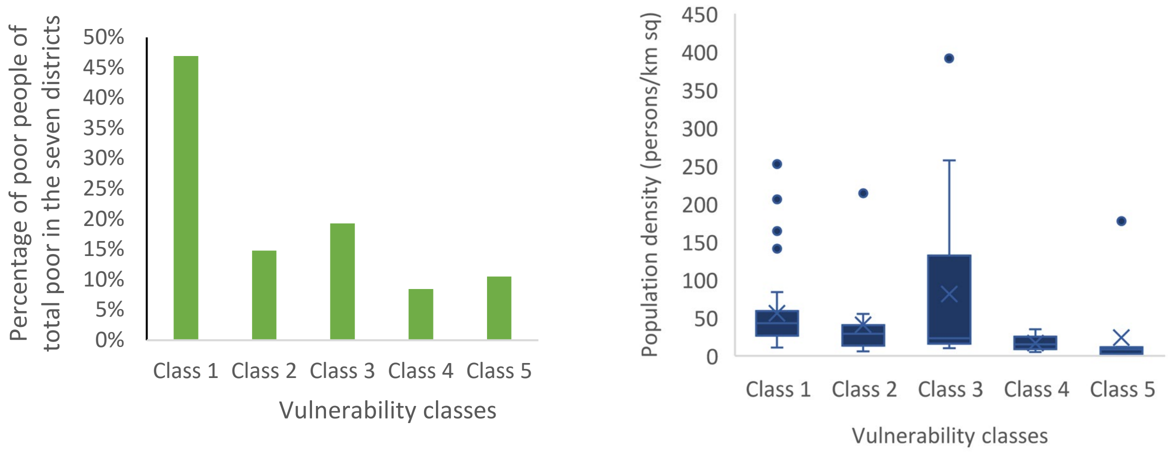


Figure 9. The total number of poor people and population density by village vulnerability class in seven studied districts in West Kalimantan Province (based on TNP2K-PPFM data published in 2017).

Hazards

Two major hazards[6] related to climate change that were recorded are floods and prolonged droughts (Figure 10). The total number of hazards was highest in villages with vulnerability class 1 and lowest in villages with vulnerability class 5. Floods are a common hazard that occurred in the seven studied districts. Prolonged droughts were reported to have only occurred in villages with vulnerability class 1 and 1. The number of hazards reported in 2018 is considered low, as it only covered around 1-2% of the total villages per vulnerability classes.

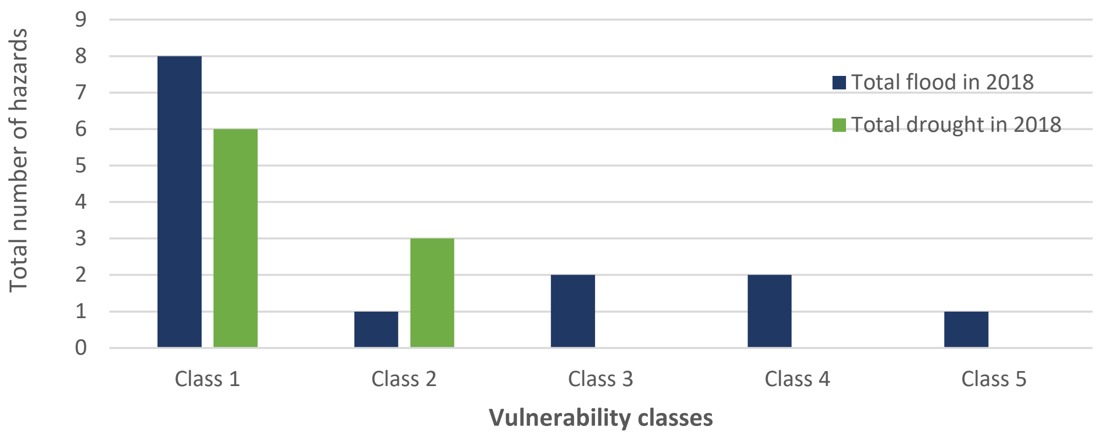


Figure 10. Total number of hazard incidences reported in 2018 by village vulnerability classes in all studied districts in West Kalimantan Province

6 Hazards or extreme climate events were analyzed using the total hazard incidences from the Indonesian Village Potential Statistics data in 2018.

Hotspot analysis

The total number of hotspots was collected from NASA data from 2009 to 2019. The highest number of hotspots occurred in 2009, with the lowest in 2010 (Figure 11). The number of annual hotspots is consistently highest in villages of vulnerability class 1. The years 2009, 2015, and 2019 are considered to have a high number of hotspots, due to the El Nino phenomenon. In 2009, the proportion number of hotspots per area is highest in vulnerability class 4, but in 2015 it was highest in class 2. Out of 5 classes, class 3 has the least number of hotspots per area, this may because villages from class 3 are located near the river.

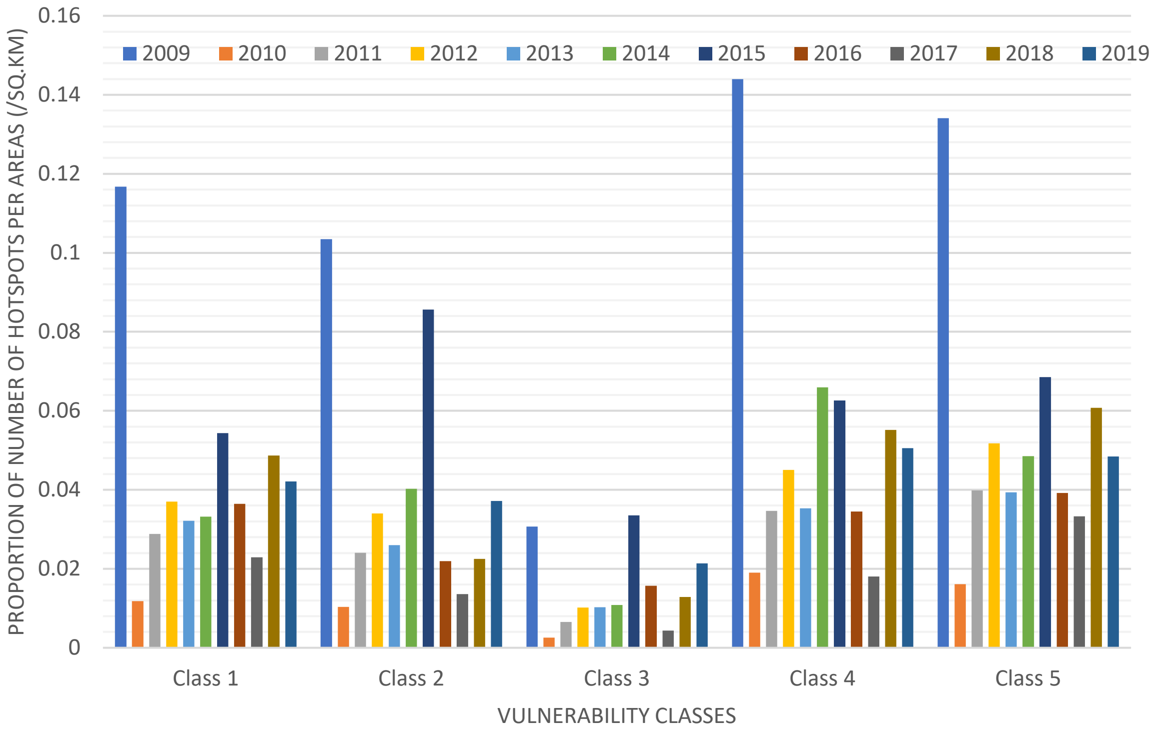


Figure 11. Proportion of number of annual hotspots per km^2 from 2009 to 2019 by village vulnerability class in all studied districts in West Kalimantan Province

Fire and deforestation risks

Fire and deforestation risks[7] per village vulnerability class were presented in Figure 15. The largest areas with high fire risks found in villages of vulnerability class 2, while the lowest in villages of vulnerability class 5 (Figure 12). On the other hand, the areas with the highest deforestation risk are largest in villages with vulnerability class 5, and lowest in villages of vulnerability class 1. There is no consistent trend in the probability of fire and deforestation.

Figure 12. Areas of high fire and deforestation risks by village vulnerability class from 2017 to 2047 projection based on 2012-2017 data

Land-use changes from 2012 to 2017

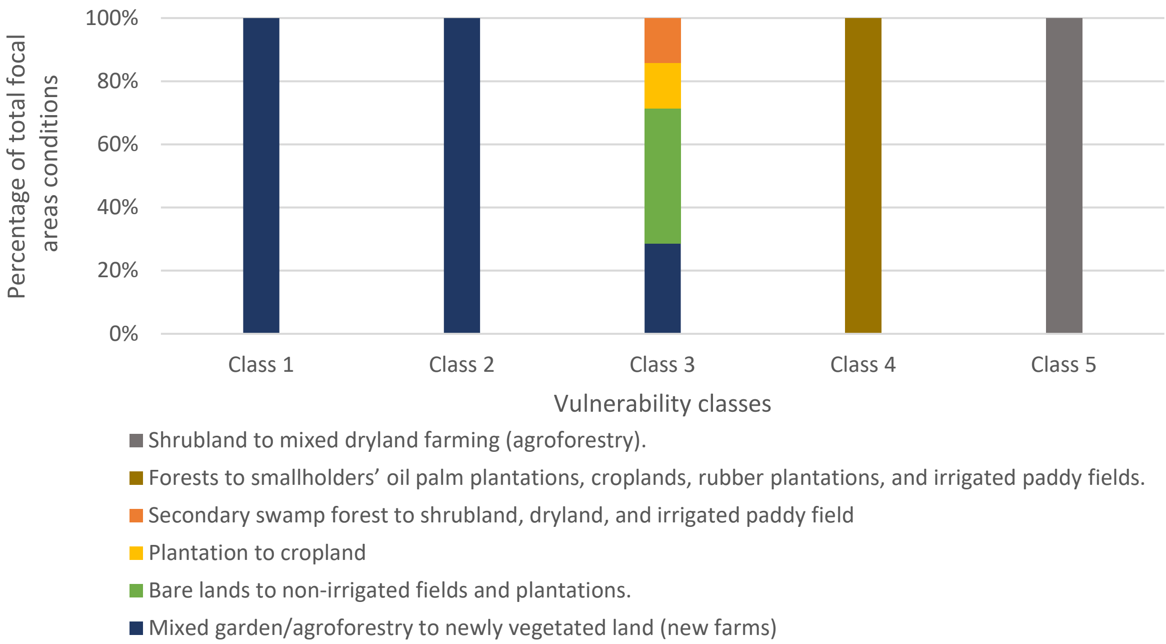
We studied recent land-use changes using the land use/cover maps of 2012 and 2017 produced by the Ministry of Environment and Forestry. Using the result of the spatial analysis and the basis, we conducted FGDs at the village-level to understand the drivers of the land-use changes. We then facilitated the visioning session with the stakeholders to capture the aspiration and their projection of future changes.

Massive land-use changes have occurred in West Kalimantan. The trends of these changes were from forests to shrublands to cropland, to more agroforestry systems, then to more monocultural systems of oil palm and rubber. The rate of changes varied between districts, depending on the district development priorities and land allocations.

---

[7] Analyzed through modeling by historical projection of 2012-2017 driving factors. The projection for the modeling is made for 2017 to 2047. Fire risk modeling was conducted with MAXENT and land use change modeling with LUMENS

The dominant land-use changes during the period were from agroforestry to newly planted monoculture systems (oil palm, rubber, or cropland). The changes were more prominent in villages of vulnerability classes 1 and 2 (Figure 13). In these villages there are minimal forest areas left to be converted to a more profitable land-use system; thus, agroforests were then converted. The amount of conversion from agroforestry to newly planted intensive land uses in five years was, on average, 12,000 ha per focal area for vulnerability class 1 and 1,000 ha per focal area for vulnerability class 2. Villages with vulnerability class 3 also experience some changes of agroforestry to monoculture systems.



Sources: FGD with local communities and analysis of land cover data in the year 2012 and 2017.

Figure 13. Dominant land-use changes from 2012 to 2017 in each vulnerability class of seven studied districts in West Kalimantan Province

Compared to the other groups, the group of villages with vulnerability class 3 has more variations in its land-use changes. It experienced a transition from areas with no forests as in the group of villages of vulnerability classes 1 and 2 to areas with large forest areas as in the group of villages of vulnerability classes 4 and 5. The dominant change in the group of villages of vulnerability class 3 was from bare lands to non-irrigated paddy fields and plantations (monocultural oil palm and rubber) with an average of 4,800 ha per focal area/subdistrict.

In the group of villages of vulnerability class 4, the dominant land-use change was from forested areas to various Class of land-use systems, depending on the needs, potential markets, and capitals to develop the land-use systems. Most of the land-use changes were to monoculture oil palm, monoculture rubber, croplands, and irrigated paddy fields. The conversion rate is considered low per focal area, with an average of 30-100 ha within five years.

In the group of villages with vulnerability class 5 that has been dominated by forested areas with their status being dominantly protected areas or national parks, land-use changes mostly occurred in shrublands. Shrublands were converted to agroforestry systems (fruit agroforestry or rubber agroforestry). The conversion rate was approximately 300 ha in 5 years.

3.2. Agricultural-based livelihood vulnerability in West Kalimantan

Assessment of vulnerability at the community level was conducted by Focused Group Discussions (FGD) in 14 focal areas (two focal areas per district). A focal area is a cluster of four contiguous villages within a sub-district. The focal areas were defined through selecting four contiguous villages under the same vulnerability classes, that through statistical analysis have the closest characteristic relatively as defined on each vulnerability class. The detailed sampling method is documented in Supplemental document 1.

Distribution of the vulnerability class varied among the 14 focal areas since we target each district to be represented by two focal areas, while the distribution of vulnerability classes of villages are not uniform, across districts. The set of 14 focal areas is composed of:

a) Seven focal areas of vulnerability class 1 (extremely vulnerable), i.e., Toho Subdistrict, Mempawah District; Ledo Subdistrict, Bengkayang District; Menjalin Subdistrict, Landak District; Ngabang Subdistrict, Landak District; Balai Subdistrict, Sanggau District; Sepauk Subdistrict, Sintang District; and Nanga Taman Subdistrict, Sekadau District;

b) One focal area of vulnerability class 2 (highly vulnerable), i.e., Kelam Permai Subdistrict, Sintang District;

c) Four focal areas of vulnerability class 3 (moderately vulnerable), i.e., Sungai Kunyit Subdistrict, Mempawah District; Seluas Subdistrict, Bengkayang District; Kapuas Subdistrict, Sanggau District; and Boyan Tanjung Subdistrict, Kapuas Hulu District;

d) One focal area of vulnerability class 4 (less vulnerable), i.e., in Belitang Hilir Subdistrict, Sekadau District;

e) One focal area of vulnerability class 5 (least vulnerable). i.e., in Mentebah Subdistrict, Kapuas Hulu District.

In each focal area, 40-70 participants from four selected villages were invited to attend the FGD. To ensure that the multiples perspectives were voiced, we invited farmers, traders, and village and subdistrict government officers. Information was collected through the FGDs using a framework developed by ICRAF on Capacity Strengthening Approach for Vulnerability Assessment (CaSAVA). In this abridged version of CaSAVA framework, the assessment part is divided into four components, following Figure 6. The first one is about the drivers and the future of land uses and land-use changes that will change the ecosystem health, which affects the buffering capacity at the village level. Extreme events as stressors that might expose communities to certain risks will then be discussed. The last two components of the assessment are the exposure that communities experienced so far under the extreme events and then the impacts of these exposures on their agricultural-based livelihoods. This assessment will then be continued with the analysis of adaptation potential in the next session.

