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USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin

# Agriculture Report

February 2014


## USAID Mekong ARCC
## Climate Change Impact and Adaptation Study for the Lower Mekong Basin

# Agriculture Report


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## USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin

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The USAID Mekong ARCC project is a five-year program (2011–2016) funded by the USAID Regional Development Mission for Asia (RDMA) in Bangkok. The larger project focuses on identifying the environmental, economic, and social effects of climate change in the Lower Mekong Basin (LMB), and on assisting highly exposed and vulnerable rural populations in ecologically sensitive areas adapt to climate change impacts on agricultural, fisheries, livestock, ecosystems, and livelihood options.

This phase of the project was led and implemented by ICEM, and focuses specifically on predicting the response of the key livelihood sectors—agriculture, livestock, fisheries, rural infrastructure and health, and natural systems—to the impacts associated with climate change, and offering broad-ranging adaptation strategies to the predicted responses.

This volume is part of the USAID Mekong ARCC study set of reports:

1. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Summary
2. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Main Report
3. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Agriculture
4. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Livestock
5. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Fisheries
6. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Non-Timber Forest Products and Crop Wild Relatives
7. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Protected Areas
8. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Socio-economic Assessment

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ACIAR | Australian Centre for International Agricultural Research |
| ASEAN | Association of Southeast Asian Nations |
| CAM | Climate Change Adaptation and Mitigation Methodology |
| CBD | Convention on Biological Diversity |
| CC | Climate Change |
| CGIAR | Consultative Group on International Agricultural Research |
| CIAT | International Center for Tropical Agriculture |
| CWRs | Crop Wild Relatives |
| FAO | Food and Agriculture Organization of the United Nations |
| FAOSTAT | Statistics Division of the FAO |
| g/L | Grams per liter |
| GAP | Good Agricultural Practices |
| GHG | Greenhouse Gas |
| GIZ | Gesellschaft für Internationale Zusammenarbeit |
| GSO | General Statistics Office of the Government of Vietnam |
| ha | Hectare |
| ICEM | International Centre for Environmental Management |
| ICT | Information and Communications Technology |
| ILRI | International Livestock Research Institute |
| IPCC | Intergovernmental Panel on Climate Change |
| IPCC AR4 | IPCC Assessment Report Four |
| IWRM | Integrated Water Resources Management |
| km | Kilometer |
| Lao PDR | Lao People's Democratic Republic |
| LMB | Lower Mekong Basin |
| LU | Standardized Livestock Units |
| LUSET | Land Use Suitability Evaluation Tool |
| $m^3/s$ | Cubic Meter per Second |
| MAFF | Ministry of Agriculture, Forestry and Fisheries, Cambodia |
| masl | Meters Above Sea Level |
| MCM | Million Cubic Meters |
| MDGs | Millennium Development Goals |
| Mekong ARCC | USAID Mekong Adaptation and Resilience to Climate Change Project |
| mm | Millimeter |
| MPI | Ministry of Planning and Investment, Lao PDR |
| MRC | Mekong River Commission |
| MT/yr | Million Tonnes per year |
| NAFRI | National Agriculture and Forestry Research Institute, Lao PDR |
| NTFPs | Non-Timber Forest Products |
| RCG | Royal Government of Cambodia |
| SLR | Sea Level Rise |
| sq km / $km^2$ | Square Kilometer |
| SRI | System of Rice Intensification |

| | |
|---|---|
| UMB | Upper Mekong Basin |
| USAID | United States Agency for International Development |
| VA | Vulnerability Assessment |
| WFP | United Nations World Food Programme |
| WRI | World Resources Institute |
| WWF | World Wide Fund for Nature |

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"A local farmer in Kok Klang Village, Sakon Nakhon Province, Thailand; and the fields in the back are rubber and cassava." *by Angela Jöhl Cadena/IUCN*

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# 1 INTRODUCTION TO THE REGION

Growing conditions for agriculture are diverse in the Lower Mekong Basin (LMB), from the mountainous areas of Lao PDR and the Central Highlands in Vietnam to the lowland plains in the Mekong Delta. Farming systems range from traditional shifting agriculture systems dominated by upland rice through industrial plantations, including smallholder intensive rice farmers.

Rainfed agriculture is the dominant type of agriculture in the LMB. Rainfed rice is the dominant crop, representing 75% of the agricultural area within the LMB. Other commercial crops such as maize, soybean, or cassava, which have growing importance in farming systems in the region, are mostly rainfed.

Therefore, agriculture, a key sector of the economy within the LMB, is highly dependent on climate and especially on rainfall frequency and distribution. With more than 1,000 mm of rainfall per year in the LMB, water shortage is not the primary constraint for agriculture. Instead, it is the un-predictability and variability of rainfall distribution during the rainy season that can lead to drought, water stress, and low yields.

Agriculture is a dynamic sector in the LMB. The production of the major crops has doubled in the last 20 years. The increase in production is resulting from an intensification of production, which is reflected in higher yields rather than strong growth in cultivated area. However, new areas for cultivation are opening in Lao PDR, the Vietnamese Central Highlands, and Cambodia. Meanwhile available arable land in Northeast Thailand is decreasing.

In the LMB, around 50% of rice output is produced in the Vietnamese Mekong Delta, followed by Northeast Thailand (around 30% in 2003). Vietnam and Thailand are among the five leading rice exporters in the world. If we include the Chao Praya Delta in Thailand, the volume of rice exported from this region represents more than 51% of rice exported worldwide (FAOSTAT 2008).

There are a number of different drivers influencing the agriculture sector in the LMB. It is estimated that food production will need to grow by 25% in the next 15 years to supply a growing population. In addition, an increasing urban population will bring changes in labor availability in the farming sector, changed patterns in food demand; and conflict over land and water use to meet the requirements of growing cities. While there are different dynamics according to local demand and crop suitability, there has also been a steady trend across LMB countries toward commercial crops and production systems at the expense of subsistence rice-based systems. For example, maize is now found across all countries. Cassava, while originally farmed in Thailand and the Vietnamese Central Highlands, is now starting to be found also in Lao PDR and Cambodia. Sugarcane is farmed mostly in Northeast Thailand with more than 70% of the planted area in the LMB. The expansion of other commercial crops and industrial plantations like rubber, coffee, and eucalyptus are driven by market demand and foreign investment. In the future, it is estimated that demand for bio-fuel (soybean, maize, sugarcane), animal feed (cassava), and starch (cassava) will rise and the demand for rubber and sugar will continue to be strong. Location-specific factors are also driving changes at the local level. For example, soil and ground water degradation and a lack of rural labor have resulted in a shift from coffee to rubber plantations in the Vietnamese Central Highlands in recent years.

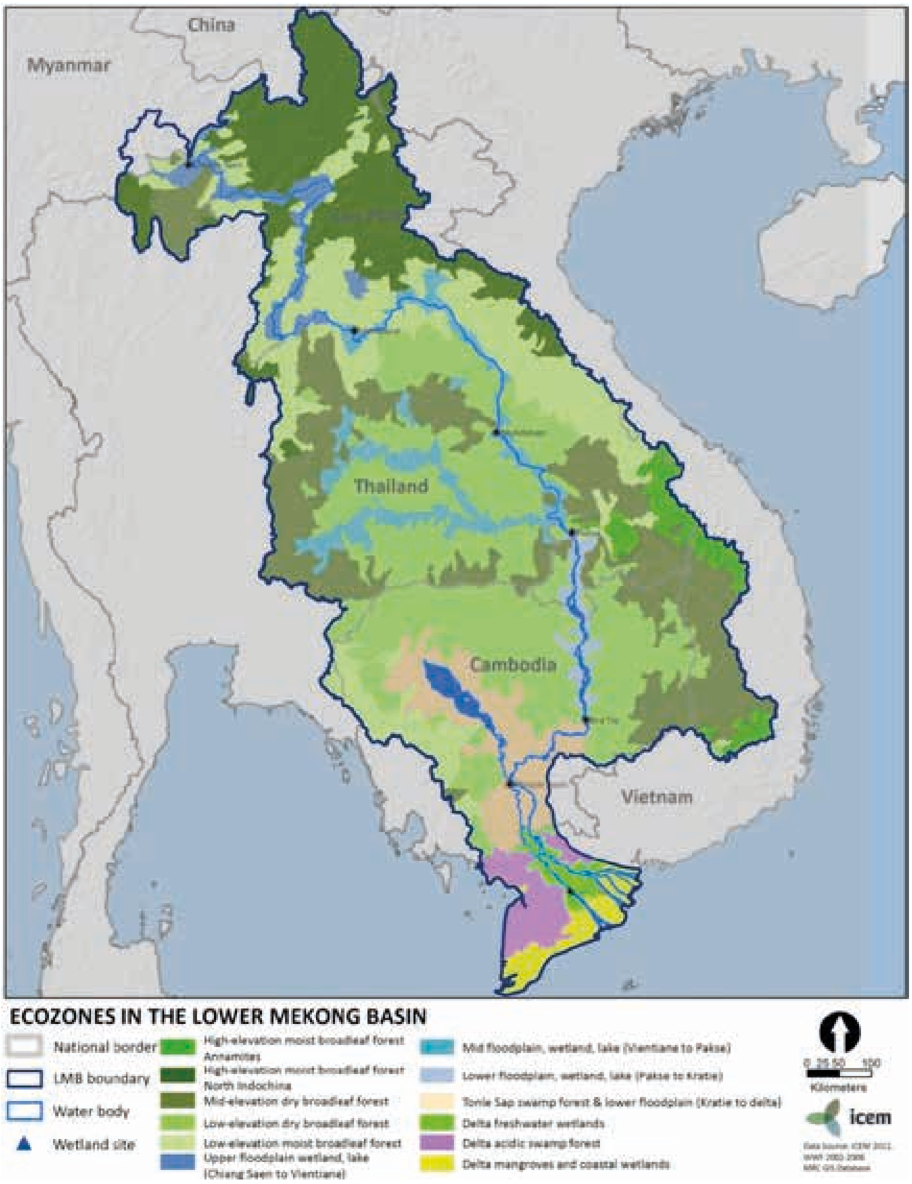
Suitability has an important influence on cropping patterns in the LMB. Crop suitability and trends in crop production may (or may not) change due to the impact of climate change. Understanding the impact of climate change on agriculture production at the basin scale is a complex task due to the diversity of production systems, lack of data, and multiple external drivers influencing growth in the sector in addition to climate factors. As agriculture in the region is mostly rainfed, changes in climate and especially rainfall patterns will likely affect the agriculture sector through higher risk of crop failures and changes in crop suitability and crop productivity for certain geographical areas.

This baseline report provides a detailed summary of the issues and trends described above by ecozone.

# 2 APPROACH AND METHODOLOGY

To assess trends in the agriculture sector by ecozone, we selected representative provinces in each ecozone (Figure 1) based on GIS analysis. Two loose criteria were used to select representative provinces to illustrate trends in the agriculture sector: 1) Where a province has more than 50% of its surface area within a particular ecozone; or 2) Where a province has less than 50% of its surface within a particular ecozone, but is considered a representative "hotspot" for a range of key sectors considered by the project (livestock, fisheries, agriculture, and natural systems). Using the second criterion some of the provinces selected may have as little as 20% of their land area representative of a particular ecozone. A list of the provinces used for each ecozone is provided in Table 1.

**Figure 1: Ecozones in the Lower Mekong Basin**




Examples of different farming systems in each ecozone were identified using a range of sources. Crop selection was based on those crops that exhibited strong rates of growth in production and cultivated area in the past 12 years. Provincial time-series data of planted and harvested areas and production of different crops was obtained from the website of the statistical office of the respective riparian countries in Lao PDR (http://www.nsc.gov.la/) for the period 2005–2010 and Vietnam (http://www.gso.gov.vn/default_en.aspx?tabid=491) for the period 2000 to 2009. These sources were supplemented by data from the *Regional Data Exchange System on food and agricultural statistics in Asia and Pacific* countries maintained by the Food and Agriculture Organization (FAO) Regional Office for the Asia Pacific Region (http://www.faorap-apcas.org/). Here data was available for the periods 1993–2005 for Lao PDR, 1993–2007 for Thailand, 1993–2005 for Cambodia, and 1993–2005 for Vietnam. Specific data for coffee production in Vietnam (1995–2005) was collected from the Ministry of Agriculture and Rural Development. Agricultural data from Cambodia (2011) was collected from the Ministry of Agriculture Forestry and Fisheries. Average yield values for the different crops were available from the sources above or computed based on available production and harvested area statistics. Crop tolerances to climate were developed based on Sys et al. (1993), FAO's Ecocrop database (http://ecocrop.fao.org/ecocrop/srv/en/home), and local expert knowledge. Farm-gate prices of the crops assessed were available from the FAOSTAT database (http://faostat.fao.org).

**Table 1: Provinces selected to illustrate the agriculture sector in the different ecozones. Percentage of the province area within the ecozone is provided in parentheses.**

| Ecozone | Country | Province |
|---|---|---|
| **High-elevation Moist Broadleaf Forest** | Lao PDR | Xiang Khoang (98%); Phongsaly (99%); Luang Namtha (93%) |
| | Vietnam | Lam Dong (93%) |
| **Mid-elevation Dry Broadleaf Forest** | Thailand | Chaiyaphum (71%) and Chiang Rai (40%) |
| | Lao PDR | Saravan (53%); Attapeu (75%) |
| | Cambodia | Mondulkiri (54%) |
| | Vietnam | Dak Lak (77%); Gia Lai (89%) |
| **Low-elevation Dry Broadleaf Forest** | Thailand | Amnat Charoen (94%); Nakhon Phanom (84%); Sa Keo (94%); Sakon Nakhon (64%) |
| | Lao PDR | Champasak (31%) |
| | Cambodia | Bantheay Meanchey (86%); Oddar Meanchey (99%); Stung Treng (68%) |
| **Low-elevation Moist Broadleaf Forest** | Thailand | Nong Kai (52%); Loei (50%) |
| | Lao PDR | Khammouan (74%); Vientiane prefecture (69%) |
| | Cambodia | Pailin (100%) |
| **Floodplains and Wetlands (upper, mid, and lower)** | Lao | Bokeao (28%); Vientiane prefecture (20%); Champasak (25%) |
| | Thailand | Roi Et (25%); Ubon Ratchathani (19%) |
| | Cambodia | Kratie (16%); Stung Treng (22%) |
| **Tonle Sap Swamp Forest and Lower Floodplains** | Cambodia | Kandal (87%); Prey Veng (99%); Kampong Thom (34%) |
| **Delta Freshwater Swamp Forest** | Vietnam | Vinh Long (92%); An Giang (53%) |
| **Delta Peat Swamp Forest** | Vietnam | Kien Giang (94%); Long An (81%) |
| **Delta Mangroves** | Vietnam | Ben Tre (95%); Tra Vinh (97%); Ca Mau (66%) |

Crops selected covered a range of management systems including commercial crops found in industrial plantations and major crops found in smallholder farming systems. Often most commercial crops exhibited a mixture of characteristics. For example, most of the cassava production in the LMB is based on smallholder production but considered an industrial crop. In the case of rice, to obtain a better picture of the range of production systems that apply to the LMB's key staple, a diverse range of cultural practices and management techniques were considered.

Based on the information above the crops selected for the baseline study and future vulnerability assessment were: rainfed rice (*Oryza sativa*), upland rice, lowland rainfed rice, and irrigated rice; maize (*Zea mais*), cassava (*Manihot esculenta)*, and soybean (*Glycine max*); sugarcane (*Saccharum officinarum*); rubber (*Hevea brasiliensis*), and Robusta coffee (*Coffea canephora*).

Finally, it is important to note that this baseline assessment focuses only on the biophysical characteristics of farming systems in LMB and does not account for political and institutional factors that have in part driven recent changes in the agriculture sector. These factors are discussed in detail in the synthesis report.

# 3 REVIEW OF CLIMATE CHANGE STUDIES FOR THE AGRICULTURE SECTOR

Because it is predominantly based on a rainfed system, the agriculture sector in the LMB is extremely dependent on climate. Different simulations (Snidvong et al. 2003; Hoanh et al. 2003; Ruosteenoja et al. 2003; TKK & SEA START RC 2009; Eastham et al. 2008; Jonhston et al. 2009; Mainuddin et al. 2010) in the LMB have shown that projected climate change includes:

- A dry season that is drier and longer;
- A delayed rainy season;
- A wetter rainy season; and
- Increased temperatures.

These changes will have an effect on crop yields, the cropping calendar, and cropping systems. Johnston et al. (2009) divided the impacts of climate change on agriculture into three categories:

1. Direct impacts, at the local scale, caused by changes in temperature, precipitation, and sea-level rise.
2. Impacts caused by changes in water regimes, at local to regional scales.
3. Indirect impacts, at global and regional scales, in physical (e.g., sea-level rise), social (e.g., migration), or economic (e.g., changes in food prices) dimensions.