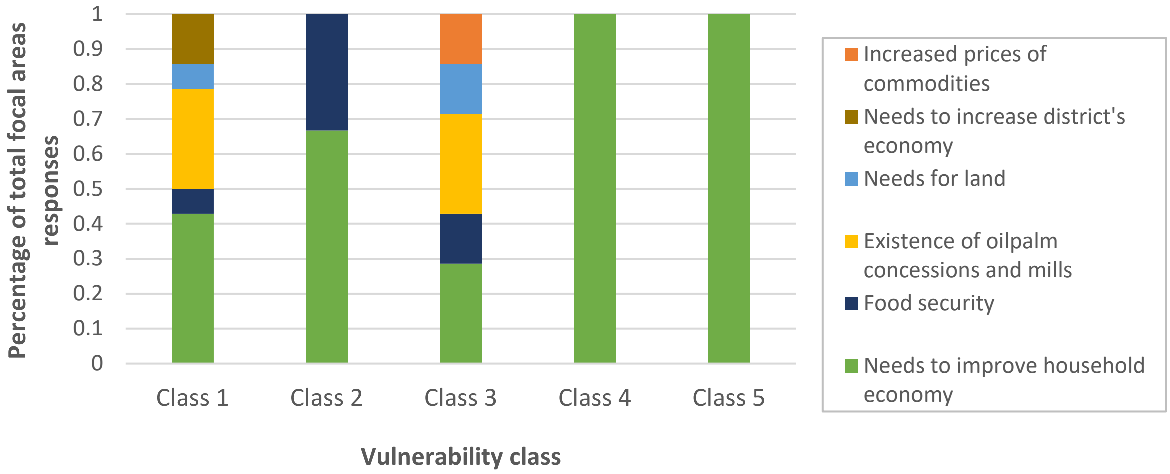
3.2.1. Land-use changes: drivers and future changes

Based on the discussions with and perspectives of the local communities across the focal areas, we summarized six main drivers of land-use changes that took place from 2012 to 2017:

1. Farmers' need to improve the household economy, for example, through the cultivation of highly economic crops and -based sources of income and improving land productivity;
2. Broader societal's demands for food security;
3. Global demands for commodities induce investments on large and small scale farming, e.g., oil palm concessions and mills, smallscale oil palm managed as plasma and independent farms;
4. Population growth leads to higher land demands, e.g., settlement, infrastructure;
5. Demands for economic growth and revenue;
6. The increased price of commodities.

The analysis of the information coming out form the FGD leads us to a very interesting set of findings. Driver #1, i.e., improving household economy, is the common driver across all focal areas, i.e., all villages across vulnerability classes. In fact, for villages with vulnerability classes 4 and 5, this driver is the only driver of land-use changes that the FGD sessions revealed (Figure 14). Food security (driver #2) was the second most common driver, that was identified across villages with vulnerability classes 1, 2, and 3. Villages under these vulnerability classes have a much higher population density and much less forested areas compared to classes 4 and 5.

Driver #3, meeting global demands for commodities, was an important driver to land-use changes in villages under vulnerability classes 1 and 3. These are villages where oil palm plantations and mills are active. Conversion of agroforestry to monoculture oil palm, were significant. This pattern is also consistent with the pattern revealed from spatial analysis. As driving factors are not completely independent from each other, we see that oil palm plantation (both managed by smallholders and companies), was expected to contribute not only to the community's source of income (driver #1) but also to the district's economy (driver #5). The increasing number of population (driver #4), as observed in villages under vulnerability class 1 and 3, also contributed to the high need for land as sources of livelihoods (driver #1) and for food security (driver #2).



Data source: FGD with local communities

Figure 14. Drivers of land-use changes by vulnerability class in seven districts of West Kalimantan Province

Upon understanding the driving factors of past land-use changes across villages of different vulnerability classes, we seek further the perception of future changes from those villages. From the discussions with the communities on the outlook for the next ten years, the communities consistently see that the monoculture rubber system will be the major crops, especially for smallholder farmers, in the areas. Although the price of rubber fluctuates, rubber provides daily or weekly income for the farmers, and the tree requires less intensive management (Figure 15). Besides monoculture rubber, the annual crop will be the major land uses in the landscape across all vulnerability classes. Cropland, such as dryland paddy, vegetables, maize, and other short-term crops, meet the demands for food. Most of the commodities produced from cropland are for subsistence uses, as part of the culture in Dayak ethnicity.

In the next ten years, agroforestry will still be extensive in some of the landscapes, although there has been a massive conversion of agroforestry in the past ten years. The communities in the studied focal areas foresee that the dominant agroforestry systems in the next ten years, will be rubber agroforestry and fruit agroforestry (*Tembawang*). Another land-use system that will dominate the landscape is the oil palm monoculture managed by smallholders as well as companies, particularly in villages of vulnerability classes 1 to 4. Up to this date, communities in villages of vulnerability class 5 do not expect oil palm to develop progressively in the next ten years. From their perception, the oil palm market/mills are too far away, and the poor road infrastructure is not adequate to reach them.

On the other hand, to increase food security, irrigated paddy fields will be dominant land-use in villages of vulnerability classes 1 and 3. In other villages, irrigated paddy fields will still exist but not as significant. Settlements and mining are projected to increase in villages of vulnerability class 3.

Data source: FGD with local communities

Figure 15. Perception of future land-uses by village vulnerability classes

3.2.2. Extreme events

Generally, extreme climate events have occurred in all focal areas in the past 15 years in the form of prolonged droughts, heavy rainfall, and whirlwinds. Heavy rains in the upstream areas combined with the low buffering capacity of watershed due to deforestation and loss of tree cover have caused floods in the regions. Pest infestation/pest boom occurred, which was commonly caused by prolonged drought. We do not find any consistent pattern of the class and frequency of extreme events with vulnerability classes (Table 3). Variations among the sites are quite high, depending on the topography surrounding the villages. Villages near the riverine have experienced floods more often than the ones located further away. Prolonged droughts generally occurred with the same frequency in all sites, particularly those shared the same climatic pattern. However, pest infestations in paddy, which is perceived to be caused by prolonged drought, have been more intensive in villages of vulnerability classes 1 and 4. In villages of vulnerability class 5, the existence of forests is assumed to stabilize the pest population in the area. Whirlwinds have occurred mostly in hilly or undulating areas and were reported in villages under vulnerability classes 1, 3, and 5. More data and information are needed from other villages in the region to draw some conclusions on the trends of extreme events across the region. Systematically recorded data sources at the village level will be a sound basis for such an analysis.

Table 3. Extreme climate events reported in the past 15 years in 14 focal areas of seven districts in West Kalimantan Province

Village vulnerability class	Focal area	Number of extreme climate events reported in the past 15 years (2004-2019)			
		Prolonged droughts	Floods	Pest infestation	Whirlwind
Class 1 (extremely vulnerable)	Toho Subdistrict, Mempawah District	1	2	1	2
	Ledo Subdistrict, Bengkayang District	1	14	0	1
	Balai Subdistrict, Sanggau District	1	1	1	-
	Ngabang Subdistrict, Landak District	1	1	2	-
	Menjalin Subdistrict, Landak District	1	1	1	1
	Sepauk Subdistrict,Sintang District	1	1	1	-
	Nanga Taman Subdistrict, Sekadau District	2	1	-	-
Class 2 (Highly vulnerable)	Kelam Permai, Sintang District	1	1	1	-
Class 3 (Moderately vulnerable)	Sungai Kunyit Subdistrict, Mempawah District	2	2	-	-
	Seluas Subdistrict, Bengkayang District	1	14	1	1
	Kapuas Subdistrict, Sanggau District	2	2	1	1
	Boyan Tanjung Subdistrict, Kapuas Hulu District	3	2	2	-
Class 4 (Less vulnerable)	Belitang Hilir Subdistrict, Sekadau District	1	4	1	-
Class 5 (Least vulnerable)	Mentebah Subdistrict, Kapuas Hulu District	2	1	-	1

Source: FGD with the community in 14 focal areas

3.2.3. Exposures and Responses

This section will discuss the exposures to the key factors of agricultural-based livelihoods that communities experience due to the external stressors of extreme climate events and also market shock. The key factors addressed here are water resources, farming systems and marketing. We will also present the responses of the commodities to each Class of exposures.

Water resources

Extreme climate events related to water resources are prolonged drought and heavy rainfall. During the dry season or prolonged drought, sources of water vary depending on the existing water sources, which are generally the river, lakes, springs, dug wells, drilled wells, and bottled water (Table 4).

Generally, prolonged drought exposes the communities to reduce water resources that lead to the lack of water to meet household needs and agricultural purposes, particularly in villages of vulnerability classes 1 to 3. In villages under vulnerability class 4, prolonged drought does not affect the water quantity, but causes turbid water. In villages of vulnerability class 5, there was no report of exposure from prolonged drought to water sources. To fulfil the need for clean water for household consumption, people with better financial conditions buy bottled water. In contrast, ordinary people depend on their sources of water from the river or springs. The communities' response to lack of water is to deepen the wells and communities with higher financial capitals have also built mini dams and water reservoirs as in villages of vulnerability class 1.

On the other hand, heavy rainfall causes turbid water that cannot be consumed or used by the communities for household needs in all villages. The responses or strategies to cope with turbid water for household consumption have generally been the same across all villages, i.e., sedimentation treatment, adding alum, and boiling the water. For agricultural land, no responses have been recorded. Besides turbid water, heavy rainfalls also cause floods, particularly more frequent in villages of vulnerability classes 1 and 3. Floods also occurred in villages of vulnerability classes 2, 4, and 5 but with very low intensity and frequency.

Besides water issues related to extreme climate events, there is also water pollution or contamination by mining in all villages. In villages of vulnerability class 4, there is also a concern about water contamination from oil palm companies. Strategies to reduce pollution are made by negotiating with companies.

Table 4. Exposures and responses of water resources to extreme climate events by village vulnerability class in West Kalimantan Province

VIllage vulnerability class	Sources of water in the dry season	Exposures	Responses
Class 1 (extremely vulnerable)	Varied across different focal areas, depending on the existing water sources.	• Prolonged drought: Lack of water; • Heavy rainfalls: turbid water and flood • Other issues of water: contaminated water from mining, fish poisons, land clearing, fertilizers, herbicides	• Varied across focal areas depending on the knowledge and capitals owned by each focal areas. • Floods: river engineering; • Lack of water: building dams, deepening wells, building water reservoirs.
Class 2 (Highly vulnerable)	River, dug wells, drilled wells, springs, rain water, bottled water, and swamps	• Prolonged drought: makes almost all water sources run dry. • Other issues of water: turbid river water caused by mining.	Turbid water: adding alum and sedimentation treatment, deepening wells, and buying clean water/bottled water
Class 3 (Moderately vulnerable)	River, bottled water, drilled wells, dug wells	• Prolonged drought: lack of water, and unpleasant odor. • Heavy rainfall: turbid water and flood • Other issues of water: turbid river water caused by mining.	• Turbid water: sedimentation. • Lack of water: digging deeper wells. • Flood: river engineering
Class 4 (Less vulnerable)	River, dug wells, drilled wells, springs, and bottled water	• Prolonged drought: existing water sources still suffice, but the water becomes turbid and not able to be consumed. • Other issues: water contamination produced by wastes from oil palm and mining companies	• Turbid water: sedimentation treatment, boiling the water, adding alum. • Water contamination: negotiations with the companies.
Class 5 (Least vulnerable)	Springs, lakes, and bottled water	• Heavy rainfall: turbid water • Turbid water also happened due to illegal mining in the river upstream.	Turbid water: sedimentation, adding alum, buying clean water, and exploring other water sources.

Source: FGD with the communities in the focal areas

In conclusion, regarding water resources, the exposures and responses of each vulnerability class depend on the natural resources capacities and available infrastructure. Villages of vulnerability classes 1 to 3 have more similar exposures and responses to extreme climate events. Better access to infrastructure in villages of vulnerability class 1 have resulted in more options for responses in coping with water resources' exposures to extreme climate events. Villages with vulnerability classes 4 and 5 have more similar water resources' exposures and responses to extreme climate events. Villages under vulnerability class 5, due to their lack of infrastructure while most forested, respond to and cope with the lack of clean water by exploring other water sources. With regards to coping capacity, villages of vulnerability classes 1, 2, and 3 rely more on the physical capital, while villages of vulnerability classes 4 and 5 rely more on nature-based solutions.

Farming systems

From the discussions with the communities in 14 focal areas, there were four dominant farming systems in the seven studied districts, i.e. irrigated paddy fields (managed by smallholders), cropland for planting dryland paddy, vegetables, and other food crops (managed by smallholders), rubber gardens consisting of monoculture rubber and rubber agroforest (mainly managed by smallholders), and oil palm plantation (primarily managed by companies, some managed under plasma scheme and some independently managed by smallholders). These farming systems are exposed to extreme climate events, such as prolonged drought/pest infestation (Table 5), and heavy rainfall/flood and whirlwind (Table 6). Responses to each exposure for each dominant farming systems are recorded and presented as well. These exposures and responses are documented for each village vulnerability class.

The worst exposure caused by prolonged drought is experienced by food crops in **cropland and irrigated paddy field** from the pest infestation of insects, birds, and rats. Pest infestation occurred in villages of vulnerability classes 1 to 4, with none reported in villages of vulnerability class 5. Response to handle pests is mainly spraying pesticides and rodenticides. Still, there are variations across the focal areas depending on the farmers' access to insecticides and rodenticides, and their knowledge to handle the pests. Besides pest infestation, drought causes food crops in the croplands to turn yellow and dry. Farmers watered the plants to prevent further damage to the food crops. Burnt land, as a result of prolonged drought, is also found in the croplands of villages under vulnerability class 1. The exposure of drought to cropland irrigated paddy is most severe in villages with vulnerability class 1 and least severe in those with class 5.

Prolonged drought exposes the **rubber farms** to conditions by which the trees experience shedding leaves, decreased rubber sap, and even die as happened in villages of vulnerability class 1. Decreased rubber sap production is experienced in villages under vulnerability classes 1 to 3, while rubber farms in villages of vulnerability classes 4 and 5 only experience shedding leaves. Farmers have only made responses in villages of vulnerability class 1 by watering, replanting dead trees, and fertilizing the exposed rubber trees. While farmers in the other villages do not take any specific responses.

On the other hand, **oil palm plantations** in villages of vulnerability classes 1 to 4 are exposed to pest infestation, yellowing leaves, decreasing growth rate, shrinking size of fruit bunches, and land fires. Villages of vulnerability class 1 have the worst exposures compared to the other village typologies, with the occurrence of all those exposures. In villages of vulnerability class 2, the oil palm leaves turn yellow and experience no exposure to its fruit bunches nor any land fire. In villages of vulnerability class 3, the quantity of fruit bunches decreases. Meanwhile, prolonged drought exposes the oil palm plantation in villages of vulnerability class 4 to land fire. Responses to the different exposures varied among the village typologies. No response has been taken for pest infestation. Meanwhile, responses to the decreasing growth rate, the shrinking size of fruit bunches, and the quantity of fruit bunches are only taken in villages of vulnerability class 1 by applying fertilizer. Yellowing leaves are handled in villages of vulnerability class 2 by pruning the leaves. Fires that take place in villages of vulnerability classes 1 and 4 are extinguished right away. Oil palm plantation in villages of vulnerability class 4 experiences the most exposure to prolonged drought, yet it has the most advanced responses. Villages of vulnerability class 2 has the least exposures, while villages of vulnerability class 3 has the least responses to prolonged drought experienced by oil palm plantation.

Table 5. Exposures and responses of dominant farming systems to prolonged drought by village vulnerability class in West Kalimantan Province

Dominant farming systems	VIllage vulnerability class	Exposures to prolonged drought	Responses to prolonged drought
Cropland	Class1	Pest infestation on food crop; yellowing paddy plants, burnt lands.	Spraying with pesticides, manually watering, extinguish fires.
	Class 2	Pest infestation (grasshopper and rice ear bugs/*walang sangit)* in paddy.	Varied, from disregarding it, spraying, and catching with nets.
	Class 3	Pest infestation in paddy and other food crops.	Varied, from doing nothing to spraying pesticides.
	Class 4	Pest infestation in all the paddy fields; and some of the paddy becomes dry.	Sprayed the pests with pesticides
	Class 5	Paddy and food crops plants become dry and die.	Watering and maintain the remaining plants.
Irrigated paddy field	Class 1	Pest (insects and rats) infestation attack the food crop; yellowing paddy plants; dried paddy plants	Spraying with pesticides and applying rodenticide
	Class 2	Pest infestation (grasshopper and rice ear bugs) in paddy	Varied from disregarding it, spraying, and catching with nets.
	Class 3	Pest infestation in paddy	Varied, from doing nothing to spraying pesticides.
	Class 4	Pest infestation in paddy	None
Rubber farms	Class 1	Rubber trees shed leaves, decreased rubber sap; dead trees.	Watering, replanting dead trees, fertilizing after the rain arrives.
	Class 2	Decreased Harvesting frequency for rubber	None
	Class 3	Rubber trees shed its leaves; decreased rubber sap	None
	Class 4 and Class 5	Rubber trees shed its leaves.	None
Oil palm plantation	Class 1	Pest infestation (*walang sangit*), decreasing growth rate, shrinking size of fruit bunch, land fires	Application of fertilizer after rain season arrived, extinguish fires, build water reservoir from plastic cover
	Class 2	Yellowing leaves for oil palm.	Pruning the yellowing leaves
	Class 3	Decreasing quantity of fruit bunches	None
	Class 4	Induced land fires in oil palm plantation.	Extinguish the fire

Source: FGD with the communities in 14 focal areas

Heavy rainfall may expose farming systems to floods and whirlwinds in ways that are different from drought (Table 5). Irrigated paddy fields are the most exposed to floods, followed by rubber farms and cropland. Meanwhile, cropland is the most exposed to whirlwind, followed by oil palm plantation. Exposures to floods for irrigated paddy field and rubber farms mostly happen because these two dominant farming systems are located near the river or in the riverine areas. Meanwhile, exposures to whirlwind in rubber farms and cropland occur in more undulating topography or in the hilly areas that are prone to the whirlwind.