In this short review, we focus on the first two impacts at the local scale. First, we briefly present the impact of climate change on crop physiology, focusing on rice culture. In the second part, we present the potential effect of extreme events such as floods, drought and saline water intrusion on agriculture production in the LMB.

## 3.1 CLIMATE CHANGE AND CROP YIELD

Change in climate can affect agricultural productivity in many ways such as through changes in temperature, total rainfall, and rainfall patterns or higher $CO_2$ levels. In addition to these direct impacts, change in climate will have an influence on pest and disease frequency. However, this last point is not covered in this review.

### 3.1.1 Tolerance and Impact to Drought

In the case of rice culture, the most sensitive periods for water deficit are flowering and the second half of the vegetative period. According to Yoshida (1981) a drought of 3 days before heading and during the reproductive stage[1] can induce a significant yield reduction. Doorenbos and Kassam (1979) estimate that rice yields start to decline when the moisture content of the soil decreases to 70% to 80% of the saturation value. When the water content of the soil is 30% of the saturation value, no yield can be expected. The impact of drought on rice becomes more severe with high salinity levels in the soil (>4 g/L) in the early rainy season (e.g., rainfed rice in the coastal Mekong Delta) (Nhan et al. 2011).

### 3.1.2 Temperature

Extreme temperatures are destructive to plant growth. For rice, the critically low and high temperature varies according to the growth stage, from below 10°C at the tillering stage to more than 40°C at germination (Yoshida 1981). However, tolerance to extreme temperature varies greatly according to rice varieties. In our context, the main threat will be the impact of high temperature stress on rice crops during the dry season, as these can induce sterility and affect rice yield. Temperatures exceeding 35°C at the anthesis stage induces sterility of the spikelet. Sheehy et al. (2006) shows that even a small difference of just 1°C could result in a large yield decrease due to a lower number of grains being formed. Rice yields will decline by 0.6 tonnes per ha per 1°C increase in average temperature (World Bank 2011). High nighttime temperatures have been shown to have a greater negative impact on rice yield, with a 1°C increase above critical temperature (>24°C) leading to a 10% reduction in both grain yield and biomass (Peng et al. 2004, Welch et al. 2010). High daytime temperatures in some tropical and subtropical rice growing regions are already close to the optimum levels. An increase in intensity and frequency of heat waves coinciding with the crop's sensitive reproductive stage can result in serious damage to rice production (e.g., Zou et al. 2009, Hasegawa et al. 2009).

In the case of maize, Lobell et al. (2011) estimated that each day spent above 30°C reduced the final yield by 1% under optimal rainfed conditions and by 1.7% under drought conditions. Daytime warming is more harmful to yield than nighttime warming. Under 'drought stress[2]', yield losses occurred at all study sites, with a 1°C warming resulting in at least a 20% loss of yield over more than 75% of the harvested area.

The impact of temperature on fruit trees such as Litchis, especially on flowering induction, has not been studied and very little evidence or research has been done to understand the effects of climate change on such crops.

### 3.1.3 Increased Concentration of $CO_2$ in the Atmosphere

$CO_2$ fertilization should theoretically tend to increase yields. Its potential role is both contentious and difficult to estimate since it depends on which factors constrain plant growth. Jaggard et al. (2010)

[1] Corresponding to the period of growth between 60 to 90 days for a 120 day rice crop.

[2] In this study authors define "drought stress" as conditions where the crops were irrigated in a rain-free period until plants were established, and then irrigation was cut off to induce moisture stress during flowering and grain-filling.

estimated a yield increase of 13% for most C3 crops, but no response for C4 crops. With increasing $CO_2$ levels, rice plants can react with increased vegetative growth, net assimilation rate, and canopy net photosynthesis (Krishnan et al. 2007). In this study, the authors observe a positive response to increased $CO_2$, with yields growing by 30% to 50% according to the crop yield model used. However, the response will vary by plant with species and nitrogen (as a nutrient) being the main limiting factors. There is further uncertainty associated with the impact of increased $CO_2$ concentrations on plant growth under typical field conditions (Lobell and Field 2008). New technology that allows for field testing trials shows that the effect of $CO_2$ fertilization is lowered by 50% compared to greenhouse-controlled trials (Long et al. 2006). This result suggests that models and simulation based on controlled environmental measurements overestimated the effect of $CO_2$ fertilization. Frenck et al. (2011) found that the response in yield and biomass of *Brassica napus* to increased atmospheric $CO_2$ varied according to the cultivar. In general, benefits from $CO_2$ fertilization could not compensate for the drop in yield due to warming and increased ozone concentrations.

For soybean, it has been found that increased $CO_2$ levels will hasten crop development and prolong crop duration (Morgan et al. 2005). In the case of maize, there is no mechanistic basis for any direct effect of $CO_2$ on C4 photosynthesis. Recent open-air field-level experiments for maize have demonstrated that there is no increase in crop yield when crops are under well-watered conditions with $CO_2$ levels of 550 ppm maintained. There is, however, a substantial reduction in water use (Leakey et al. 2009).

The combination of increased temperature and $CO_2$ fertilization will contribute to increased greenhouse-gas (GHG) emissions from rice paddies—by more than 30% according to some estimates. Groenigen et al. (2012) found that for each 1°C increase in temperature, GHG emissions from rice systems were estimated to increase by more than 10%. The study further suggests that, if there are no changes in management practices, GHG emissions from rice paddies will double by 2100.

### 3.1.4 Impact of Season Shift or Delay

A delay of the rainy season by a few weeks can be problematic in the rainfed-based agriculture systems prevalent in the Mekong Delta. Seventy-five percent of the rice is rainfed and therefore dependent on rainfall patterns. The delay of the rainy season will shift the transplanting and the entire crop. As a result, the plant might flower or ripen in the dry period, and the yield gap generated by the hydric stress at the end of the crop will require supplementary irrigation.

In addition, in a traditional rice-based system, like the one used in the uplands and some lowland areas of the LMB, farmers are still using traditional photoperiod sensitive varieties. For those varieties, a delay in the rainy season might induce a shorter vegetative growth period and a lower yield.

### 3.1.5 Pest and Disease Incidence

Little is known about the impact of climate change on pest and disease incidences on crops. Increased temperatures and changes in rainfall patterns and precipitation may lead to more pressure from parasites, pests, and fungal diseases. With increased temperatures, plant disease will be capable of infecting areas at higher altitudes, as is suspected in the case of coffee rust in Nicaragua (see http://www.promedmail.org/direct.php?id=20121128.1429421). In his review, Jaggard et al. (2010) concluded that airborne disease will not cause issues with increasing temperature and rainfall unless crop protection chemicals are not available. Three key cassava pests, the mealybug, the cassava green mite and the whitefly, have displayed increased virulence in response to higher temperatures (Herrera et al. 2011). In the case of soybean, plant response to key diseases was found to differ according to atmospheric conditions (increase of $CO_2$ and ozone). For example, downy mildew displayed lower virulence, while *Spetoria* displayed increased severity (Eastburn et al. 2010). Jaggard et al. (2010) highlights that soil-borne pest diseases will be the main threat to crops, with less effective chemical protection.

While potential benefits of $CO_2$ fertilization and increased temperature might be largely impaired by increased pest and disease virulence, this trade-off has generally not been considered in detail in existing crop modeling literature.

## 3.2 RESPONSE TO EXTREME EVENTS

### 3.2.1 Flood and Drought

Increased flow in the Mekong River will increase water availability in the dry season and increase the risk of flooding in the wet season. Eastham et al. (2008) projected a 21% increase in overall flow in the river and an increase in the probability of "extreme" flood events from 5% to 76%. Low-lying areas including the Tonle Sap Great Lake area and areas downstream of Kratie to the Delta regions, are at particular risk of flooding. Already, Cambodia has been greatly affected by flood events, with 12 floods affecting crops between 1987 and 2007. With the potential increase in the frequency and intensity of floods in the central agricultural plains, farmers will likely be exposed to higher risk of crop failure (Ponlock 2010). Several simulations and models indicate that rice production will be at risk due to rainfall patterns and increased river flow from upstream (Dasgupta et al. 2007; TKK & SEA START RC 2009). Ashigh yielding rice varieties are less resilient to floods than traditional ones, increased frequency of flooding may have disproportionately large impacts on intensified agricultural systems in the Mekong Delta (Eastham et al. 2008).

Similarly, changes in rainfall patterns will affect agriculture production. As noted earlier, rainfed rice culture is affected by prolonged drought. Ponlock (2010) found that in the case of Cambodia, rainfall variability will affect yield and increase crop losses due to extreme events and prolonged droughts during the rainy season.

### 3.2.2 Sea Level Rise and Saline Water Intrusion

In the Mekong Delta, the most important factor related to flooding is expected to be sea level rise (SLR). Most of the agricultural land in the Mekong Delta is only slightly above mean sea level (below 2 m). As a result, it is predicted that 60% of the Mekong Delta will be highly vulnerable to SLR. Approximately 1 million hectares (ha) are already affected by tidal flooding and 1.7 million ha by salt water intrusion.

Rice production will be negatively affected by excessive flooding and longer flooding (Wassmann et al. 2004). The projected area inundated to a depth greater than 0.5 m will increase from 2,813,000 ha to 3,089,000 ha—a net increase of 276,000 ha, or about 10 percent (World Bank 2011). Assuming a 30 cm rise by 2050, there will be a loss of 193,000 ha of rice farming area due to inundation (World Bank 2011).

In the event of a SLR of 1 meter, about 30% of Vietnam's Mekong Delta region would be inundated (Carew-Reid 2007). The water level during the onset and the peak of the flood season is also expected to increase significantly.

SLR will also increase saline water intrusion in the Mekong Delta, necessitating protection measures or radical changes in farming systems to account for the influence of saline water. With a SLR of 30 cm, the total area affected by salinity intrusion with concentrations greater than 4 g/l will increase from 1,303,000 ha to 1,723,000 ha, a net increase of 420,000 ha (World Bank 2011).

## 3.3 PREVIOUS RESULTS IN CLIMATE CHANGE IMPACTS ON AGRICULTURE PRODUCTIVITY IN THE LOWER MEKONG BASIN

Only a few studies have looked at the impact of climate change at the basin level. Eastham et al. (2008) assessed the impact of climate change on crop yields at the sub-basin level using the FAO yield response function based on 11 different climate models. In this study, predicted increases in temperature, atmospheric $CO_2$ concentrations, and wet season rainfall lead to conflicting changes in agricultural productivity. According to this study, the yield of rainfed rice will slightly decrease in the upper part of Lao PDR (up to 1.5%) and increase (up to 3.3%) in the sub-basins comprising the areas of Northeast Thailand. As a whole, the yield of irrigated rice fields in the LMB was predicted to decrease by 2% if irrigation requirements are not met. Rainfed agriculture was predicted to be affected by changes in rainfall patterns with dry spells disrupting specific periods of the plant growth cycle or heavy rainfall damaging rice production during the rainy season. Even if agriculture production could improve as a result of rainfall and temperature changes, it was considered that the impact of flood damage and dry spells could easily erase these gains (Eastham et al. 2008).

In the Mekong Delta in Vietnam, TKK & SEA START RC (2009) predicts that rainfed rice yield will be severely impacted with reductions of over 40%. Recent studies in Vietnam predict declines in rice yields of 6.3% to 12% and declines in the yield of other crops by 3.4% to 26.5% by 2050 according to different climate scenarios (World Bank 2011).

In contrast, other models have predicted increased rice yields in the Mekong Delta of between 10% (2010–2039 timeframe) to 40% (2070–2099 timeframe) under the A2 climate scenario and 10% (2070–2099 timeframe) under the B2 scenario (Hoanh et al. 2004).

These differences illustrate the wide degree of uncertainty when estimating the impact of climate change on the agriculture sector using the current understanding of climate systems and the corresponding diversity of results according to the model and scenario used. This was nicely illustrated by Krishnan et al. (2007), who found wide variations in rice yields according to the type of crop productivity model used (here ORIZA1 and INFOCROP) for the same location in India.

While rice is generally the focus of most climate change impact studies in the region, a few have investigated impacts on other crops. Kono et al. (2001) predicted productivity changes of non-rice crops, with a crop modeling method for evaluating the productivity of rainfed agriculture in Northeast Thailand. Chinvanno (2004) and Chinvanno and Snidvongs (2005) tested the impact of climate change on maize, sugarcane, and cassava in various locations in Lao PDR and Northeast Thailand. The results show that climate change is likely to have a positive impact on rice, maize, and sugarcane yields in the future while the yield of cassava is projected to decrease (Chinvanno 2004). A World Bank (2011) study in Vietnam estimated the impact on the main crops in the country (maize, cassava, sugarcane, coffee, and vegetables) in addition to rice and predicted a yield decrease by 2050 for all crops tested.

Recently, a comprehensive study at the basin scale (Mainuddin et al. 2010) investigated the impact of climate change on rice and maize productivity under the A2 and B2 climate scenarios. The basin was divided into 14 different zones based on annual rainfall and potential evapotranspiration. The study used the FAO crop growth simulation model (AquaCrop) to estimate productivity changes in rainfed and irrigated rice as well as maize productivity across the basin. This study found that the yield of rainfed rice may increase significantly in the upper part of the basin in Lao PDR and Thailand and decrease in the lower part of the basin in Cambodia and Vietnam. Irrigated rice was found to be unaffected. The yield of maize was predicted to increase in both scenarios across the basin mainly due to increased $CO_2$ concentrations. Also, the study tested different adaption strategies and found that negative impacts on rainfed rice can be offset and increased yield can be achieved by using fertilizers, changing planting dates, and using supplementary irrigation. However, this study did not take into account extreme events such as floods, drought, or sea level rises that might severely impact agriculture productivity in the LMB.

In addition to the effect of climate change on agriculture yields, a recent study by CIAT in Lao PDR investigated the change of landuse suitability for 17 crops and trees in the entire country (Lefroy et al. 2010). The approach included projections for future climate (temperature and rainfall) to 2020 and 2050 and the use of landuse suitability models based on the bioclimatic suitability range of crops recorded in the FAO Ecocrop database (http://ecocrop.fao.org/ecocrop/srv/en/home).

At the country level, the changes of bioclimatic suitability to 2050 were positive for some crops (sugarcane, cassava, and paddy rice) and negative for other crops (maize and soybeans). Meanwhile some crops did not show any change in terms of bioclimatic suitability. The approach, which used GIS tools to illustrate and interpret the results, did not take in account soil and terrain interactions or management of pests and disease incidence. The approach could be used to inform future geographical (vertical) shifts in crop suitability in response to changes in temperature or rainfall patterns. A similar approach has been used in the Greater Mekong Subregion for actual rainfed agriculture where the current bioclimatic suitability of the entire region is presented for key crops (Johnston et al. 2012).

In summary, numerous studies have found that crop yields will change in response to climate change. The predicted changes to yields vary widely according to climate change scenario and model used. In addition, similar climate change scenarios provide different results according to the crop yield model used. Data sources and data quality are key concerns and can increase uncertainty regarding the accuracy of any estimates produced.

At the basin scale, studies have not taken soil data into account. Models generally only take into account common crop varieties and do not consider future changes in crop variety and their potential to adapt to new climate conditions and withstand associated challenges such as increased incidence of pest and disease. Very little is known about what will happen in terms of pest populations and disease outbreaks in new bioclimatic conditions.

Despite the uncertainties, estimating the impact of climate change on crop yields provides a useful guide for decision-makers regarding future adaptation requirements and possible adaptation mechanisms. However, it is important to keep in mind that climate is just one of the drivers of agriculture development and changes in agricultural production systems. For example, estimates of changes in crop productivity due to climate change are in the range of 2% to 30% over a 20-30 year period (Eastham et al. 2008; Cruz et al. 2007; Hoanh et al. 2004). By comparison, total agricultural production has increased almost 80% in Vietnam and over 200% in Cambodia over the past 15 years.

Therefore, studies also have to take into account other drivers such as market demand (national and international), migration, and population growth in order to better understand the future challenges facing the agriculture sector in the region.