In **irrigated paddy fields**, paddy plants experience unusual inundation that causes damage and disrupts paddy plants, this only happens in villages of vulnerability classes 1 to 4, because in villages of vulnerability class 5, there is no irrigated paddy field. The level of exposures are almost similar among four village typologies; however, the responses have been slightly different. In villages of vulnerability class 1, the farmers wait for the water to recede before they start replanting. In villages of vulnerability class 2, as irrigation systems are available, the responses are to repair the irrigation channel. Villages of vulnerability classes 3 and 4 are more focused on the development of flood control through river engineering, trenches, and drainage systems.

Floods in **rubber farms** expose the trees to inundated conditions, so the trees could not be tapped. The levels of exposure are relatively the same in all village typologies, except for villages of vulnerability class 1 where the rubber trees would have rotten roots. The responses that have been taken varied between the villages of different vulnerability classes. In villages of vulnerability class 1, the response was to let the water recede and construct a bridge. The response of villages of vulnerability classes 2 and 3 has been to ignore the exposures. Villages of vulnerability class 4 responded by constructing drainage after the water receded. Meanwhile, villages of vulnerability class 5 responded by replanting after the flood occurred in the area with a whirlwind that caused the rubber trees to fall.

For whirlwind, exposures and responses are found in the **cropland** of villages of vulnerability classes 1 and 3. Whirlwind exposes the plants in croplands to be destroyed and disrupted. The responses in villages f both vulnerability classes were almost the same, i.e., by replanting.

Table 6. Exposures and responses of dominant farming systems to floods and whirlwind by village vulnerability classes in West Kalimantan Province

Dominant farming systems	Village vulnerability class	Exposures to floods and whirlwind	Responses to floods and whirlwind
Cropland	Class 1	Whirlwind: destroyed annual crops	Replanting
	Class 3	Whirlwind: disrupted paddy and maize plants.	Whirlwind: cleaning the garden from debris and replanting
		Floods: affected the cropland (vegetables) near the river.	None
Irrigated paddy fields	Class 1	Floods: damaged paddy plants	Farmers waited for the water to recede for replanting
	Class 2	Floods: disrupted paddy plants	Repairing the irrigation channels
	Class 3	Floods damaged paddy plants	Flood control through river engineering and building trenches
	Class 4	Inundated and disrupted paddy fields	Wait for the water to recede, and constructing drainage to prevent the future flood.
Rubber farms	Class 1	Floods -- inundated trees cannot be tapped to rotten roots of rubber trees	Let the water receded, constructing a bridge to rubber farm.
	Class 2	Floods: rubber trees cannot be tapped	None
	Class 3	Floods: inundated the rubber trees.	None
	Class 4	Inundated rubber trees	Wait for the water to recede; construct drainage to prevent the flood.
	Class 5	Floods and whirlwind: fallen rubber trees	Vary from ignoring the damage to replanting
Oil palm	Class 1 to Class 4	Oil palm is not exposed to floods as it mostly in higher altitude/hills areas. No whirlwind was reported.	None

Source: FGD with the communities in 14 focal areas

In summary, exposure of extreme events on the farming systems was common and most heavily caused by prolonged drought compared to other extreme climate events. Cropland and irrigated paddy were the most exposed farming systems to extreme climate events compared to rubber farms or oil palm plantations. Across vulnerability classes, we found that farming systems in villages of vulnerability class 1 experienced the most substantial exposures. However, at the same time, responses to the exposure were best in villages under this vulnerability class due to better access to information and other capitals. Meanwhile, villages of vulnerability class 5 have the least exposure and, at the same time, the least responses. Farming systems in the villages of vulnerability classes 2, 3, and 4 have relatively the same level of exposures to extreme events. Villages of vulnerability class 2 have more responses than villages of vulnerability classes 3 and 4.

Marketing of dominant agricultural commodities

There are three major existing agricultural commodities across the seven studied districts: paddy, rubber, and oil palm. In Kapuas Hulu District, there is also a new commodity that contributes to the local livelihood, i.e., kratum (*Mitragyna speciosa*). In areas located near the coastal regions, such as Mempawah, fish, and coconuts are also the main agricultural commodities that contribute to the local livelihoods. In this study, for each focal area, exposures from commodity-market shocks and responses of communities with regards to the three dominant commodities were explored.

Extreme events for **paddy** have mainly been driven by climate, i.e., flood and drought, however from the discussions with the local communities (farmers and middlemen), we found that decreased stocks due to crop failure have induced market shocks (Table 7). The responses have been slightly different among villages with different vulnerability classes. In villages of vulnerability classes 1 and 3, the farmers would buy rice for daily needs, and the middlemen would source stocks from other areas. The response from villages of vulnerability class 2 was that farmers obtained additional income from rubber tapping and gold mining, whereas no response was recorded from the middlemen in the FGD. The market exposure and responses of paddy were only identified in villages of vulnerability classes 1 to 3 because in villages of vulnerability classes 4 and 5, farmers cultivate paddy for own consumption.

Contrary to paddy, market shock for **rubber** has been mostly influenced by global supplies and demands, since significant amount of rubber production is exported. However, some extreme events related to climate, i.e., floods and droughts, also affect the production and harvesting of rubber. Exposure from flood occurs less than the prolonged drought. The farmer's response to the flood was to stop tapping their rubber trees for a while. Meanwhile, their response to prolonged drought was to stop tapping rubber and obtain other sources of income. On the other hand, more responses were made to market shocks, in the form of price drops, by stockpiling rubber slabs/yield, stop rubber tapping, and obtaining other sources of income. In some areas, rubber gardens were converted to other uses. For middlemen, similar responses to price drops were made, i.e., stockpile rubber and obtain sources of income from other commodities. The exposure of rubber price drops was experienced more frequently in villages of vulnerability class 1 compared to the other villages. Villages of vulnerability classes 1, 3, and 4 have been exposed to combined extreme events between climate-driven events and market shocks. While in villages of vulnerability classes 2 and 5, only market shocks that affect rubber marketing were experienced.

As in the case of rubber, extreme events in **oil palm** marketing have also been a combination of climate-driven events and market shocks. The prolonged drought was noted as an extreme climate event that influenced the production and productivity of oil palm, causing a decreased supply of oil palm fruit, which occurred only in villages of vulnerability class 1. Three types of market shocks concerning oil palm are: (i) CPO mills refusing to buy oil palm fruit bunches because the bunches specification is not as required by the mills; (ii) decreased price due to global market; (iii) oil palm companies ceasing their operations. Two of those market shock conditions happened in villages of vulnerability class 1. For villages of vulnerability classes 2 and 5, no market shocks for oil palm were experienced since there is no oil palm plantation in villages of vulnerability class 5, and oil palm is a new crop in the villages of vulnerability class

2. The communities' responses to oil palm market shocks were the same across the relevant vulnerability classes, i.e., obtain new sources of income to support the decrease or loss of income from oil palm.

Table 7. Exposures and responses of dominant commodities market shock across village vulnerability classes in West Kalimantan Province

Commodities	VIllage vulnerability class	Extreme events related to market	Market exposures	Responses from farmers	Responses from middlemen
Paddy	Class1 and Class 3	Floods and prolonged drought	Decreased paddy stock due to crop failure	Buying rice for daily needs	Sources stocks from other areas
	Class 2	Prolonged drought	Decreased stocks due to crop failure	Obtain additional income from rubber tapping and gold mining	No responses were recorded in the FGD
Rubber	Class1 and Class 4	Floods	Decreased stocks (but not significant)	Stop tapping rubber	Obtain other sources of income
	Class 1, Class 3, and Class 4	Prolonged drought	Decreased stocks	Stop tapping rubber; obtain other sources of income	Obtain other sources of income
	All village typologies	Market shocks (global crisis)	Decreased price of rubber	Stockpile the rubber latex; stop tapping rubber, obtain other sources of income	Obtain other sources of income
Oil palm	Class1	Prolonged drought	Decreased supply of oil palm fruit bunches	Obtain other sources of income	Obtain other sources of income
	Class 1	Market shocks (CPO mills refuse to buy oil palm fruit bunches)	No market to sale oil palm bunches	Obtain other sources of income	Obtain other sources of income
	Class 1 and Class 3	Market shocks	Decrease price of oil palm	Obtain for other sources of income	Obtain for other sources of income
	Class 2	No report from the FGD as oil palm is a new crop in the focal area.			
	Class 4	Market shocks (Oil palm companies ceased their operations)	No market to sale oil palm bunches	Obtain other sources of income	Obtain other sources of income
	Class 5	None oil palm farms in the focal area			

Source: FGD with the communities in 14 focal areas

In conclusion, exposures and responses of dominant agricultural commodity marketing to extreme events varied depending on the commodities and the conditions in each village vulnerability class. Rice market is greatly driven by extreme climate events, while rubber and oil palm are more driven by market shocks. In comparing among the vulnerability classes, villages of vulnerability class 1 experienced more frequent extreme events than the other vulnerability classes. Villages of vulnerability class 5 have the least frequent extreme events. While villages of vulnerability classes 2, 3, and 4 have a high variation of extreme event frequencies with no particular trend. Responses to extreme events were almost similar among the vulnerability classes, showing potentially weak capitals and capacities of the farmers and middlemen to cope with the extreme events.

Besides the aforementioned extreme events, the structure of a market chain and power relations between farmers and middlemen, farmers and companies, or middlemen and companies also contribute to the level of the farmers' and middlemen's vulnerability to extreme market events. In rubber market, there is a high dependency of farmers on the middlemen due to the lending system relationship between the farmers and middlemen that affects the price rate received by the farmers. Although, this is particularly more apparent in rubber marketing. For oil palm, the relationship between farmers and the company, whether through a partnership or informally, affects the price rate or profit received by the farmers.

3.2.4. Impacts of extreme events

In this session, we discuss the negative impacts of extreme events on livelihoods (household economy, food security, and access to water for households and agricultural purposes), agricultural commodities, and landscapes. Extreme events were classified into two major groups, extreme events related to climates such as prolonged drought and heavy rainfall; and extreme events related to market shocks. This section discusses the impacts of the extreme events experienced by the communities, after being buffered by the village-level endowment, and responded accordingly to the communities' and households' capacities and capitals.

Prolonged drought

In comparing the extreme events related to climate, there were more negative impacts identified due to prolonged drought than heavy rainfall. Negative impacts of prolonged drought were seen from two primary exposures, i.e., exposure of limited rainfall, limited water quantity, and increased temperature; and exposure of frequent incidences of pest infestation (Table 8). In all focal areas, prolonged drought causes increased household expenses for buying bottled water for potable water. Drought causes limited quantity and quality of water. Buying bottled water can only be afforded by people with better financial conditions, while the poor community depends on their sources of water from the river and apply water treatment to have potable water. Increased use of bottled water may cause an increasing plastic waste in the area that may affect the environmental quality in the area.

Besides increased household expenses, prolonged drought also decreases household income due to the reduced production from agricultural commodities. Prolonged drought also causes the community to borrow money for fulfilling their daily expenses; some of them also obtain alternative on-farm jobs, such as fishing, and off-farm jobs, such as construction labours and gold miners. Impacts of prolonged drought on livelihoods have been most intense in villages of vulnerability class 1, with some people having to sell their assets such as land to fulfil their needs. The second most impacted were villages of vulnerability classes 5 and 2, followed by villages of vulnerability classes 3 and 4. In the focal area of villages of vulnerability class 4, there was no report of decreased household income. The reason was that the focal area has good adaptive capacities to cope with the negative impacts of prolonged drought. The examples of the adaptive capacities are such as preventing pest infestation by spraying insecticides, and good extension services to inform farmers on what they need to do to cope with the negative impacts of prolonged drought to the agricultural commodities.

The impact of prolonged drought on agricultural commodities is most severe for paddy production due to the high temperature causing the wet paddy field to dry and pest infestation induced by the heat. All of the villages have experienced paddy crop failure, which caused some of the communities in villages of vulnerability classes 1, 2, and 5 to buy rice to fulfil their needs for staple food. Besides paddy, prolonged drought also decreases rubber production in all villages. Oil palm production also reduces, as in villages of vulnerability classes 1, 2, and 4. In villages of vulnerability class 3, there was no report on the impact of prolonged drought on oil palm production because oil palm is considered new in villages of vulnerability class 3 focal areas. Meanwhile, in villages of vulnerability class 5, there is no oil palm plantation. Impacts of prolonged drought on fisheries are more severe in villages of vulnerability class 1, as there was no report from the other villages. Thus, the impacts of prolonged drought on agricultural commodities are most severe in villages of vulnerability class 1. The level of severity was not clearly distinguished for the other villages.

At the landscape scale, prolonged drought has induced land fires, mainly in cropland areas and oil palm plantations that are located more in the hill areas, and as reported, they occur more frequently in villages of vulnerability class 1 and vulnerability class 4. Pest infestation in paddy fields also occurs in a large area at the landscape scale. Pest infestation causes paddy crop failure, and some of the people in the community have to obtain alternative jobs to substitute for their loss from paddy harvesting.

Other condition that was not recorded during the FGD but was noted from the discussion with key stakeholders at district level, was that in areas where river is used for transportation mode, the prolonged drought made the villagers who live in the upstream areas cannot buy their daily needs to the city and are vulnerable to food insecurity situation. This situation is mostly happened in villages of vulnerability class 5, as in the upstream part of Sintang District and Kapuas Hulu.

Table 8. Negative Impacts of prolonged drought on the livelihoods, agricultural commodities, and landscapes in all studied vulnerability classes in West Kalimantan Province, based on the local community's perception.

Exposures	Levels	Impacts from prolonged drought	Vulnerability class				
			1	2	3	4	5
Limited rainfalls, limited water quantity and increased temperatures	Livelihoods	Decreased household income	v	v	v		v
		Increased household expenses	v	v	v	v	v
		Increased debt from Credit Union or middlemen	v	v			v
		Increased household income sharing from alternative on-farm jobs, i.e., fishing	v		v		v
		Increased household income sharing from off-farm jobs	v	v	v		
		Asset loss	v				
		Increased household expenses for purchasing bottled water	v	v	v	v	v
		Increased household expenses for purchasing rice and vegetables	v	v			v
	Agricultural commodities	Paddy crop failures	v	v	v	v	v
		Agricultural short term crops production decreased	v		v		
		Rubber production decreased	v	v	v	v	v
		Oil palm production decreased	v	v		v	
		Fisheries production decreased	v				
	Landscape	Induced land fires	v			v	
Pest infestation	Livelihoods	Increased household income sharing from alternative jobs (e.g., tapping rubber, gold miners)	v	v			
	Commodities	Paddy crop failures	v	v	v	v	
		Oil palm production decreased	v				
	Landscape	Impacts were not reported in the FGD	-	-	-	-	-

Source: FGD with the communities in 14 focal areas

Heavy rainfalls

Besides prolonged drought, another extreme climate event is the heavy rainfall that causes floods and is associated with whirlwinds. Heavy rainfall was not reported to have caused floods in the focal areas of villages of vulnerability class 2 (Table 9). Floods were only reported in villages of vulnerability classes 1, 3, 4, and 5.