# 4 AGRICULTURE AND ECOZONE

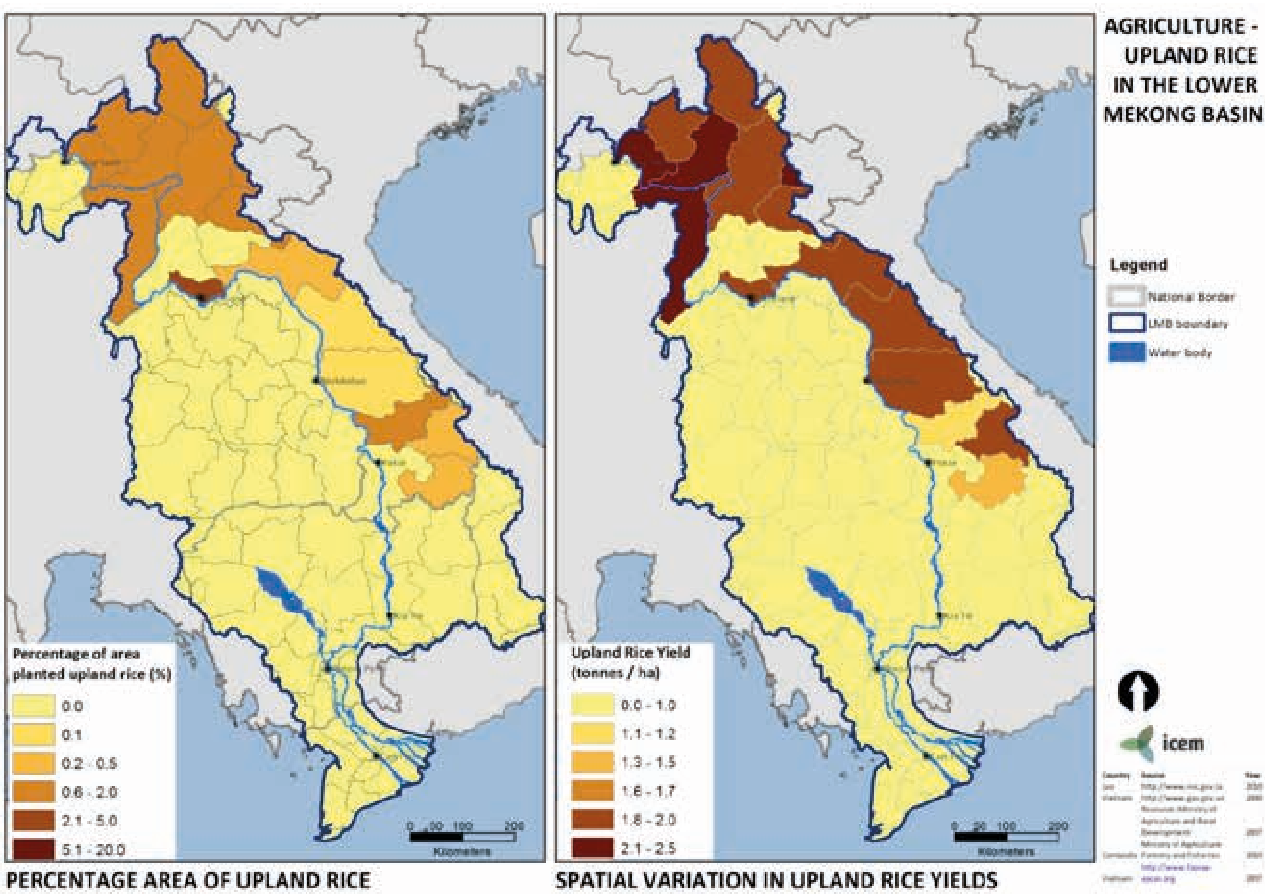
## 4.1 HIGH-ELEVATION MOIST BROADLEAF FOREST

### 4.1.1 Farming Systems Profile

#### Important species

This high elevation zone is found in the Central Highlands of Vietnam and both in southern and northern Lao PDR. The area is mostly covered by forest. Forested areas are cleared for upland rice cultivation (glutinous and non-glutinous rice varieties) and more recently for industrial plantations such as rubber (*Hevea brasiliensis*) and coffee (*Coffea canephora*), but also to a lesser extent cassava, maize, soybean and also sugarcane in lowlands (Figure 2 and Figure 3).

**Figure 2: Yields and relative cultivated area per province for upland rice in the Lower Mekong Basin**



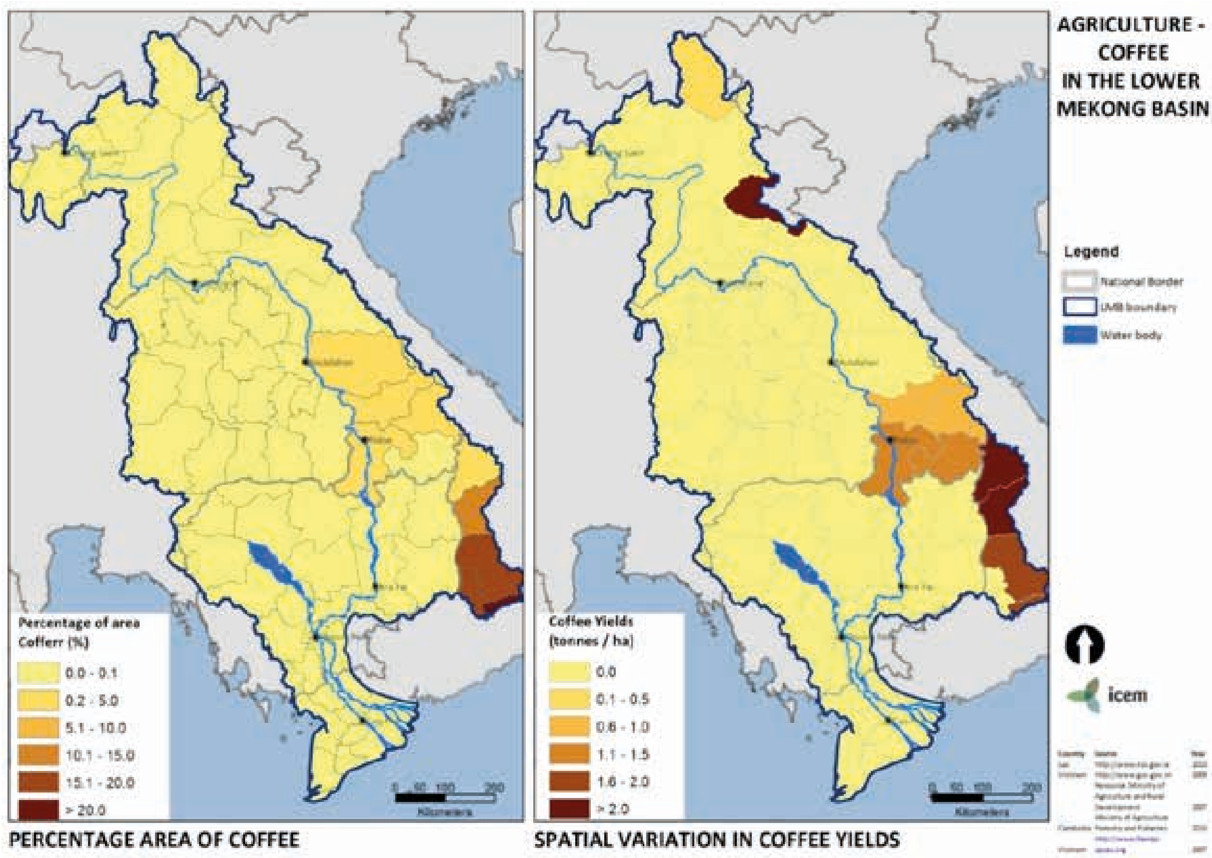
## Important areas and habitats

The fertility of this zone is usually considered poor with steep slope and low to moderate depth (30–50 cm). This it is not suitable for agriculture in most cases. However, a wide range of climatic conditions allows the cultivation of industrial crops such as rubber or coffee. Slopes range from 0° to 62° with an average of 13°. Annual precipitation averages more than 1,700 mm but ranges from 1,111 to 3,377 mm. The temperature range is wide as well, with an average maximum temperature between 17°C and 32°C.

## Cropping systems

Like in most of the LMB, the cropping systems in this zone are rainfed. Small-scale farming is dominated by shifting agriculture systems, with clearing of forest land for cereals (upland rice or maize). This system requires long fallow periods (five to 10 years) in between two cultivation periods of three to five years. Established shifting agriculture systems can include rotational cultivation of trees and annual crops such as cassava (*Manihot esculenta*), maize (*Zea mais*), and rice (*Oriza sativa*). With upland rice, farmers especially in Lao PDR mix other crops such as groundnut (*Arachis hypogea*), chili, or Job's tears (*Coix lacryma-jobi)* to diversify their production (Yasuyuki et al. 2004). The cropping calendar for upland rice and maize is from April/May to September. Cassava is planted in April and harvested in January, but can also be cultivated for more than one year. In this cropping system, yields are generally low without fertilizers—sometimes lower than 1 tonne/ha for rice and maize and around 4 tonnes/ha for cassava—even if those yields can be higher.