Among the vulnerability classes, villages of vulnerability classes 1 and 3 experience more severe impacts due to heavy rainfall, particularly because villages of vulnerability class 3 is located closest to the river, while villages of vulnerability class 1 is located closest to mining areas. Based on the local perspectives during the FGD, mining has contaminated the water sources during heavy rainfall. Villages of vulnerability class 3 experiences the most severe impacts due to flood, which causes decreased production of rubber and crop failure for paddy and other food crops that lead to their reduced income. The second most severe impact is experienced by villages of vulnerability class 1, followed by villages of vulnerability classes 5, 4, and villages of vulnerability class 2 with the least severe impacts. Villages of vulnerability class 2 experiences the least negative impacts from floods, which may be due to the good water regulation by the natural lakes that occur in the villages of vulnerability class 2 areas, however, this need further investigation.

Table 9. Negative Impacts of heavy rainfall on the livelihoods, agricultural commodities, and landscapes by vulnerability classes of studied districts in West Kalimantan Province, based on the local community's perception.

Exposures	Levels	Impacts from heavy rainfall	Vulnerability class				
			1	2	3	4	5
Floods	Livelihoods	Decreased income	v		v		v
		Increased debt from the village mini-stores, village leaders, credit union	v				
		Increased household income sharing from alternative off-farm jobs (gold miners)	v		v		v
		Increased household income sharing from alternative on-farm jobs by fishing or selling fuelwood			v		
		Increases expenses for purchasing rice and vegetables			v		
		Skin diseases	v	v	v	v	v
	Agricultural commodities	Fisheries production decreased	v				
		Oil palm production decreased				v	
		Paddy and food crops failure	v		V		
		Paddy production decreased				v	
		Rubber production decreased			v	v	v
		Loss of income from rubber	v		v		
	Landscape	Enlarged inundated areas in riverine	v		v	v	
Heavy rainfalls and whirlwind	Livelihoods	Minor destruction in the garden	v				v
		Destruction of houses	v				v
	Commodities	None reported in FGD					
	Landscape	Enlarged inundated areas in riverine, and fallen trees in more hilly areas	v				v
Heavy rainfalls	Livelihoods	None reported in FGD					
	Commodities	Paddy production decreased		v			
		Rubber production decreased		v			
	Landscape	None reported in FGD					

Source: FGD with the communities in 14 focal areas

Other potential negative impacts from the heavy rainfalls, although not reported by the community during the FGD, are that it influences the transportation for marketing the agricultural products produced in the farms. The limited road accessibility during heavy rainfalls particularly happened in areas with poor road infrastructure as commonly encounter in villages of vulnerability classes 4 and 5. For oil palm, limited road accessibility will cause the fruit cannot be transported and sell to the factory. The oil palm fruit bunches will be rotten on-farm, and the farmers cannot obtain income from their oil palm trees. While for rubber, farmers will still be able to keep their rubber sheet and wait until the road condition is accessible, or they can transport it via the river.

Impacts of extreme climate events to water resources

Negative impacts of prolonged drought and heavy rainfall may also be related to the impacts of decreased quality of water resources. Additionally, mining activities have polluted the water sources (Table 10). Turbid water and polluted water were the most reported impacts occurring in all of the vulnerability classes, causing the communities to buy bottled water because the water cannot be consumed as potable water. In all of the village vulnerability classes, polluted water has caused skin diseases, and in vulnerability class 1 it was perceived to potentially affect human health in the long term. Impacts of turbid and polluted water on agricultural commodities were only reported in villages of vulnerability class 1; this may be related to the fact that villages of vulnerability class 1 are located closest to mining areas.

Table 10. Negative Impacts of decreased quality of water (turbid and polluted water) to livelihoods, agricultural commodities, and landscapes in all village vulnerability classes in studied districts of West Kalimantan Province, based on the local community's perception.

Levels	Impacts from decreased quality of water	Vulnerability class				
		1	2	3	4	5
Livelihoods	Increased expenses for purchasing bottled water	v	v	v	v	v
	Skin diseases	v	v	v	v	v
	Polluted water affected health in the long term	v				
Agricultural commodities	Cattles production decreased	v				
	Fisheries have limited sources of water	v				
	Paddy production from wet paddy field was decreased	v				
Landscape	Limited quantity of clean water from the existing water resources	v	v	v	v	v

Source: FGD with the communities in 14 focal areas

Market shocks

Extreme events related to market shocks were only reported for rubber and oil palm (Table 11). A negative impact of market shocks that were reported in all of the village vulnerability classes is decreased income from rubber farms. At the same time, market shocks were reported to affect income from oil palm in villages of vulnerability classes 1, 3, and 4. Decreased income has caused the farmers to borrow money from available financial agencies, such as village leaders, middlemen, and credit union. Some of the farmers have also obtained alternative jobs.

The drastic drop in rubber price experienced by all of the vulnerability classes has motivated the farmers to convert their rubber farm to oil palm plantation and other more profitable land uses. In particular cases, as in villages of vulnerability class 1, the drastic drop in rubber price has caused children to drop out of school to help their parents to fulfil their livelihood needs.

Market shocks have not directly affected the supply of agricultural commodities at the farm level. In the case of rubber, the drop of price in 2008 reached a level that has demotivated the farmers to maintain their rubber farms, which in the long term will reduce the rubber production in the area. At the landscape level, the price drop of rubber farms has stimulated a massive conversion of rubber farms to oil palm farms that are considered more profitable; this mainly takes place in villages of vulnerability classes 1, 3, and 5. In villages of vulnerability classes 2 and 4, there were no reports of the massive conversion of rubber farms to oil palm farms because there were other areas that could be converted to non-rubber farms.

Table 11. Negative Impacts of market shocks on livelihoods, agricultural commodities, and landscapes in all village vulnerability classes in the studied districts of West Kalimantan Province, based on the local community's perception.

Levels	Impacts of market shocks	Vulnerability class				
		1	2	3	4	5
Livelihoods	Decreased income from rubber farms	v	v	v	v	v
	Decreased income from oil palm farms	v		v	v	
	Increased debts from village leaders, middlemen, credit union	v	v	v	v	v
	Increased household income sharing from alternative jobs	v	v	v	v	
	Shifts from rubber farmers to oil palm farmers or other crops that are more profitable	v		v		v
Agricultural Commodities	Rubber price decreased drastically	v	v	v	v	v
	Rubber trees were not tapped and maintained, causing decreased rubber production		v	v		v
	Oil palm price decreased drastically	v		v		
	Oil palm CPO mils ceased operation				v	
Landscape	Large conversion of rubber farms (rubber agroforestry and monoculture) caused reduced rubber garden area	v		v		v
	Increased oil palm areas	v		v		

Source: FGD with the communities in 14 focal areas

In conclusion, the impacts of extreme events on the livelihoods, agricultural commodities, and the landscapes varied depending on the type and level of exposures in the landscape/village and responses, stem from the adaptive capacities, of the communities. During prolonged drought, a higher proportion of non-tree based land-use systems was increasingly exposed to the increased temperature that affects the humidity and, eventually, water availability in the areas. Better adaptive capacities, as in villages of vulnerability class 4 reduce the vulnerability to negative impacts of prolonged drought. During the extreme event of heavy rainfall, villages closed to the river are exposed to floods. The existing natural water regulation has reduced the vulnerability of villages of vulnerability class 2 to flood. Villages in the vicinity of mining areas may increase the potential of contaminated water. And for market shocks, the main impacts can be observed through the land-use conversion rate at the landscape level. Lands are used for more intensive agriculture and for growing commodities to achieve more profitable land-use systems.

Out of all the negative impacts experienced by the villages, villages of vulnerability class 1 has received the most severe impacts from all of the extreme events. Meanwhile, the level of severity in the other villages was difficult to be assessed since the level of adaptive capacities per village vulnerability classes varied and potentially reduced their severity level. More detailed studies need to be conducted through household interviews to assess a more detailed level of severity of the negative impacts in each of the vulnerability class.

3.3. Climate risks and adaptation potentials of agricultural-based livelihoods: a synthesis across seven districts

Climate risk is the probability of the occurrence of hazardous events or trends multiplied by the impacts of these events or trends occur (IPCC 2014). Risk results from the interaction of vulnerability, exposure, and extreme events, thus in this study, climate risks were analyzed based on the exposures, responses, and negative impacts of the agricultural systems to extreme climate and market events. Climate risks can be managed through adaptation potentials, i.e., potential response strategy to anticipate and cope with impacts that cannot be (or are not) avoided under different scenarios of climate change (Denton et al. 2014). In this study, the adaptation potentials were identified from the strategies taken and expected by the communities to cope with the anticipated negative impacts. Climate risks and adaptation potentials were analyzed from three levels, i.e., livelihoods, agricultural commodities, and landscapes. Based on the discussion with the communities, extreme events (climate and market) that impacted the livelihood, agricultural commodities, and landscapes in the seven districts, are prolonged drought, heavy rainfall that leads to floods, and market shocks (drastic price drop and closure of mils and factory).

The results in the next section showed that climate risk and adaptation potentials varied between different extreme events, particularly those related to the agricultural commodities and landscape. Meanwhile, the livelihoods' impact associated with climate risk and their adaptation potentials are generally similar under all three extreme events, i.e., loss of income, increased expenses, dependency on illegal gold mining as off-farm sources of income, higher dependency on money lender, and food insecurity issues.

3.3.1. Risks and adaptation potentials from prolonged drought

Based on the information obtained through FGD with the communities, prolonged drought is the extreme climate events that have more negative impacts on livelihood, agricultural commodities, and the landscapes, compared to other extreme events such as heavy rainfalls and market shocks. Prolonged droughts that happened in the seven districts have caused increasing temperatures and limited rainfalls up to 3-5 months.

Climate risks and its adaptation potentials during the prolonged drought from **livelihoods** perspectives are related to farmers' on-farm income and food security for their daily consumption (Table 12). The risks lead to loss of income, increased household expenses, increasing gold mining activities, higher dependency on moneylenders, and asset loss. The adaptation potentials to cope with the risks on on-farm income are mostly related with (a) reserving alternative sources of income from on-farm and off-farm activities; (b) existences of government interventions to provide alternative sources of income for the impacted community during prolonged drought; and (c) existence of village financial institution that provides soft-loan for farmers. Increasing gold mining activities in the river as an alternative source of income need to be limited through regulation and law enforcement, as this in the longer term will lead to water pollution.

Table 12. Risks, anticipated impacts, and adaptation potential from prolonged drought in seven studied districts in West Kalimantan Province.

Risks to prolonged drought	Anticipated impacts of prolonged drought	Adaptation potentials to prolonged drought
Livelihood		
Increasing temperatures and limited rainfalls affect on-farm sources of livelihoods (crop failures for food crops; decreased yields for rubber and oil palm)	Income loss from on-farm activities	• Farmers to be better prepared to seek and engage in an alternative source of income from on-farm and off-farm, e.g., through developing new skills and networks
	A shift in income sources to off-farm, e.g., illegal gold mining	• Regulation and law enforcement to control illegal gold mining in the river • Government's anticipations and interventions to provide alternative sources of income during prolonged drought
	Higher dependency on moneylenders Assets loss	• Strengthening or developing the village financial institution that provides soft-loan for farmers when they experienced income loss from on-farm activities
Crop failures caused farmers buying rice to fulfill daily consumption	Increased household expenses	• Alternative income source • Access to loanmoneylender • Rice-storage at household level or community level
Agricultural commodities		
Limited rainfalls and high temperatures during the prolonged drought have dried the food crops that lead to decreased stock for staple food.	Insecure staple food stocks due to crop failures and decreased yields.	• Irrigation and other rainwater harvest technologies to maintain water sources in the wet paddy field and other cropland • Planting staple crops other than paddy, that are resistant to drought and pest infestation, such as cassava, tubers • Install mini water reservoir to water the crops during dry season • Change planting calendar in El NNino year.
Increased temperatures and	Decreased stock of rubber latex	• Planting drought-resistant rubber clones

Risks to prolonged drought	Anticipated impacts of prolonged drought	Adaptation potentials to prolonged drought
limited rainfalls inhibit the growth of rubber and oil palm, and decreased its production.		• Included trees on rubber farms to maintain humidity during drought and manage it as agroforestry
	Decreased stock of oil palm fresh fruit bunches	• Planting drought-resistant oil palm varieties • Provide tree maintenance such as pruning yellowing leaves, and applies organic fertilizers
High temperature during prolonged drought dried fish pond	Decreased stock of fishes from aquaculture	• Regulate the schedule of aquaculture by avoiding the dry season (from June to September). • Select fishes that can grow well in a limited quantity of water, such as catfish.
Landscape		
Increased temperature during the prolonged drought have induced drastic increase in pest population	Frequent incidences of pests infestation	• Farmers are well equipped with knowledge and facilities to handle pests (insects and rodents) in paddy, agricultural crops, and oil palm. • Intensive extension services to introduce integrated pest management to farmers. • Planting trees on the agricultural farm and increase agrobiodiversity to maintain microclimate that limited the drastic increase of pests (insects)
Increased temperatures and limited rainfalls induced uncontrolled fires from slash-and-burn land clearing	Frequent incidences of fires	• Application of alternative to slash and burn land clearing techniques. • Regulation at village and district level that prevent the incidences of fires
Increased temperatures and limited rainfalls, dried and limited the water sources.	Competition for obtaining potable water from public sources of water	• Drilled wells as public sources of potable water and regulate its uses. • Techniques to treat turbid water for household consumption

Source: FGD with the community in 14 focal areas

Risks from prolonged drought to **agricultural commodities** are (a) dried crops that lead to insecure staple food stocks; (b) slow growth of rubber and oil palm that decreased production; and (c) dried fish pond. Adaptation potentials to cope with the anticipated impacts are (a) planting drought-resistant crops; (b) provide crops or trees maintenance such as application of organic fertilizer; (c) provide irrigation or mini water reservoir to ensure enough water for the plants and fishes; and (d) re-arrange planting calendar during *El-Nino* years.

At the landscape level, risks from prolonged drought are related to (a) increasing temperatures that lead to a drastic increase of pest population; (b) uncontrolled fires from slash-and-burn land clearing; and (c) limited available water sources for potable water. The adaptation potentials to cope with the climate risks at the landscape level, are mainly by (i) increasing farmers knowledge and capacities to handle pests through integrated pest management approach; (ii) application of alternative to slash-and-burn land clearing techniques; and (iii) application to treat turbid water for household consumption. Extension services are vital in building farmers' knowledge and capacities to cope with the anticipated impacts. For preventing fires, regulation at village and district level need to be developed.

3.3.2. Risks and adaptation potentials from heavy rainfalls

Heavy rainfalls in the studied districts have caused floods and whirlwind, although whirlwind did not occur as frequently as the floods. Risks from heavy rains to **livelihood** are (a) floods in agricultural systems in the riverine areas that caused crop failure; (b) increased water turbidity from floods caused skin diseases; and (c) food security issues due to crop failures from the floods (Table 13). The anticipated impacts and adaptation potentials to heavy rainfalls generally the same as the prolonged drought', except the heavy rains there are also risks of increasing skin diseases of the communities. And from the heavy rainfalls, there was no report on the potential risk of having assets loss as happened during the prolonged drought.

Table 13. Risks, anticipated impacts, and adaptation potentials from heavy rainfalls in West Kalimantan Province.

Risks of heavy rainfalls	Anticipated impacts of heavy rainfalls	Adaptation potentials of heavy rainfalls
Livelihood		
Heavy rainfalls caused floods in the riverine agricultural systems that affect on-farm sources of income (through crop failure of paddy and decreased rubber yield)	Income loss from on-farm activities	• Reserve alternative source of income from on-farm and off-farm
	Increasing gold mining activities	• Government interventions to provide non-mining sources of income during the floods • Regulation and law enforcement to control illegal gold mining in the river
	Higher dependency on the moneylender	• Strengthening or developing village financial institution that provides soft-loan for farmers when they experienced income loss from on-farm activities
Floods caused turbid water and lead to skin diseases	Increasing people with skin diseases	• Reserve alternative sources of water for household consumption
Crop failures caused farmers buying rice to fulfil daily consumption	Increased household expenses	• Reserve the alternative source of income from on-farm and off-farm • Borrow money from moneylenders • Constructing rice-storage at household level or community level
Agricultural commodities		
Flood causes decreased yield to crop failure of paddy	Insecure paddy stocks	• Apply drainage to avoid floods in irrigated paddy fields or paddy fields that located in the riverine
Heavy rainfalls and floods caused rubber trees cannot be tapped, and eventually decreased yield	Decreased stock of rubber	• Apply the drainage system in rubber farms that are located in the riverine

Risks of heavy rainfalls	Anticipated impacts of heavy rainfalls	Adaptation potentials of heavy rainfalls
Floods caused oil palm farms inundated that limit activity to harvest the fruit	Decreased stock of oil palm fruit bunches	• Apply the drainage system in oil palm farms that are located in the riverine
Floods caused turbid and polluted water that affect water quality for aquaculture	Decreased stock of fishes from aquaculture	• Apply techniques to handle polluted and turbid water that affected the fish production
Landscape		
Floods caused inundation in the riverine areas	Flooded agricultural lands and settlements in the riverine areas	• River normalization/river engineering
Floods caused turbid and polluted water in water sources for potable water	Limited quantity of clean water for household and aquaculture	• Apply techniques to treat turbid and polluted water for household consumption and aquaculture • Explore alternative sources of clean water

Source: FGD with the community in 14 focal areas

Risks of heavy rainfalls to **agricultural commodities** were mainly due to flood that inundated the agricultural systems near riverine for days to weeks. Floods risk the paddy field to have a decreased yield and crop failures. The heavy rainfalls and floods made the rubber trees cannot be tapped. While for oil palm, the flood limits the harvesting frequencies of oil palm due to inundation in the oil palm farm. And for aquaculture, the floods caused turbid and polluted water that affect water quality for aquaculture. The anticipated impacts of floods are generally the same as in the prolonged drought, i.e., to cause decreased yield in paddy, rubber, oil palm and fishes. However, the adaptation potentials are different from the prolonged drought. Adaptation potentials to floods are generally to apply drainage systems in the paddy field, rubber farms and oil palm farms for avoiding a long inundation period. While aquaculture is by using techniques to treat polluted and turbid water.

At the **landscape** level, the risks mostly related to floods that inundated agricultural lands and settlements in the riverine areas and decreased level of water quality due to increase in its turbidity and pollution levels. Adaptation potentials to handle the inundation in the riparian areas is river normalization or engineering as have been applied in some areas. Issues with turbid and polluted water need to be resolve by using techniques to treat turbid and polluted water and explore alternative sources of clean water.

3.3.3. Risks and adaptation potentials from market shocks

Market shocks to agricultural commodities drive massive conversion of the tree-based land-use system, which in the long term influence the microclimate, pests population, crop failures and increase local vulnerability to climate change. Market shocks caused by sudden price drop or increased price were considered the extreme events in this study. The market shocks happened in all typologies and influence the communities, agricultural commodities, and landscape vulnerability to climate change. Market shocks were reported to happen more frequently for rubber and oil palm. Paddy is considered as commodities that not for commercial purposes, except there is a high surplus and demand from their neighbours.

Risks of market shocks to **livelihoods** are generally related to decreased income due to drastic price drops, and dependency on one commodity as a source of livelihood if the price of the commodity is drastically increased (Table 14). Adaptation potentials to price dop are reserving alternative source of income and developing or strengthening village financial institution that provides soft-loan for farmers. In comparison, the adaptation potentials for a sudden increased price are reserve alternative off-farm sources of income and increase commodity diversity as options for sources of livelihoods.

Market shocks related to **agricultural commodities** are closing of oil palm mils, sudden increased price, and sudden price drop. The risks of those market shocks are (a) farmers cannot sell their commodities; (b) farmers focus planting only one commodity under monoculture systems; (c) decreased farmers' motivation in maintaining and harvesting their crops. Adaptation potentials to cope with the anticipated impacts need to include multi-stakeholders participation such as through the establishment of a partnership scheme between farmers with oil palm factories or plantation to secure farmer's market access and involvement of government for motivating farmers in maintaining their commodities. Commodity diversification also can be one of the adaptation potentials to cope with a dependency on only one commodity. Commodity diversification needs to be supported by the options of profitable commodities to be promoted to farmers.

At the **landscape** level, the market shocks influence the land-use changes. Thus the risks are related to increased unproductive lands, increased number of oil palm farms, increased deforestation rate, and increased fire incidences due to slash-and-burn land clearing. Adaptation potentials to market shocks are mostly related to government interventions, regulations, socialization and promotion of alternative farming systems that mixed profitable commodities in the same farms, such as in agroforestry systems.

Table 14. Risks, anticipated impacts, and adaptation potentials from market shocks in West Kalimantan Province.

Risks of market shocks	Anticipated impacts of market shocks	Adaptation potentials of market shocks
Livelihood		
Decreased price of the dominant commodities as sources of livelihood, decreased farmers and middlemen income.	Income loss from on-farm activities	• Reserve alternative source of income from on-farm and off-farm
	Higher dependency on the moneylender	• Strengthening or developing the village financial institution that provides soft-loan for farmers when they experienced income loss
The sudden increased price of a commodity caused farmers to plant and depending on their livelihood to only one commodity	High dependency on the source of income from only one commodity	• Reserve alternative off-farm sources of income • Increase commodity diversity as options for sources of livelihoods.

Risks of market shocks	Anticipated impacts of market shocks	Adaptation potentials of market shocks
Agricultural commodities		
Closing of mills or factory of oil palm caused farmers cannot sell their oil palm fruit	No market to sell oil palm fruits	• Establish a partnership scheme between farmers with oil palm plantation or mils to secure farmer's market access
Sudden increased price of a commodity caused farmers to focus on planting the commodity under monoculture systems	Less commodity diversity	• Explore alternative commodities with high economic value and not difficult to cultivate
Sudden price drop of oil palm and rubber commodities decreased farmers motivation in harvesting and maintaining their crops	Decreased production of rubber and oil palm	• Government interventions to assist and motivate farmers for maintaining their rubber and oil palm farms.
Landscape		
The sudden price drop of oil palm and rubber commodities reduced farmers motivation to maintain their crops	Increased number of unproductive lands	• Government interventions to assist and motivate farmers to maintain their rubber and oil palm farms. • Government interventions to assist farmers in utilizing unproductive lands
The sudden price drop in rubber caused increased rubber farms conversion to other crops	Frequent fires incidences from slash and burn land clearing in land conversion	• Introduction and application of alternative to slash-and-burn land clearing techniques. • Regulation at village and district level that prevent the incidences of fires
The sudden price drop in rubber commodity caused farmers to change their farming systems to more profitable systems	Increased land-use conversion	• Regulation to control rate of land-use conversion. • Promote alternative farming systems (such as agroforestry systems) that enable mixed of profitable species without a major change in its land-use system.
Increased needs for lands to plant new commodities caused forest conversion into agricultural lands	Increased deforestation	• Socialization of regulation and rights to use forest state land, such as through social forestry schemes • Promote alternative farming systems that mixed profitable commodities in the same farm such as agroforestry systems

Source: FGD with the community in 14 focal areas

As mentioned above, the distribution of village vulnerability classes is not uniform across districts. There are districts closed to coastal areas which are dominated by vulnerability classes 1 and 2, and there are districts in the upstream of Kapuas which are dominated by vulnerability classes 4 and 5. The climate risks and their impacts on livelihoods, agricultural commodities and landscapes also vary. Moreover, the adaptation potentials not only should be sought to address the direct impacts of extreme events but should also anticipate the secondary impacts. For example, the harvest failures due to prolonged drought caused people to lose income. To meet their need, people shift to illegal gold mining during that period. Such activities polluted the river and reduced their access to clean water that caused some health issues and also increased expenses from having to buy bottled water, even for this who do not conduct illegal gold mining. Some measures can be in the form of policies, programs, partnerships and incentives. To increase the adoption rates of communities to reduce their vulnerability to extreme events, farmers, government, and other stakeholders need to change their behaviours. Combinations of awareness-raising sessions, communications, trainings, aids and incentive schemes are required. Last but not least, the livelihood capital platform of financial, human, social, physical and financial capitals need to be assessed carefully as they can function as enabling factors to realize the adaptation potential. The nest session will discuss this issue.

3.4. Enabling factors of agricultural systems' adaptation to climate change in West Kalimantan

Vulnerability level of a system to hazards or extreme events is not only determined by its exposures to those extreme events but also depending on its adaptability or adaptive capacities. The higher the adaptive capacities, the less vulnerable the system to extreme events. Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, including adjustments in both behaviors and resources and technologies (IPCC WG2 2007). In this study, adaptive capacities to cope with extreme events such as prolonged drought, heavy rainfalls, and market shocks were determined in general contexts through the identification of determinant factors in adaptation potentials of agricultural systems to extreme events. The enabling factors were identified from the adaptation potentials, as explained in subsection 3.3. These enabling factors can be used and considered in the development of strategies to increase the resilience of agricultural systems in West Kalimantan to climate change (Table 15).

Table 15. Enabling factors of agricultural systems adaptation to climate change in West Kalimantan Province

Category	Enabling factors
Natural resources	• Sources of clean water during the dry season • Forests as sources of alternative livelihoods • Biodiversity to balance pests' food chain that can reduce the level of pest infestation in the areas • Distance to riverine areas • Agricultural systems with diverse commodities • Tree-based agricultural systems
Infrastructure	• Technologies to handle the impacts of extreme climate events • Water resources infrastructures (irrigation, wells, drainage construction, water reservoir, water treatment systems) • Roads infrastructures • Market-related infrastructures (mills, factories) • River normalization (engineering) • Provision of agricultural facilities (seedlings, fertilizers, pesticides, agricultural equipment)
Human resources	• Farmers' knowledge to handle pests and diseases stimulated by extreme climate events • Farmers' knowledge to cope with the negative impacts of extreme climate events on their agricultural systems • Farmer's access to sources of alternative income
Financial resources	• Access to soft loan • Access to government credit programs • Existence of finance-based institution at the village level
Social	• Extension services to disseminate new technologies and information that will assist farmers in coping with the exposures of extreme climate events, such as techniques of climate-smart agriculture • Local community information dissemination systems • Collective actions in agricultural practices • Policy and regulations related to land-use change and water management issues • Mutual partnership in market mechanism between farmers with middlemen, farmers with factories or concessions and middlemen with factories

The enabling factors under the five livelihood capitals are not only varied from village to village, but also from district to district. Districts in coastal areas tend to have better physical and financial capitals, but a lower level of natural capitals. The opposite patterns can be seen in districts in the upstream of the watershed. Even though those in the coastal areas tend to be higher in the human and social capitals, the differences are not as marked as the other two capitals. The district-level intervention has to take into account the enabling factors, along with specific risks of extreme events on the livelihoods, agricultural commodities and landscapes, in achieving resilience and sustainable livelihoods and landscapes. The balances between nature-based solutions and engineering-based solutions are needed, but they will be local context-specific. This study strives to address agricultural-based livelihood vulnerability to extreme events. Therefore we will next be zooming in into agricultural specific strategies, or known as climate-smart agriculture.

4 CLIMATE-SMART AGRICULTURE TO INCREASE RESILIENCE

Based on the discussions with the communities in the 14 focal areas, agriculture has been the main source of livelihood in the seven districts for generations. As explained in section 3.2, in the seven studied districts, extreme climate events have brought impacts on the agricultural production in the area, such as (a) Decreased production of food crops that lead to insecure food stock for local consumption; (b) Decreased production of primary commodities such as rubber and oil palm that lead to reduced income and has significant implications for household strategies to maintain sufficient income to pay for their daily expenses, in the long term this may lead to increased poverty; and (c) Extreme climate events have also influenced the quality and quantity of water for daily needs and agricultural purposes, this particularly happened in areas near the river, mining sites, and areas with fewer trees or shrublands.

Actions have been taken by the community to cope with the negative impacts of extreme events. However, in the future, to mitigate the negative impacts of extreme climate events on agriculture, farmers need to modify their agricultural practices and systems to be more resilient to extreme climate events. Strategies under the frame of climate-smart agriculture (CSA), as defined by FAO (2010) are expected to guide the actions needed to transform and reorient agricultural systems to effectively support livelihood resilience and ensure food security in a changing climate. CSA aims to enhance the capacity of agricultural systems to support food security, incorporating the need for adaptation and the potential for mitigation into sustainable agriculture development strategies. CSA is not a set of practices that can be universally applied, but rather an approach that involves different elements embedded in local contexts (FAO, 2010). CSA includes actions, both on-farm and beyond the farm, and incorporates technologies, policies, institutions, and investments. CSA is intended to tackle three objectives that were used to frame the strategies for resilient agriculture-based livelihood developed for this study, i.e.:

a) Strategies on sustainable agricultural productivity and income. These strategies are related to agricultural production and livelihood systems. Examples of the strategies are the promotion of integrated systems to diversify food sources and consequently strengthen the resilience of farmers' livelihood, such as crop-livestock systems, rice-fish systems, and agroforestry.

b) Strategies on adaptation and building farming system resilience to extreme events. These strategies are related to measures to directly make available enabling factors needed in building farming systems that rightly address the extreme events. They encompass infrastructure development, farming practices, and technologies. Examples of the strategies are introducing plants or varieties that are tolerant to high temperatures and drought, fire-resistant and tolerant, resistant to diseases and pests.

c) Strategies on reducing greenhouse gas emissions. These strategies are related to enabling factors in practices, technologies, and policies. Examples of the strategies are reducing the use of/judiciously using inorganic fertilizers, avoiding soil compaction or flooding to reduce methane emissions (e.g., in paddy rice systems), and sequestering carbon (e.g., planting perennial crops and cover crops).

FAO recommendation for developing climate-smart agriculture strategy (FAO, 2012) that when designing a CSA strategy, one must consider that, at the micro (farmer) level, adaptation strategies encompass a wide range of activities that will need to be evaluated and prioritized. Examples are including modifying planting times and switching to varieties resistant to heat and drought; developing and adopting new cultivars; changing the farm portfolio of crops and livestock; improving soil and water management; including conservation agriculture; integrating the use of climate forecasts into cropping decisions; improving fertilizer use and increasing irrigation; increasing labour or livestock input per hectare to increase productivity; increasing the storage of food/feed or the reliance on imports; increasing regional farm diversity; and shifting to non-farm livelihoods. At households who depend mostly on agriculture for their livelihoods, the definition of adaptation benefits can be considered, for practical purposes, as the extent to which income is increased or stabilized for an acceptable livelihood level by a combination of the following: (i) productivity increases and reduced variability by adopting certain practices; (ii) diversifying livelihood strategies on the farm; and (iii) diversifying income through off-farm activities.

In this study, strategies to increase livelihood resilience through climate-smart agriculture was analyzed based on the enabling factors to support the implementation of adaptation potentials, as identified in section 3.3 and 3.4, in achieving the three objectives of climate-smart agriculture. The strategies were identified in three levels, i.e.,(1) general strategies for all studied districts and village vulnerability classes; (2) Strategies per village vulnerability class; and (3) Strategies at the district level. At the village level, the identified strategies are only for non-peat villages as villages with peat have vulnerability levels exceeding those of the non-peat villages in terms of livelihoods and the ecosystem vulnerability. At the district level, the strategies are prioritized based on specific strategies for each village vulnerability class.

4.1. General strategies on climate-smart agriculture

General strategies on climate-smart agriculture are referring to common strategies for all village vulnerability classes in the seven studied districts. These strategies were developed based on three different extreme events (prolonged drought, heavy rainfall, and market shock). Although market shock is not an extreme climate event, it indirectly affects the vulnerability of agricultural-based livelihoods to extreme climate events.

4.1.1. Strategies for sustainable agricultural productivity and income

The extreme events such as prolonged drought and heavy rainfalls have caused crop failures and decreased yields for rubber and oil palm, to a level that affects farmers' income. Crop failures also caused farmers to buy rice to fulfil their daily consumption. Some farmers also borrow money from village moneylenders such as middlemen to fulfil their needs. To cope with the negative impacts of extreme events on agricultural production and income, these are the strategies that can be developed:

a) Strategies for increasing food security, such as promoting the production of diverse staple food besides rice. The communities in the seven studied districts greatly depend on rice as their staple food. They need to start planting maize and cassava to diversify their staple food. Besides the diversification of staple food, they also need to manage their rice storing system, by constructing rice storage at the household or community level. Planting fruit trees such as banana, jackfruit, breadfruits, can also be used to secure food in the area.

b) Strategies for achieving income security, such as diversify sources of income from on-farm and off-farm. Currently, the sources of on-farm income are mostly from rubber monoculture or oil palm monoculture. These monocultural systems are prone to market shocks and have lower yield during prolonged drought or heavy rainfalls. In areas where the communities are depending on monoculture systems, integrated farming systems need to be promoted for on-farm income diversification, such as by integrating livestock with oil palm plantation or fisheries-poultry-plantation system. For areas where integrated farming systems have been applied, the market potentials of the products need to be improved through improving the quality of the products or through innovative post-harvest handling and shortening the market chain.

c) On the other hand, the current off-farm income is obtained mostly from gold mining because there are not many options for off-farm sources of income in the area. Gold mining activities caused the drinking water quality in the areas are decreased. Thus, other sources of off-farm income with lower environmental risks need to be explored in the area.

d) Strategies on coping with continuous debts due to sudden increase in household expenses and income loss. One of the strategies are supporting farmers' access to soft loans via village financial institutions or banks, or improving farmers' household financial literacy and management. Currently, the communities depend on middlemen or village leaders or wealthier members of the community for loans.

e) Strategies on coping with market shocks of a particular commodity (e.g. sudden changes in price, oil palm mils closure) are such as not only depending on only one specific commodity as sources of income. Developing diverse commodities are expected to mitigate the anticipated impacts of market shocks. Moreover, to ensure farmers’ market access, a fair partnership between farmers and the private sector need to be established.