**Figure 3: Yields and relative cultivated area per province for Robusta coffee (*Coffea canephora*) in the Lower Mekong Basin**



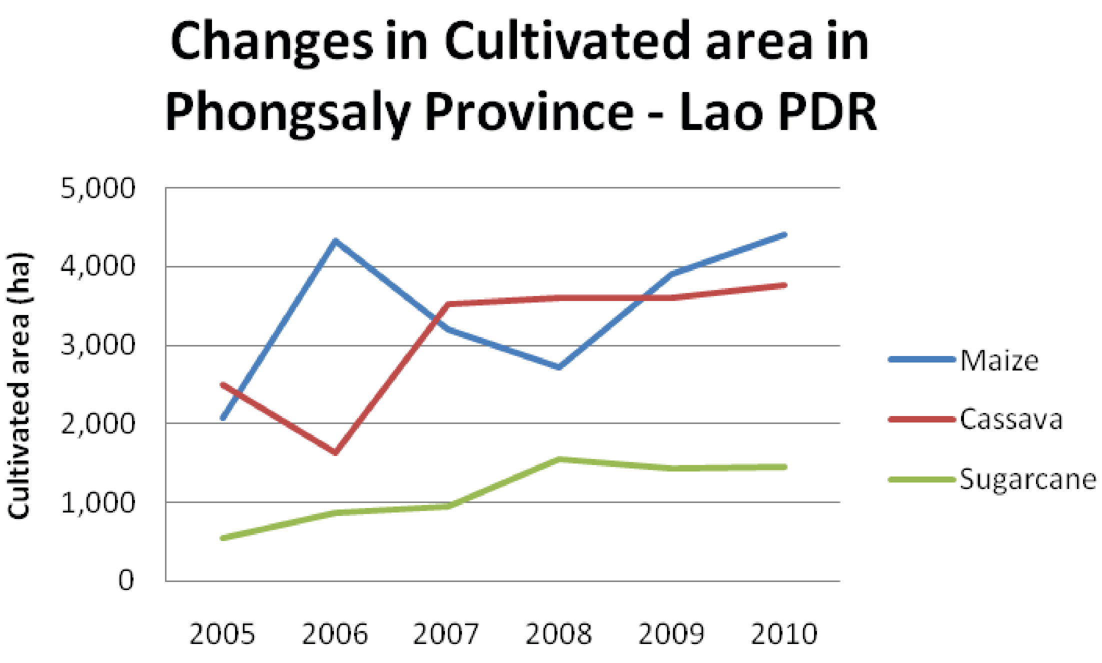
Industrial plantations of perennial (rubber, coffee) or annual (cassava) crops are based on monoculture. In some cases, inter-cropping of cassava and rubber can be found in the Central Highlands of Vietnam, with cassava sometimes integrated during the early stages of rubber plantations (3 to 4 years).

In northern Lao PDR and the Central Highlands of Vietnam, lowland rainfed rice is popular and represents the major grain crop cultivated during the rainy season together with upland rice. When rice fields are irrigated, a dry season crop or early wet season crop is possible. Significant areas of irrigated rice are found in the Central Highlands (Lam Dong Province) with more than 10,000 ha and to a lesser extent in northern Lao PDR (Luang Namtha Province) with 1,600 ha. Lowland fields can also be used for cassava, maize, or sugarcane (*Saccharum officinarum*) cultivation. The Bolaven Plateau in Champasak province is a specific area in Lao PDR with coffee (*C. canephora*) plantations using a rainfed system. This area is a unique agro-system, with deep soil and high rainfall. Coffee production is well established with almost 30,000 ha.

### Trends, threats and opportunities

The forest cover in this zone is declining due to the expansion of industrial crops. In northern Lao PDR, according to government planning, rubber plantations are supposed to cover more than 54,000 ha in Phonsaly, Luang Namtha, and Luang Prabang Provinces by 2010, while the area covered in 2006 was around 11,000 ha. A similar trend is expected in Sekong Province (10,000 ha) in the southern part of Lao PDR, where in 2006 only 100 ha of rubber was planted (Douangsavanh et al. 2008). In 2011, the total area planted with rubber in Lao PDR reached 300,000 ha[3].

**Figure 4: Change in cultivated area of maize, cassava, and sugarcane in Phongsaly Province (Source: Lao Statistic Bureau 2012)**




[3] http://www.forestcarbonasia.org/in-the-media/limits-set-on-future-rubber-plantations-in-laos/

Other industrial and cash crops are also expanding in this zone, with the example of Phongsaly Province where maize and cassava, but also sugarcane, have expanded by 1.5 to 3 times between 2005 and 2010 (Figure 4). During the same period, the area of maize harvested increased by four times in Huaphanh Province reaching more than 20,000 ha in 2010 (Lao Statistic Bureau 2012[4])

In the Central Highlands of Vietnam, coffee plantations already expanded in the 1990s and early 2000s to reach a certain level of stability with 108,000 ha now in Lam Dong Province. Rubber is now largely developed in this area, like in Lao PDR, while annual crops are expanding and replacing rainfed rice in some cases. In Lam Dong Province, the cultivated area of maize increased by 5,000 ha between 2000 and 2009 (General Statistic Office of Vietnam 2012[5]).

The expansion of industrial plantations and cash crops has caused soil fertility and erosion problems as agriculture has expanded to hills with steep slopes. Erosion issues are particularly important in the case of annual crops such as cassava. In addition, the increase in population as reported by Valentin et al. (2008) is one of the factors that has led to reduced availability of land per capita, thus limiting the fallow period necessary for traditional shifting cultivation systems and resulting in further erosion and decline in soil fertility.

## 4.2 MID-ELEVATION DRY BROADLEAF FOREST

### 4.2.1 Farming Systems Profile

#### Important species

In this ecozone, similar crops are found to those present in *High-elevation Moist Broadleaf Forest*. Both upland farming with shifting agriculture and perennial plantations are present. Commercial crops such as sugarcane, cassava, and maize are also well developed in Thailand and the Central Highlands. In the Central Highlands and Northeast Cambodia, cashew and black pepper farms are also found, but their production is limited compared to other perennial crops. In northern Thailand, orchards and fruit trees such as Litchi plantations are important species in agriculture.

#### Important areas and habitats

Coffee production in the Central Highlands is concentrated in a specific area in Gia Lai and Dak Lak Provinces with red basaltic soil otherwise known as *ferralsols* (FAO/UNESCO classification), which represent around 10% of the total ecozone area. This area is extremely suitable for coffee production, combining adequate climate and soil conditions. A similar soil type can also be found in other ecozones (e.g., *Low-elevation Dry Broadleaf Forest*). The potential irrigated area is higher than in other ecozones (except for the Mekong Delta) with about 20% of the ecozone area being irrigated (more than 600,000 ha).

[4] http://www.nsc.gov.la/
[5] http://www.gso.gov.vn/default_en.aspx?tabid=491

### Cropping systems

Small-scale agriculture cropping systems like those in the previous ecozone (i.e., *High-elevation Moist Broadleaf Forest*) are dominated by upland rice and rainfed crops. However, in this ecozone there are more plantations with cassava, sugarcane, soybean (*Glycine max*), and maize compared to the previous ecozone with larger planted areas (more than 20,000 ha of each crop in Gia Lai Province in Vietnam, for example).

Rubber plantations usually follow a monoculture system but can use an inter-cropping system with cassava in the first years of the plantation. Coffee plantations in Vietnam are monoculture systems, sometime associated with black pepper and are irrigated mostly with ground water. For both coffee and rubber, the productivity is similar to that in the previous ecozone with coffee around 2 tonnes/ha and dry latex around 1.5 to 2 tonnes/ha.

In Northeast Thailand and the Central Highlands of Vietnam, cassava, maize, (Figure 5 and Figure 6), sugarcane, and soybean accounted for smaller shares of planted area but have yields that are relatively high for the region. In the Central Highlands and Northeast Cambodia, maize and cassava yields are between 1 and 4.5 tonnes/ha and 5 and 15 tonnes/ha respectively (MAFF 2011 and General Statistic Office of Vietnam 2012). In Chaiyaphum province (Thailand) for the same ecozone, yields are around 22 tonnes/ha and 3.3 tonnes/ha for cassava and maize respectively. Yields of soybean and sugarcane are about 1.4 tonnes/ha and 60 tonnes/ha respectively. In Chang Rai yields are within a similar range (4 tonnes/ha for maize; 20 tonnes/ha for cassava, 1.32 tonnes/ha for soybean and 53 tonnes/ha for sugarcane). However, the results for this province are spread over several ecozones. This province supports a large area of maize (51,000 ha), irrigated rice in lowlands (18,000 ha) and rubber (37,000 ha in 2010), while cassava is a minor crop. In the Central Highlands, there are more than 20,000 ha of irrigated rice found in Dak Lak and Gia Lai provinces with high yields. While two rice crops per year is not common in the ecozone, lowland areas are suitable for such a culture with adequate rainfall and temperature.