4.1.2. Strategies for adaptation of farming systems to build resilience

Based on the discussion with the communities in the seven studied district, there is no clear pattern on the interval of extreme climate events, nor it can be predicted. Thus the communities need to adapt and build resilience to the extreme events. Strategies to reduce the anticipated impacts of extreme events need to be developed. In the context of the agricultural-based source of livelihood, the strategies are involving the transformation of the current farming systems into more adaptable systems. The transformation will be different between farming systems, depending on the systems' responses to extreme climate events. In our seven studied districts, two major extreme climate events have a great impact on the agricultural-based livelihoods, i.e., the prolonged drought and heavy rainfall. And four major farming systems are contributing to the local livelihood, i.e., wet/irrigated paddy field, dry paddy field, rubber-based system, and oil palm monocultural systems. As explained in chapter 3, the negative impacts from prolonged drought to the agricultural systems are higher than the heavy rainfall. Wet or irrigated paddy field and dry paddy field are more prone to extreme climate events than rubber-based or oil palm-based systems. As part of the adaptation strategies, farmers' access to extension services is key for assisting farmers in adapting to extreme climate events.

Adaptation strategy to prolonged drought

During prolonged drought, paddy field (wet and dry) is the most impacted compared to the rubber-based farming system or oil palm-based plantation. Limited rainfalls and high temperatures during the prolonged drought have dried the food crops and increased the pests population, which eventually lead to crop failures. For rubber and oil palm, increased temperatures and limited rainfalls inhibited the growth, and in the worst case, it leads to decreased latex and oil palm fruit bunches production.

The drought that is commonly happened in the seven studied districts from June to September. This coincides with the dry period when communities and companies, especially in the past, conduct their land clearing with fire for planting rice, oil palm or other crops in dryland. When drought is prolonged, or there is El Nino phenomenon that increased the temperature rate in the area, the slash and burns activities lead to an uncontrolled fire.

Based on the discussion with the communities during the FGD, there is still limited adaptation activities to anticipate the negative impacts of prolonged drought. There is no transformation in the farming systems because there is still limited awareness building or capacity building given to farmers for anticipating the negative impacts of extreme climate events. Although from infrastructures, there are supports from the local government for constructing water reservoirs. Strategies that will assist farmers in transforming their farming systems need to be developed and implemented. These strategies are:

a) Strategies on coping with the insufficiency of water resources for agriculture during prolonged drought. The strategies are involving infrastructure development, such as the construction of mini water reservoirs or wells to water the farms. Other strategies are changing the planting calendar by shifting the planting season of food crop from June to September or October when there is an indication that prolonged drought will happen. The evidence of prolonged drought usually announced by the climatology station in the area. Farmers need to be well informed and aware of the potential adaptation they need to take when there is a prolonged drought. The introduction of varieties that able to be grown under limited water resources is expected.

b) Strategies on coping with pest outbreak in cropland and oil palm plantation. Farmers need to be well-equipped on integrated pest management for anticipating the pest outbreak. Pest outbreaks can also be avoided by understanding the life-cycle of the particular pests and time when the pests usually have the highest infestation. Farmers need to avoid planting food crops when there is a potential for high pest infestation. Farmers also need to be well informed on the use of pesticides and their potential environmental risks when they applied it in their farms. Extension systems will be vital for assisting farmers in handling the pest outbreak. Studies also need to be conducted to select local varieties that resistant to the pest outbreak.

c) Strategies on coping with decreased yields of rubber and oil palm during prolonged drought. The strategies will involve farm maintenance such as tree maintenances, planting cover crops as a natural mulch, applying organic fertilizer to support soil humidity during drought, and planting varieties that are resistant to drought. There is also a need to modify the microclimate in the landscape to a level that supporting good growth of rubber and oil palm during prolonged drought. Adding more trees in the landscape is expected to stabilize the microclimate in the area during prolonged drought.

d) Strategies on preventing uncontrolled fire during prolonged drought. Currently, there is a regulation to prohibit burning in land clearing activities. There are suggestions on alternatives methods to burning in the land clearing; however, there is still require further investigations on the cost-effectiveness of those alternative methods. Besides providing the alternative technique to burning, shifting planting calendar to the end of prolonged drought can also reduce the possibility of fire incidences in the area. A system to distribute information about drought from the climatology station to farmers need to be established. The climatology stations need to be well-equipped with technology and knowledge for predicting when the prolonged drought will be ended.

Adaptation strategy to heavy rainfall

Heavy rainfalls affected agricultural systems that are located near riverine. In the seven studied districts, in the riverine, farmers usually plant rice or other food crops and rubber, because of better soil fertility of the alluvial soil. In comparison, the reason for planting rubber was because of transporting rubber slabs to the city via the river. For oil palm, farmers usually plant it in the hill areas; thus, oil palm received fewer exposures to floods. The impact of heavy rainfall on oil palm is mostly related to the reduced number of days for harvesting the fruits. For rubber, the impact is relatively the same as for oil palm, that the heavy rainfalls reduced the number of days for tapping the rubber trees. The rubber tree is quite tolerant of inundation; the tree will be recovered after the inundation.

Heavy rainfall is commonly caused floods; however, usually, the floods only happen for three days to a week. In the worst case, it can be up to 2 weeks. Often, when floods occur, the water will quickly recede after 1-3 days. Thus, the impact on the agricultural systems is not as worst as when there is a prolonged drought. During the FGD, from 14 FGDs, there is only one case in Menjalin, Landak District, that was reported to experience landslide due to heavy rainfalls.

a) Strategies on inundated ricefield, cropland and rubber farms in the riverine during floods. Constructing drainage systems will shorten the inundation duration and help the water to recede quickly. Currently, when floods happen, farmers usually will wait for the water to recede, thus constructing drainage systems will reduce the potential impacts from the inundation process to the crops. Inundated ricefield and cropland often lead to crop failures.

b) From the landscape-level perspective, there is also a need to inform the village government for developing zonation systems for avoiding planting food crops in areas that are commonly experienced floods. River normalization or engineering has also been applied in some areas that experienced floods. The river normalization also needs to be supported by the landscape management in the upstream areas that can reduce the number of soil sedimentation in the river.

c) Strategies on soil erosion from farming systems during heavy rainfalls. These strategies involving the application of soil conservation techniques such as terracing in slope areas, no-tillage, and contour-line farming. Natural Vegetation Strip terracing technique can be introduced to farmers that are planning to do farming in slope areas. Currently, the adoption level of soil conservation techniques is still low. The extension systems need to be improved for supporting farmers' high level of adoption on soil conservation techniques.

d) Strategies on handling decreased water quality for aquaculture and other agricultural systems. Turbid water during heavy rainfalls was reported in all focal areas during the FGDs. Turbid water has decreased the production of fishes from aquaculture, also affecting the irrigated rice field. Turbid water may be caused by the high-level of soil sedimentation in the river, and some may come from the gold mining activities in the river that also caused the turbid river water. Thus, the strategies for handling water quality are correlated to the strategy for handling soil erosion.

e) From the landscape-level perspective, policy to regulate opening areas in upstream areas for plantation needs to be enforced. The massive land-use conversion from forested areas to plantations in the upstream areas increased landscape and village vulnerability to landslide and soil erosion.

4.1.3. Strategies for reducing greenhouse gas emissions

In the seven studied districts, there are two significant sources of greenhouse gas emissions, i.e., fire-induced by prolonged droughts (El Nino), and fire-induced by land management, particularly the slash and burn land clearing method. During prolonged droughts, oil palm plantation and croplands are prone to fire. Besides the increased emissions, the reduction of carbon sequestration also occurs due to tree-based land-use conversion to bareland or cropland. Thus, strategies for reducing greenhouse gas emissions are:

a) Strategies on coping with fire incidences, such as adopting technologies as alternatives to the slash-and-burn land clearing method and developing regulations at the village and district level to prevent fires.

b) Strategies on maintaining or increasing carbon sequestration, such as by planting trees. Trees can be planted as fences in the cropland areas or oil palm plantation. Fruit trees are recommended, as it does not have to cut to be used as sources of income. Promoting agroforestry that integrates trees with annual crops is expected to increase farmers' motivation for planting trees in their farms. Planting trees will also provide benefits to a more stable microclimate in the areas. Besides planting trees, reducing conversion rates of tree-based land-use systems will also contribute to strategies on carbon sequestration. Massive land-use change needs to be controlled through regulations at the village and district level.

4.2. Strategies on climate-smart agriculture of different across village vulnerability classes

Based on the analysis in chapter 3, there are different degree of exposures, responses, and impacts of varying village vulnerability classes that are developed in this study. Different levels of vulnerability will lead to different prioritization for implementing or developing strategies that can increase agricultural-based livelihoods through climate-smart agriculture. From chapter 3 analysis, the vulnerability in each of village vulnerability class to extreme events (climate and market shocks) is not only determined by the level of exposures and sensitivity to extreme events, but also by its adaptive capacities. In this section, prioritization of the strategies that need to be applied to support the development of climate-smart agriculture will be elaborated in each village vulnerability class.

4.2.1. Village vulnerability class 1 (most vulnerable)

Village vulnerability class 1 is classified as having agricultural-based livelihood that most vulnerable to extreme climate events. From the analysis in chapter 3, this village vulnerability class is most vulnerable to floods, pest outbreaks, prolonged drought, and fire. This village vulnerability class has the highest number of villages, based on the data in 2017, developed in this study. Compared to other vulnerability classes, it has the highest rate of land-use change, and almost no forested areas remain. This village vulnerability class also has the highest village population, which increases the demand for large agricultural lands for the source of livelihood.

Despite its vulnerability status, these villages of this vulnerability class have better infrastructures compared to the other villages, as these villages are closest to oil palm plantations, oil palm concession areas, mining areas, roads, and palm oil factories. Thus, its adaptive capacities related to infrastructure are better, including the provision of agricultural facilities for anticipating adverse impacts of extreme climate events. However, adaptive capacities related to natural resources are quite weak. The reasons are: no more forests left as sources of alternative livelihoods; poor access to clean water; the farming systems are dominated by monocultural systems that are prone to market shocks. Also, the biodiversity is lower than other village vulnerability classes, thus affecting the imbalance of pests' food chain, which leads to a higher potential of exposure to pest outbreaks. From human resources, financial resources, and social aspects, there is no apparent difference between this vulnerability class with the other village vulnerability classes.

Prioritization of strategies for climate-smart agriculture in village vulnerability class 1, needs to be include strategies related to floods, pest outbreaks, prolonged drought, and fire management. For supporting sustainable production and livelihood, the community needs to develop agricultural diversification as the area will potentially be dominated by one commodity, i.e., oil palm and the village is surrounded by oil palm concessions and factories. Planting trees on farms in the village vulnerability class 1 is expected to cope with the negative impacts of extreme events on plant production. Compared to the other vulnerability classes, the impacts of extreme climate events on aquaculture in village vulnerability class 1 are the most significant; thus adjustment of aquaculture need to be prioritized in this village vulnerability class such as selecting fish species that tolerant to turbid water and will still be developed under limited water resources. A partnership between oil palm companies with the community is expected to support the farmers' market access to sell their oil palm fruit bunches. For reducing emissions due to fire incidences that often happen during land-use conversion, in this village vulnerability class, strategies need to be developed to cope with massive land-use change, by enforcing regulation on land-use conversion.

To support the development of climate-smart agriculture, referring to the enabling factors in Table 15 in subchapter 3.4., in village vulnerability class 1, the category of adaptive capacities that need to be enhanced in this village vulnerability class is mainly the one that related with natural resources. Other than natural resources, human resources, financial resources, and social resources also need to be improved.

4.2.2. Village vulnerability class 2 (highly vulnerable)

Village vulnerability class 2 is categorized as a highly vulnerable agricultural-based livelihood to extreme climate events. Based on the analysis in chapter 3, this village vulnerability class is most vulnerable to fire suggested by its closest proximity to burnt areas that indicate the more frequent fire happens in this village vulnerability class than the other vulnerability classes. Impacts of extreme climate events in this village vulnerability class are more from prolonged drought than the other extreme events. Prolonged drought has caused pest outbreaks. From our focal area of village vulnerability class 2, there was no flood reported in the past 15 years. Heavy rainfalls affected a slight decrease in paddy and rubber production. The impact of market shocks only occurs in rubber commodity.

Adaptive capacities in this village vulnerability class are stronger in its market infrastructure as it located closest to rubber factory and closer to oil palm concession areas compared with the other vulnerability classes. As like village vulnerability class 1, this village vulnerability class has low natural resources adaptive capacities. As there is almost no more forested area remain in the area. Based on the case study in Sintang District, where the village vulnerability class 1 was compared to village vulnerability class 2, from its vulnerability, there is not much different level of vulnerability between the two village vulnerability classes. The only difference is on the rate of land-use conversion that is higher in village vulnerability class 1.

Based on its impacts of extreme events, in village vulnerability class 2, the specific strategies need to prioritize in reducing the potential of fire incidences, particularly during prolonged droughts. The primary trigger of fire in this village vulnerability class is the land-use conversion that uses the slash and burns method. The community converted their land because they want to change their farming systems from rubber-based system to oil palm-based system, to improve their household economy. Thus, the land-use conversion is expected can be reduced if integrated farming systems promoted. An integrated farming system will allow diverse sources of income from commodities, fishes, and livestock. The alternative method to slash and burns also need to be introduced to the communities in this village vulnerability class.

Regarding the development of climate-smart agriculture in this village vulnerability class, this village vulnerability class has some similarity with village vulnerability class 1, i.e., its weak adaptive capacities are the natural resources. At the same time, its infrastructure development is better than village vulnerability classes 3, 4, and 5. Thus, to support the development of climate-smart agriculture, farm diversity needs to be enhanced, trees need to be planted as part of the land rehabilitation program. Besides natural resources, the other adaptive capacities that need to be prioritized are social resources, human resources, and financial resources.

4.2.3. Village vulnerability class 3 (moderately vulnerable)

Village vulnerability class 3 is categorized as a moderately vulnerable agricultural-based livelihood to climate change. From the analysis of information collected at the community level, this village vulnerability class is most vulnerable to floods but also vulnerable to pest outbreaks and prolonged drought. Its location that is the closest to the river compared to the other vulnerability classes, made village vulnerability class 3 become the most vulnerable to floods that mostly happen during heavy rainfalls. Floods caused crop failures of crops that are planted along the riverine. The communities in this village vulnerability class are trying to cope with the floods by developing flood control through river engineering, trenches, and drainage systems. Floods also affected rubber production from rubber farms located along the riverine. Floods have caused farmers to buy rice for their needs and search for other sources of income to fulfil their needs. Besides floods, prolonged drought also caused crop failures due to pests outbreak and dried crops due to increased temperatures and limited rainfalls, decreased number of tapping days for rubber farmers, and reducing the quantity of oil palm fruit bunches. Although there is crop failure during prolonged drought, it didn't cause farmers to buy rice and vegetables because the intensity of crop failure is not as high as when there are floods. Impact of market shocks on the local livelihoods reported to happen for rubber and oil palm, i.e., the drastic drop in the price for the two commodities.

From its landscape characteristics, village vulnerability class 3 has a large percentage of oil palm plantation in its village despite its farther distance to the current oil palm companies. The better road conditions to transport oil palm fruit bunches from the village to oil palm factories may become one of the reasons there is a large development of oil palm in village vulnerability class 3. The land-use conversion in these areas is the second-highest rate after village vulnerability class 1. The large remaining forested areas and shrub areas in the village, and the high population density, triggered the land conversion in the areas. Based on local perception, the driver of land conversion in this village vulnerability class is mostly for the needs to improve the household economy and food security, also the existence of new oil palm concessions and mills.

In the context of climate-smart agriculture, sustainable agricultural production and income in village vulnerability class 3 need to be supported by a transformation related to its impacts from floods, prolonged drought and market shocks. In village vulnerability class 3, there is infrastructure development to cope with floods. However, in the future, there is also a need to do zonation of cultivation areas that are prone to floods in the riverine/riverbank to avoid the same crop failures when heavy rainfalls occur. While for coping with prolonged drought, farmers' access to drought-tolerant varieties of food crops and rubber clones need to be enhanced, and farmers' awareness and knowledge for handling pests outbreaks. Transforming farmers' monocultural systems into more diverse systems is expected to reduce the potential risks of pests outbreak. As the village vulnerability class 3 is now preferring more monocultural systems, farmers' awareness of the importance of having more diverse systems need to be enhanced. In addressing market shocks, particularly with oil palm prices, a partnership between oil palm companies with the community is expected will support farmers' market access to sell their oil palm fruit bunches.

On the other hand, for achieving the climate-smart agriculture objective to reduce emissions, strategies need to be developed to cope with massive land-use changes. An example is promoting integrated farming systems that will provide better benefits without having to convert their remaining forested areas. Strategies for reducing emissions induced by tree losses due to massive land-use conversion should include the promotion of trees on farm planting.

Adaptive capacities of village vulnerability class 3 to support the development of climate-smart agriculture, can be categorized as medium. It has moderate adaptive capacities on natural resources, infrastructure development, human resources, financial resources and social. Gaps from the current adaptive capacities need to be identified to support the strategy. Among others, regulation to allocate the remaining forests area needed as a reserve/protected areas, enhancing farmer's access to information and new knowledge for innovation in farming systems, and improving access to financial resources.

4.2.4. Village vulnerability class 4 (less vulnerable)

Village vulnerability class 4 is categorized as less vulnerable agricultural based-livelihood to climate change. Based on the analysis of vulnerability conducted via FGD with the local community, the agricultural livelihoods in this village vulnerability class is most vulnerable to prolonged drought and pest outbreaks that occur mostly during prolonged drought. Although compared to the other vulnerability classes, the impact of pest outbreak to cropland is not as much as in village vulnerability classes 1 and 2. At the landscape scale, prolonged drought has induced land fires, mainly in cropland areas and oil palm plantations that are located more in the hill areas. If compared to the other village vulnerability class, oil palm plantation in village vulnerability class 4 experiences the most exposure to prolonged drought, yet it has the most advanced responses. Besides prolonged drought, other extreme events that affect the agricultural livelihoods in village vulnerability class 4 are heavy rainfalls and market shocks in oil palm. Heavy rainfalls caused floods that decreased the paddy production, while the market shocks made some of the farmers cannot sell their oil palm bunches to the oil palm factory and causes them to obtain other sources of income.

From the landscape characteristics, this village vulnerability class has the closest to deforestation areas and has the highest deforestation rate. This particularly because in this village vulnerability class, the forested areas remain in a large portion, and there is a trend of converting the forested land for better sources of livelihood, such as to monoculture rubber, cropland, and oil palm plantation. Currently, the rate of land-use conversion is still low, but as the population density is increasing, there is a possibility for more rapid and extensive conversion in the future. This village vulnerability class is located the furthest from the river, that is why this village vulnerability class is less vulnerable to floods. From its market infrastructure, this village vulnerability class is located farther from oil palm concession areas and rubber factories, however, the road accessibility is better than the village vulnerability class 5. Accessible road condition is important for transporting oil palm fruit bunches because they need to reach the factory in less than 24 hours after harvest, or else it will be rotten and will not be able to sell. While for rubber, farmers can store the latex sheets for a long time after it is dried. Thus road accessibility is not the main issue to sell the rubber slabs or sheets.

In the context of developing sustainable production and income from climate-smart agriculture, in this village vulnerability class, the priorities need to focus more on the strategies to mitigate the negative impact of prolonged drought on food crops and market shocks of oil palm. To cope with the impact of prolonged drought on agricultural livelihood, the infrastructures that improve farmers' access to sources of water for agricultural purposes need to be enhanced. Farmers' access to food crops varieties that resistant to prolonged drought also needs to be improved. And farmers need to be equipped with the knowledge to handling pests outbreak. In addressing the effects of market shocks in village vulnerability class 4, it is not easy to establish a partnership between oil palm companies with the community, as the location is farther from oil palm concession areas. This is of the different cases compared to villages of vulnerability classes 1 and 2, where schemes can be developed to ensure oil palm farmers with market access. The local government is expected to facilitate the farmer's access to various sources of oil palm factories.

In ensuring more sustainable income, farmers' awareness about income diversification needs to be built. The adoption of integrated farming systems that mix profitable commodities in agroforestry systems needs to be promoted.

In regards to reducing emissions, there are two sources of emissions that possibly happen in village vulnerability class 4, i.e., the high potential of deforestation and forest encroachment, and fire that occur mostly during prolonged drought and has a close correlation with the deforestation activities. Based on the discussion with the community, the driver of the potential deforestation is the need to have better sources of livelihood. Thus, the transformation of the current farming systems is a priority. This transformation includes the promotion of integrated farming systems that mix profitable commodities with trees on farms. By providing more sustainable income from the current farming areas, it is expected that the pressure to deforestation and forest encroachment will be decreased. The development of the social forestry scheme for managing the remaining forest can be another option for reducing the deforestation rate and potentials.

Adaptive capacities in the village vulnerability class 4 are stronger in its natural resources. However, natural resources can soon be depleted if there are no actions implemented to reduce the deforestation rate in the areas. On the other hand, the least adaptive capacities in this village vulnerability class are infrastructure development, human resources, and financial resources. Hence, the development of climate-smart agriculture in village vulnerability class 4, needs to improve farmer's access to market, farmer's access to extension services and knowledge for handling pests outbreaks in food crops, and farmer's capacities for optimizing their farming systems into a more profitable system.

4.2.5. Village vulnerability class 5 (least vulnerable)

Village vulnerability class 5 is categorized as the least vulnerable for its agricultural-based livelihoods to climate change. Based on the local perspective of the community in village vulnerability class 5 focal areas, prolonged drought is identified as the extreme climate event that affects the local agricultural-based livelihoods. Prolonged drought caused paddy crop failures due to increasing temperature that dried the wet paddy land, and dried the dryland paddy. Besides its effect on paddy, prolonged drought also caused a decrease in rubber production because farmers cannot tap their rubber trees when there is a drought or prolonged drought. Compared to other village vulnerability class, the pest outbreak was not reported by the community in village vulnerability class 5. This may because, in village vulnerability class 5, there are still quite large forested areas if compared with the other vulnerability classes.

The village vulnerability class 5 is the least common vulnerability class in the seven districts, covering only 93 villages of 1073 villages in the seven districts. This village vulnerability class has the largest percentage of forested areas per village. From its infrastructure development, this village vulnerability class is the least developed, which indicated by the furthest location from the roads, and market infrastructures such as rubber and oil palm factories. Its location that is the furthest away to oil palm concession areas made the development of oil palm plantation in the area is low. In the past three years, some wealthier farmers have started to plant oil palm on their farm. The low population density in this village vulnerability class (7 persons/Km^2) and the status of forested land as protected areas made the land conversion rate is the lowest compared to the other village vulnerability class. Future population growth may increase the deforestation rate in this area. Currently, the local livelihood is depending on rubber-based farming systems for a cash crop and cropland as sources of food. Forests are used as sources of income if the farmers have a decreased income from their rubber farms and cropland. Products extracted from the forests are honey, rattan, and fishes.

In the context of climate-smart agriculture, the focus of strategies in this village vulnerability class is on sustainable production and adaptation, such as increasing the adoption of integrated farming systems (such as agroforestry systems) that mix profitable commodities with livestock and or fisheries. By increasing the adoption of an integrated farming system, the community will find alternative sources of income without opening new areas or converting forested areas into agricultural lands. Strategies of selling NTFPs from the forests need to be balanced with domestication efforts of those NTFPs and the improvement of its market potentials. While for the strategy on reducing emissions is to focus on socialization on coping with potential deforestation and forest encroachment. The application of the social forestry scheme is also expected to reduce the pressure of forest encroachment.

From 5 aspects of adaptive capacities, the natural resources have become the strength of village vulnerability class 5; however, in terms of infrastructure aspects, it has the poorest. Financial resources are also quite inadequate, such as access to credit. Access to information and extension services also quite poor. As the areas are sometimes cannot be accessed via road, the frequency of extension services visit to the area is very limited. Although this village vulnerability class is categorized as least vulnerable to climate change, however, this village vulnerability class can be categorized as economically vulnerable because of the slow pace of development occur in the areas. Thus, to support climate-smart agriculture, besides maintaining the natural resources, the adaptive capacities related to the infrastructure, financial resources, social resources, and human resources also need to be strengthened.

4.3. District-specific strategies on climate-smart agriculture

The vulnerability of the seven districts to extreme climate events is divided into four district groups, i.e., Group 1 for the districts of Bengkayang, Mempawah, and Landak, covering villages of vulnerability classes 1 and 3; Group 2 for Sanggau District covering villages of vulnerability classes 1, 3, and 4; Group 3 for Sekadau District covering villages of vulnerability classes 1, 2, 3 and 4; and Group 4 for the districts of Sintang and Kapuas Hulu, covering all villages of vulnerability classes 1 to 5. District-level strategies for increasing livelihood resilience through climate-smart agriculture combine the general strategies in section 3.5.1 with the district-specific strategies as listed in this section. Some of the strategies may be similar among the district groups since the strategies for adaptation and building resilience in district group 2 are similar to the strategies in groups 3 and 4, and the emissions reduction strategies in district group 3 are similar to those in the district group 4.

4.3.1. Group 1: Bengkayang, Mempawah, and Landak District

The districts of Bengkayang, Mempawah, and Landak are located adjacent to each other in the western part of West Kalimantan Province. The villages in this district group have the characteristics of villages of vulnerability classes 1 and 3, with the following proportions:

a) Bengkayang District: 64% village vulnerability class 1 and 27% village vulnerability class 3

b) Mempawah District: 24% village vulnerability class 1 and 42% village vulnerability class 3

c) Landak District: 90% village vulnerability class 1 and 6% village vulnerability class 3

The percentages of the village typologies are based on the situation in 2017. There might be slight changes in the exact percentages in the future. Based on the vulnerability level in each village vulnerability class in this district group, village vulnerability class 1 is the most vulnerable, with all of the negative impacts potentially occurring in this vulnerability class. While for village vulnerability class 3, the most apparent vulnerability is landscape vulnerability to floods.

Specific strategies for increasing livelihood resilience through climate-smart agriculture for Bengkayang, Mempawah, and Landak based on the CSA objectives are as follows:

a) **Sustainable increase in agricultural productivity and income**

   Sustainable agricultural production and income are expected to be obtained from strategies that are related to agricultural commodities diversification for sources of livelihoods, a fair partnership between oil palm companies and the community, and developing zonation for crop cultivation in the riverine areas to avoid floods.

b) **Adapting and building resilience to climate change**

   Farming systems in this district group have a growing trend of being dominated by monocultural farming systems with fewer trees growing on the farms. Thus, adaptation and resilience to climate change can be developed through planting trees on farms (with the options of fruit trees such as durian and petai (*Parkia speciosa*)) for maintaining a conducive micro-climate for agriculture crops during extreme events. Aquaculture has become a source of livelihood in this district group and was affected by the decreased water quality during prolonged drought and floods. Adjusting the aquaculture calendar and selecting fish that can grow well in a limited quantity of water, such as catfish, have become one of the strategies for adapting and building resilience to climate change.

c) **Reducing greenhouse gas emissions.**

   The reduction of greenhouse gas emissions can be achieved by focusing on strategies for promoting integrated farming (such as agroforestry systems), with expectation that it can help avoiding massive land-use change, where the driver of the land use change was mainly for economic purposes.

4.3.2. Group 2: Sanggau District

Out of the seven districts, Group 2 only consists of Sanggau District. Sanggau District is located in the mid-part of the West Kalimantan Province. Villages in Sanggau District are classified into three vulnerability classes, i.e., 62% village vulnerability class 1, 24% village vulnerability class 3, and 12% village vulnerability class 4. The vulnerability of this district to climate change is the combination of the vulnerability of the three vulnerability classes to extreme events. Village vulnerability class 1 is generally most vulnerable to all extreme events, village vulnerability class 3 is most vulnerable to floods, and village vulnerability class 4 is vulnerable to prolonged drought and pest outbreaks.

Based on the vulnerability of this district group, specific strategies for increasing livelihood resilience to climate-smart agriculture (CSA) for Sanggau District are as follows:

a) **Sustainable increase in agricultural productivity and incomes**

   Strategies to achieve this CSA objective of sustainable agricultural productivity and income consist of strategies that are related to ensuring continuous income through agricultural commodities diversification; strategies for avoiding crop failure due to floods through zonation of crops cultivation in the riverine areas; strategies related to guarantee oil palm market access through a fair partnership between oil palm companies with the community; and strategies to assist farmers in the utilization of unproductive lands and to motivate farmers in intensifying the management of their rubber and oil palm farms.

b) **Adapting and building resilience to climate change**

   Strategies for adaptation and building resilience to climate change in this district group are related to planting trees on farms (with the options of fruit trees such as durian and petai), to maintain conducive micro-climate for agriculture crops during drought. For aquaculture, the adaptation strategies are related to adjusting the aquaculture calendar and select fish that can grow well in a limited quantity of water, such as catfish. For maintaining income stability, the strategies are related to the adoption of integrated farming systems that combine profitable commodities in the system, such as agroforestry systems.

c) **Reducing greenhouse gas emissions**

   Greenhouse gas emission is expected to be reduced through the promotion of integrated farming (such as agroforestry systems) to avoid massive land-use change. Since there might be increased deforestation rates in forested areas, social forestry schemes, in combination with the promotion of NTFPs as a source of local livelihood, are expected to be able to maintain the remaining forests and their ecosystem function for carbon sequestration.

4.3.3. Group 3: Sekadau District

The third district group consists of only Sekadau District. Sekadau District is located between Sanggau and Sintang District. The villages in this district are 59% village vulnerability class 1, 20% village vulnerability class 2, 1% village vulnerability class 3, and 20% village vulnerability class 4. The vulnerability level of this district group is a combination of vulnerability classes 1, 2, 3, and 4.

Specific strategies for increasing livelihood resilience through climate-smart agriculture for Sekadau district based on the CSA objectives are as follows:

a) Sustainable increase in agricultural productivity and income

Strategies on sustainable agricultural productivity and income in this district group are related to on-farm livelihood diversification through commodities diversification, a fair partnership between oil palm companies with the community, and interventions to assist farmers in utilizing unproductive lands and intensifying their rubber and oil palm farms.

b) Adapting and building resilience to climate change

Strategies for adapting and building resilience to extreme events in this district group are the same as in district group 2, i.e., Sanggau District. These strategies consist of: planting trees on farms (with the options of fruit trees, such as durian and petai) to maintain conducive micro-climate for crops during drought; regulating the aquaculture calendar and select fishes that can grow well in a limited quantity of water, such as catfish; and promoting the adoption of integrated farming systems that mix profitable commodities, such as agroforestry systems.

c) Reducing greenhouse gas emissions

In this district group, the vulnerability to fire as the main vulnerability of village vulnerability class 2 makes it important to include issues on fire management as a strong emphasis on the strategies for reducing greenhouse gas emissions. The other strategies are related to the promotion of integrated farming (such as agroforestry systems) to avoid massive land-use change, and social forestry schemes combined with the promotion of NTFPs as sources of local livelihoods to avoid deforestation and forest encroachment.

4.3.4. Group 4: Sintang and Kapuas Hulu District

This district group consists of two districts, i.e., Sintang and Kapuas Hulu. Both districts are located in the eastern part of West Kalimantan Province. Sintang District has 15% of its villages classified as village vulnerability class 1, 49% village vulnerability class 2, 5% village vulnerability class 3, 14% village vulnerability class 4, and 13% village vulnerability class 5. Kapuas Hulu District has 1% village vulnerability class 1, 21% village vulnerability class 2, 21% village vulnerability class 3, 17% village vulnerability class 4, and 19% village vulnerability class 5. The vulnerability level of each village vulnerability class is varied.