**Figure 5: Yields and relative cultivated area per province for cassava in the Lower Mekong Basin**

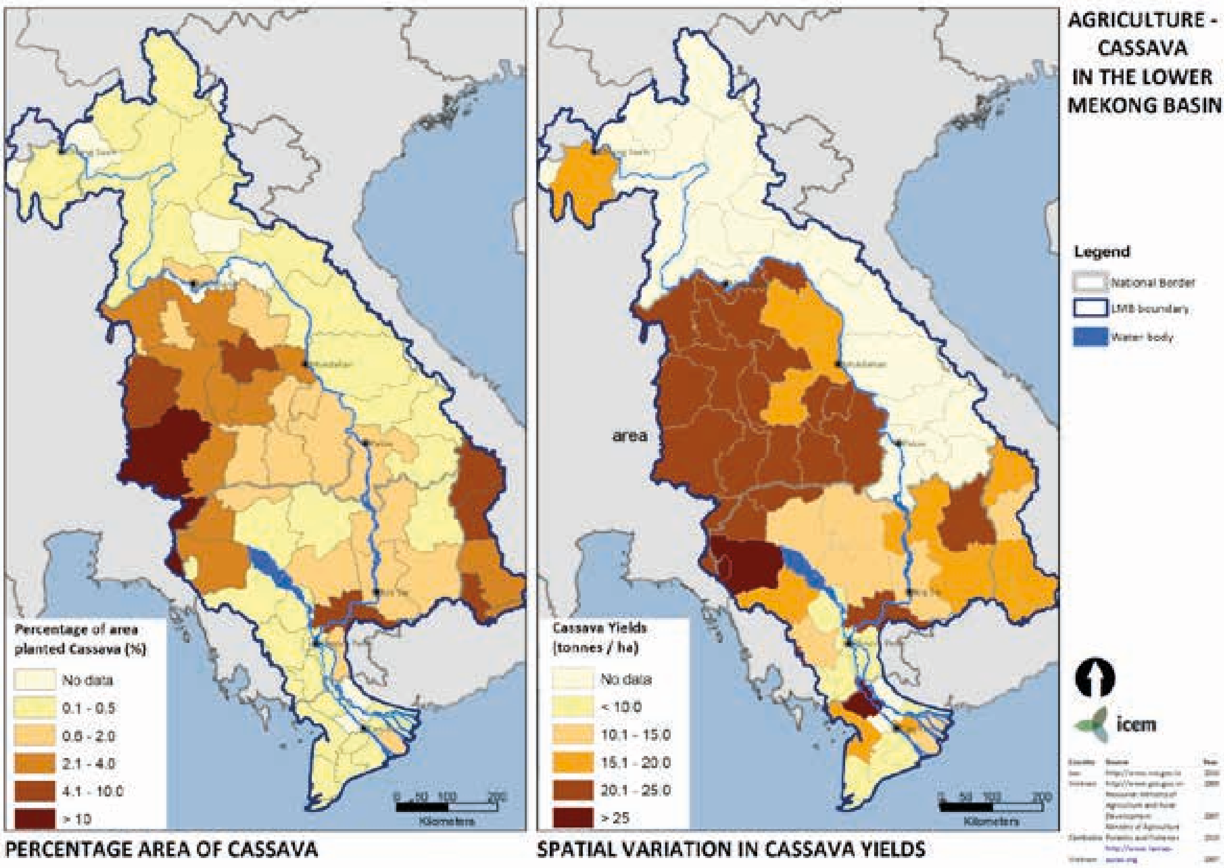
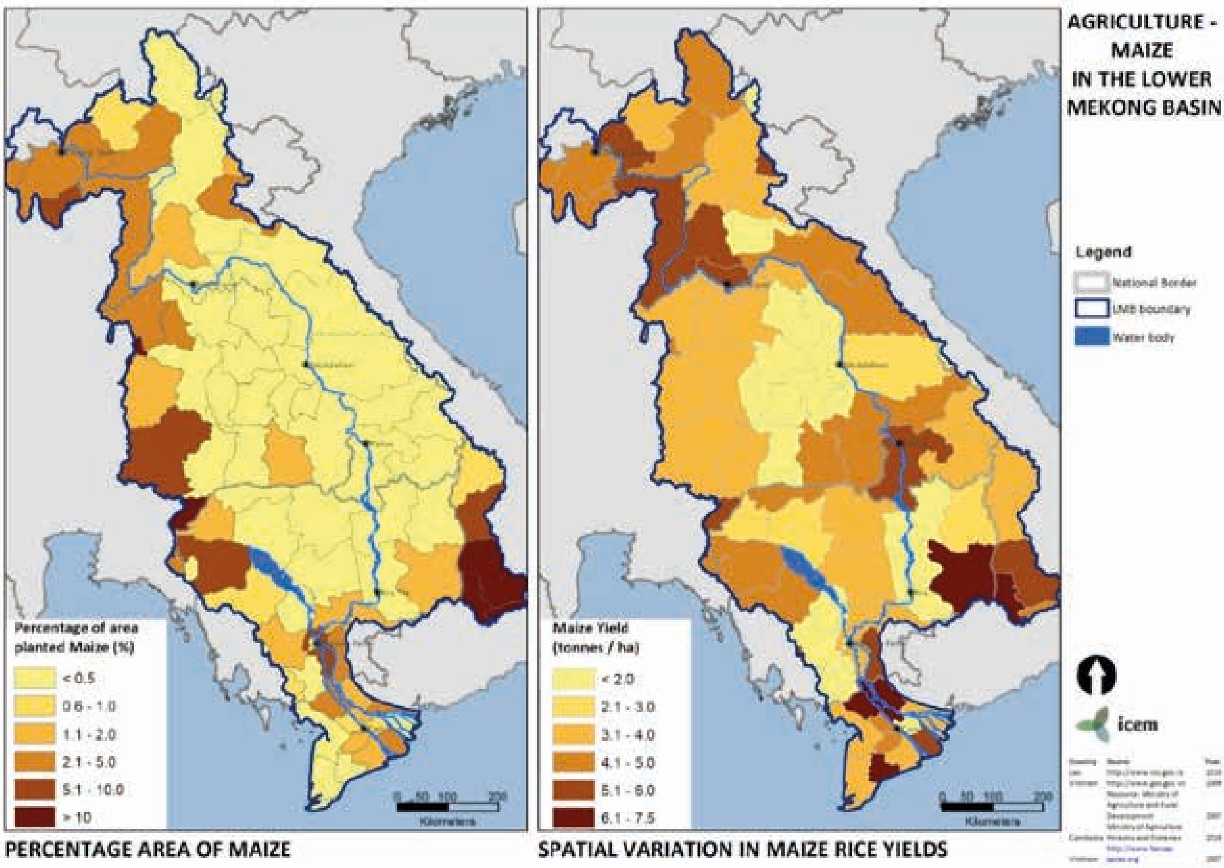


Figure 6: Yields and relative cultivated area per province for maize in the Lower Mekong Basin