Specific strategies through climate-smart agriculture for increasing livelihood resilience for the districts of Sintang and Kapuas Hulu based on the CSA objectives are as follows:

a) Sustainable increase in agricultural productivity and income

Strategies on sustainable agricultural productivity and income for this district group are related to agricultural commodities diversification for sources of livelihood, a fair partnership between oil palm companies with the community, and interventions to assist farmers in utilizing unproductive lands and intensifying farmers' rubber and oil palm farms. Zonation of agricultural crop cultivation in the riverine areas is also important for avoiding crop failures due to floods. In this district group, non-timber forest products (NTFPs) are still extracted from the remaining forests. The NTFPs are used as sources of local livelihoods if there are crop failures or decreased rubber production, thus promoting sustainable harvesting and domestication of NTFPs as well as market improvements of NTFPs are important strategies for income diversification in this district group.

b) Adapting and building resilience to climate change

Strategies for adapting and building resilience in this district group are similar to those in district group 2 (Sanggau District) and group 3 (Sekadau District). The strategies are: planting trees on farms (options of fruit trees such as durian and petai) to maintain conducive micro-climate for agriculture crops during drought; regulating the aquaculture calendar and selecting fish that can grow well in a limited quantity of water, such as catfish; and promoting the adoption of integrated farming systems that mix profitable commodities, such as agroforestry systems.

c) Reducing greenhouse gas emissions

Strategies for reducing greenhouse gas emissions are similar to the strategies in district group 3 (Sekadau District). The strategies are fire management, promotion of integrated farming (such as agroforestry systems) to avoid massive land-use change, and social forestry schemes combined with the promotion of NTFPs as sources of local livelihoods to avoid deforestation and forest encroachment.

5 CONCLUSIONS

A vulnerability assessment was conducted in the seven studied districts (Bengkayang, Mempawah, Landak, Sekadau, Sanggau, Sintang, and Kapuas Hulu) with 14 sample areas (referred to as focal areas in this study). Sampling was conducted by developing village vulnerability class that results in five village vulnerability classes: most vulnerable, highly vulnerable, moderately vulnerable, less vulnerable, and least vulnerable. The vulnerability class were produced based on the contexts and trends of a set of spatially explicit variables that serve as proxies of potential climate hazard and capacity to adapt, which together define their vulnerability potentials to climate change. The vulnerability level of each village vulnerability class was assessed through a participatory approach based on local knowledge of the community in the focal areas.

Based on the discussions with the local communities through FGDs in the seven studied districts, extreme climate events that occur across the villages are mainly prolonged drought and heavy rainfall that cause floods, with varying intensities among the village vunerability classes. The cause of the variations cannot be captured through the current study; it requires further detailed investigations. Besides the extreme climate events, the study also captured market shock as an extreme event that indirectly affects exposures, responses, and impacts in the villages regarding climate change.

Exposures and responses to extreme climate events varied among the vulnerability classes depending on the landscape characteristics that were indicated by the variations of land-use change over the past five years (2012-2017). Water resources, farming systems, and marketing of dominant agricultural commodities were used as the main components analyzed in this study to understand the exposures and responses of agricultural systems to extreme events.

Water resources issues such as turbid water and lack of clean water were reported in most vulnerability classes. However, more substantial impacts of water issues have been more prevalent in the villages with vulnerability classes 1 to 3 than those in 4 and 5. In the areas where mining occurs, there are also issues of contaminated water that have caused health issues in the community who consume it. Responses to water issues varied across the different communities, depending on their capitals and knowledge.

Issues related to farming systems among the different village vulnerability classes also varied mainly depending on the location of the farming systems (near riverine or on the hills). Crop failure due to flood and drought happen mostly for paddy in almost all village vulnerability classes with different severity levels across the different village vulnerability classes. Similar to the issues of water, responses of the communities regarding extreme events that hit the farming systems varied depending on the communities' capitals and knowledge.

Meanwhile, issues related to the marketing of dominant commodities and their relations to extreme climate events showed that the trend of decreasing production of agricultural commodities could influence the supply in the market. Major issues related to marketing are the ceased purchase of commodities from the traders or factories and the money lending systems between farmers and middlemen that may affect the price received by the farmers for the commodities they produced.

Extreme climate events have impacted local livelihoods, commodities, and landscapes in the seven studied districts with varying severity across the different village vulnerability classes, from the more severe impacts in village vulnerability class 1 to the less severe impacts in village vulnerability class 5. Impacts on livelihoods are generally reduced income from the agricultural systems and increased expenses of the farmers' households when they need to buy rice due to paddy crop failure and buy clean water when there is a lack of clean water. Impacts on commodities range from reduced production to crop failure, with paddy experiencing the highest impact. At the landscape level, extreme climate events have induced issues of pest infestation along with water quality and quantity issues.

Climate risks and potential adaptation of different agricultural systems in the landscape vary across the different village vulnerability classes. In terms of adaptation potentials, enabling factors in the agricultural systems' adaptation to extreme events were determined. Five livelihood capitals (natural, finance, infrastructure, human resources, and social) were used to categorize the factors. These factors can be used to develop strategies to increase the resilience of agricultural systems to climate change, specifically in the context of West Kalimantan, with modifications for usage in contexts that differ from those occurring in West Kalimantan.

Strategies to increase agricultural-based livelihood resilience through climate-smart agriculture were analyzed in three levels. These are the general strategies that need to be applied in all villages of all the districts, village-specific strategies that are unique per village vulnerability class, and district-specific strategies that are unique per district. For the district-specific strategies, the districts were grouped based on their village vulnerability class. The groupings are Group 1, which consists of Bengkayang, Mempawah, and Landak, covering villages of vulnerability classes 1 and 3 and considered more vulnerable than the other district groups; Group 2, which consists of Sanggau District, covering villages of vulnerability classes 1, 3, and 4; Group 3, which consists of Sekadau District, covering villages of vulnerability classes 1, 2, 3 and 4; and Group 4, which consists of Sintang and Kapuas Hulu, covering all village vulnerability classes. Different strategies were developed for each group of districts.

Acknowledgements

This study was conducted in collaboration between The World Agroforestry (ICRAF) and Solidaridad, with support from the National Initiative for Sustainable and Climate-Smart Oil Palm Smallholders (NISCOPS) project supported by Ministry of Foreign Affairs of the Netherlands. We highly appreciate the communities and local government agencies in Bengkayang District, Landak District, Mempawah District, Sekadau District, Sanggau District, Sintang District and Kapuas Hulu District. They have participated very actively in providing data and information through FGD and secondary data collection. We are also thankful to Meteorology and Climate Station in West Kalimantan, that has shared data on the climate change trends in West Kalimantan, and Environmental Department of West Kalimantan Province that has facilitated the stakeholder meetings with representatives from different government agencies in West Kalimantan Province.

This report was made through contributions of ICRAF staffs (Endri Martini, Sonya Dewi, Betha Lusiana, Ni'matul Khasanah, Subekti Rahayu, Budi, Arga Pandiwijaya, Harry Tri Atmojo Aksomo, Adis Hendriatna, Aulia Perdana, Isnurdiansyah, Arizka Mufida) and Solidaridad staffs (Jimmy Wilopo, Kulbir Mehta, Nila Silvana, Auviar R. Wicaksanti, Andi Januar Patottongi, Edi Santoso, Bella Amalia, Nevi Dewi Saraswati, Bahtera Tarigan, Sutarto, Irwan Matsyah, Boni Fasius, Chandra Oktavianto, Grin Chulis, Winda Haerumi, Kiki Radina, Yosef Kafaso, Paulus Jito, Kelementinus Endro, Nurmanto, Viona, Uni Qalbarri, Adzani Rahim Safrudi, Adrianus Aping, Osyi Rusmini, Erwan Kow). The language editing was finalized by Dita Novita Maharani. The report layout was assisted by Riky Hilmansyah.

References

BPS-Statistics of Kalimantan Barat Province. 2019. West Kalimantan Province in Figure. BPS-Statistics.738p.

BPSa. 2019. Kabupaten Bengkayang Dalam Angka 2019. Badan Statistik Kabupaten Bengkayang. Bengkayang

BPSb. 2019 Kecamatan Seluas Dalam Angka 2019. Badan Pusat Statistik Kabupaten Bengkayang. Bengkayang.

BPSc. 2019. Kecamatan Ledo Dalam Angka 2019. Badan Statistik Kabupaten Bengkayang. Bengkayang

BPSd. 2019. Kabupaten Kapuas Hulu dalam Angka 2019. Badan Pusat Statistik Kabupaten Kapuas Hulu, Putussibau

BPSe. 2018. Kecamatan Boyan Tanjung dalam Angka 2018. Badan Pusat Statistik Kabupaten Kapuas Hulu. Putussibau

BPSf. 2018. Kecamatan Mentebah dalam Angka 2019. Badan Pusat Statistik Kabupaten Kapuas Hulu. Putussibau

BPSg. 2019. Kabupaten Landak dalam Angka 2019. Badan Pusat Statistik Kabupaten Landak. Ngabang. Ngabang

BPSh. 2019. Kecamatan Ngabang dalam Angka 2019. Badan Pusat Statistik Kabupaten Landak. Ngabang. Ngabang

BPSi. 2019. Kecamatan Menjalin dalam Angka 2019. Badan Pusat Statistik Kabupaten Landak. Ngabang. Ngabang

BPSj. 2019. Kabupaten Sanggau dalam Angka 2019. Badan Pusat Statistik Kabupaten Sanggau. Sanggau.

BPSk. 2019. Kecamatan Kapuas dalam Angka 2019. Badan Pusat Statistik Kabupaten Sanggau. Sanggau.

BPSl. 2019. Kecamatan Balai dalam Angka 2019. Badan Pusat Statistik Kabupaten Sanggau. Sanggau.

BPSm. 2019. Kecamatan Belitang Hilir dalam Angka 2019. Badan Pusat Statistik Kabupaten Sekadau. Sekadau

BPSn. 2019. Kecamatan Nanga Taman dalam Angka 2019. Badan Pusat Statistik Kabupaten Sekadau. Sekadau

BPSo. 2019. Kabupaten Sintang dalam Angka 2019. Badan Pusat Statistik Kabupaten Sintang. Sintang.

BPSp. 2019. Kecamatan Kelam Permai dalam Angka 2019. Badan Pusat Statistik Kabupaten Sintang. Sintang.

BPSq. 2019. Kecamatan Sepauk dalam Angka 2019. Badan Pusat Statistik Kabupaten Sintang. Sintang.

BPSr. 2019. Kabupaten Mempawah Dalam Angka Tahun 2019. Badan Pusat Statistik Kabupaten Mempawah.

BPSs. 2019. Kecamatan Toho dalam Angka 2019. Badan Pusat Statistik Kabupaten Mempawah.

BPSt. 2019. Kecamatan Sungai Kunyit Dalam Angka 2019. Badan Statistik Kabupaten Mempawah. Mempawah.

Desa Terap. 2019. Profil Desa Terap Tahun 2019. Kantor Desa Terap.

Desa Toho Ilir. 2017. Profil Desa Toho Ilir Tahun 2019. Kantor Desa Toho Ilir.

Desa Pak Laheng. 2019. Profil Desa Pak Laheng Tahun 2019. Kantor Desa Pak Laheng.

Desa Kecurit. 2017. Profil Desa Kecurit Tahun 2017. Kantor Desa Kecurit.

Desa Kumpang Bis. 2017. Profil Desa Kumpang Bis Tahun 2017. Kantor Desa Kumpang Bis.

Desa Menawai Tekam. 2018. Profil Desa Menawai Tekam Tahun 2018. Kantor Desa Menawai Tekam.

Desa Semadu. 2019.Profil Desa Semadu Tahun 2019. Kantor Desa Semadu.

Desa Empajak. 2016. Profil Desa Empajak Tahun 2016. Kantor Desa Empajak.

Direktorat Jenderal Bina Pemerintahan Desa. 2019. Data Potensi Desa Nanga Danau, Nanga Boyan, Delintas Karya, Landau Mentail. Jakarta, Indonesia: Kementerian Dalam Negeri.

Direktorat Jenderal Pengendalian Perubahan Iklim Kementerian Lingkungan Hidup dan Kehutanan. 2015. Sistem Informasi Data Indeks Kerentanan (SIDIK). Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia. Jakarta.

Denton, F., T.J.Wilbanks, A.C. Abeysinghe, I. Burton, Q. Gao, M.C. Lemos, T. Masui, K.L. O'Brien, and K.Warner, 2014: Climate-resilient pathways: adaptation, mitigation, and sustainable development. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1101-1131.

Food and Agriculture Organization of the United Nations (FAO).2012. Developing a climate-smart agriculture strategy at the country level: lessons from recent experience. Background paper for the Second Global Conference on Agriculture, Food Security and Climate Change. FAO. Rome. 46p.

IPCC. 2014. Summary for policymakers. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 1–32

Kecamatan Ledo. 2019. Profil Kecamatan Ledo Tahun 2019. Kantor Camat Bengkayang.

Kecamatan Seluas. 2017. Profil Kecamatan Seluas 2017. Kantor Camat Seluas.

Kecamatan Boyan Tanjung. 2018. Profil Kecamatan Boyan Tanjung 2018. Kantor Kecamatan Boyan Tanjung. Nanga Boyan.

Kecamatan Mentebah. 2019. Profil Kecamatan Mentebah 2019. Kantor Camat Mentebah. Mentebah.

Kecamatan Ngabang. 2019. Profil Kecamatan Ngabang 2019. Kantor Kecamatan Ngabang Kabupaten Landak. Ngabang

Kecamatan Menjalin. 2019. Profil Kecamatan Menjalin 2019. Kantor Kecamatan Menjalin Kabupaten Landak.

Kecamatan Toho. 2019. Profil Kecamatan Toho Tahun 2019. Kantor Kecamatan Toho.

Kecamatan Mempawah. 2019. Profil Kecamatan Sungai Kunyit Tahun 2019. Kantor Kecamatan Sungai Kunyit.

Kecamatan Nanga Taman. 2018. Profil Kecamatan Nanga Taman Tahun 2018. Kantor Camat Nanga Taman.

Kecamatan Belitang Hilir. 2019. Profil Kecamatan Belitang Hilir Tahun 2019. Kantor Camat Belitang Hilir.

Sipayung, SB, Nurlatifah A, Siswanto B, Slamet LS. 2018. Analysis of climate change impact on rainfall pattern of Sambas district, West Kalimantan. IOP Conference Series: Earth and Environmental Science 149:012029.

Widayati A, Khasanah N, Dewi S, Roshetko JM, eds. 2017. Panduan Penggalian Pengetahuan Lokal dalam Kerangka CaSAVA - Capacity Strengthening Approach for Vulnerability Assessments (Penguatan Kapasitas melalui Kajian Kerentanan). Bogor, Indonesia. World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Supplemental documents

Supplemental documents are published under separated documents from this synthesis report. These supplemental documents can be acquired by sending email to ICRAF SEA Pulication contact person email: icrafseapub@cgiar.org.

Supplemental document 1. Methodology of climate vulnerability assessment in 7 districts of West Kalimantan (online version; only in English version)

Supplemental document 2. Brief on the results of vulnerability assessment to increase livelihood resilience through climate-smart agriculture in Bengkayang District (only in Indonesian version)

Supplemental document 3. Brief on the results of vulnerability assessment to increase livelihood resilience through climate-smart agriculture in Mempawah District (only in Indonesian version)

Supplemental document 4. Brief on the results of vulnerability assessment to increase livelihood resilience through climate-smart agriculture in Landak District (only in Indonesian version)

Supplemental document 5. Brief on the results of vulnerability assessment to increase livelihood resilience through climate-smart agriculture in Sanggau District (only in Indonesian version)

Supplemental document 6. Brief on the results of vulnerability assessment to increase livelihood resilience through climate-smart agriculture in Sekadau District (only in Indonesian version)

Supplemental document 7. Brief on the results of vulnerability assessment to increase livelihood resilience through climate-smart agriculture in Sintang District (only in Indonesian version)

Supplemental document 8. Brief on the results of vulnerability assessment to increase livelihood resilience through climate-smart agriculture in Kapuas Hulu District (only in Indonesian version)

Supplemental document 9. Indonesian version of the synthesis report of vulnerability assessment to increase livelihood resilience through climate-smart agriculture in West Kalimantan

World Agroforestry

Solidaridad

Ministry of Foreign Affairs of the Netherlands