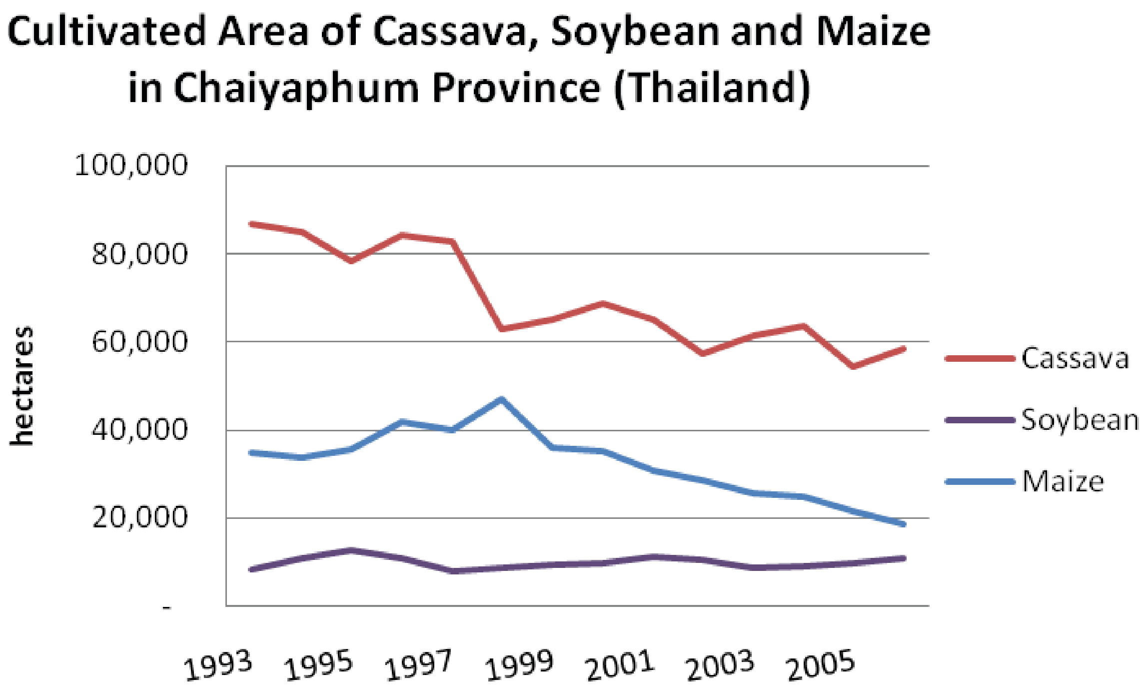



## Trends, threats and opportunities

In the 1990s cassava and maize spread in Northeast Thailand including into provinces found in this ecozone. But the situation differs by province. For example, in Chaiyaphum Province more than 50,000 ha of cassava, 10,000 ha of soybean, 18,000 ha of maize, and 100,000 ha of sugarcane were cultivated in 2006. However, in Chiang Rai less than 1,000 ha are cultivated alongside 50,000 ha of maize.

Since the early 2000s the planted area of annual crops in this ecozone has been declining (Figure 7). This decline is partially the result of an expansion in rubber plantations. Recently, rubber plantations have boomed in the region and, for example, now cover 37,000 ha in Chang Rai province.

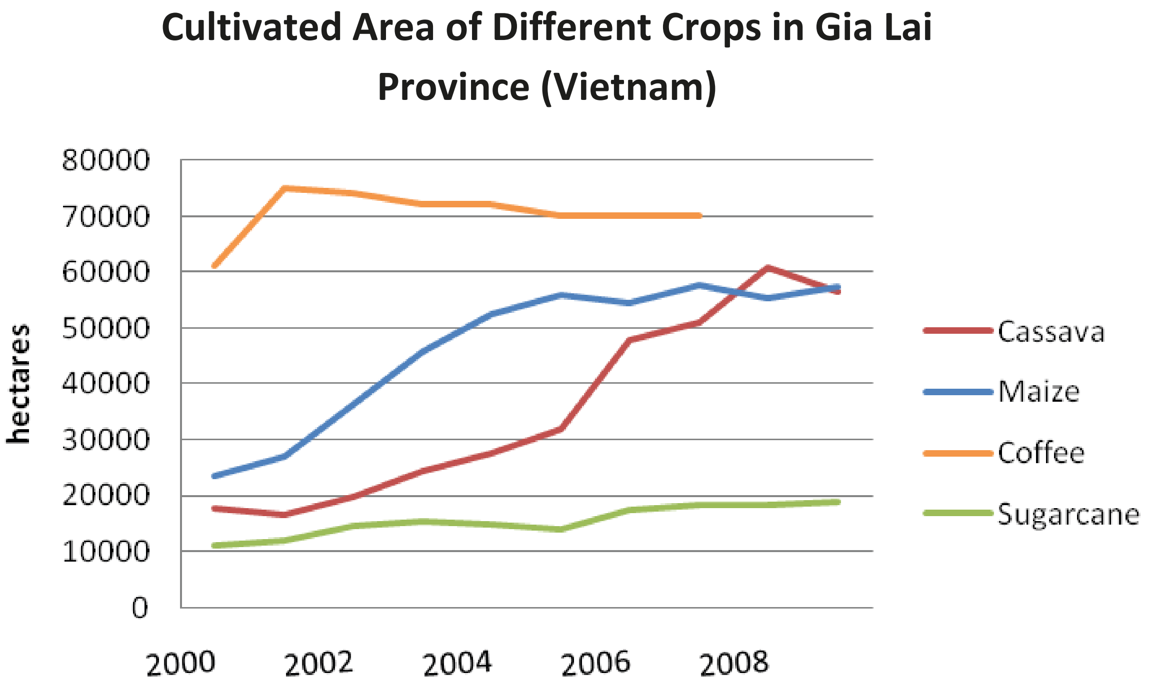
**Figure 7: Cultivated area of cassava, soybean, and maize in Chaiyaphum Province (Thailand) from 1993 to 2006 (Source: FAO 2012)**




Mondulkiri province in Northeast Cambodia is dominated by forest cover. Subsequently, traditional farming based on upland and lowland rainfed and vegetable gardening represent relatively small areas in this region. However, recent expansion of cassava and rubber plantations (6,280 ha in 2009) by private concessions and smallholders has resulted in some deforestation.

In the Central Highlands, the expansion of coffee plantations has stabilized and most of the suitable area for this crop is now in use. During the past decade the planted area of irrigated rice, maize, cassava, and sugarcane has been expanding in Dak Lak and Gia Lai provinces. In Gia Lai province, the area planted with cassava has grown by about 13% per annum for the last 10 years. A similar rate of growth is found for maize (10% p.a.). (Figure 8)

**Figure 8: Cultivated area of cassava, maize, coffee, sugarcane in Gia Lai Province, from 2000 to 2009 (Source General Statistic Office of Vietnam 2012)**




These trends are the result of growing market demand and higher prices for commercial crops originating in this ecozone and across the LMB. In hilly and mountainous areas such expansion has resulted in environmental consequences such as erosion and reduced soil fertility. Similar trends are also observable in Northeast Cambodia.

## 4.3 LOW-ELEVATION DRY BROADLEAF FOREST

### 4.3.1 Farming Systems Profile

#### Important species

In this zone, which covers a large part of the Khorat plateau and the plains in Cambodia, a large diversity of subsistence and commercial crops are found. Rainfed rice, for subsistence and sale, is the dominant crop covering more than 75% of the total planted area. Commercial crops such as cassava, maize, sugarcane, and soybeans are also common. Rubber is also a suitable crop in this ecozone.

#### Important areas and habitats

In the ecozone, almost 10% of the total area is irrigated, corresponding to about 1.4 million ha, mostly located in Northeast Thailand on the Isan plateau. This irrigation allows for the production of dry season crops such as sugarcane, soybean, and rice, while also providing supplementary irrigation for early wet season rice. Soil fertility is generally low in this ecozone.

Similar to the *Mid-elevation Moist Broadleaf Forest* ecozone, parts of this ecozone, including Kampong Cham, Mondulkiri, Kratie, and Ratanakiri Provinces in Cambodia, are rich with red basaltic soil or f*erralsols*. These areas are highly suitable for rubber plantations when there is also adequate suitable climate. However, the total area of this soil is limited to less than 5% of the ecozone.

### Cropping systems

Cropping systems in this ecozone are dominated by rainfed rice culture from May/June to October/November. Commercial annual crops (e.g., sugarcane and cassava) and rubber are also significant. In Thailand, access to irrigation allows for dry season rice from November/December to February/March and supplementary irrigation in the rainy season. Access to supplementary irrigation in Thailand might explain the higher yields recorded in this part of the ecozone. In Cambodia, the cropping systems are mostly rainfed. Rainfed rice yields are low at around 2.5 tonnes/ha in Cambodia, while dry season irrigated rice yields are around 3.5 tonnes/ha (MAFF 2011).

**Table 2: Yield ranges in Thailand and Cambodia for the main crops cultivated in the Low-elevation Dry Broadleaf Forest ecozone**

| | Cambodia | Thailand |
|---|---|---|
| | tonnes/ha | tonnes/ha |
| **Soybean** | 1.5[a] | 1-3.7[a] |
| **Maize** | 2.2-4.4[b] | 4-5[c] |
| **Sugarcane** | 15-20[b] | 63[c] |
| **Cassava** | 20[b] | 20-24[c] |
| **Rainfed rice** | 2.5[b]-2.8[b] | 2.1[c] |
| **Irrigated rice** | 3.5[b] | 2.3-3.7[c] |

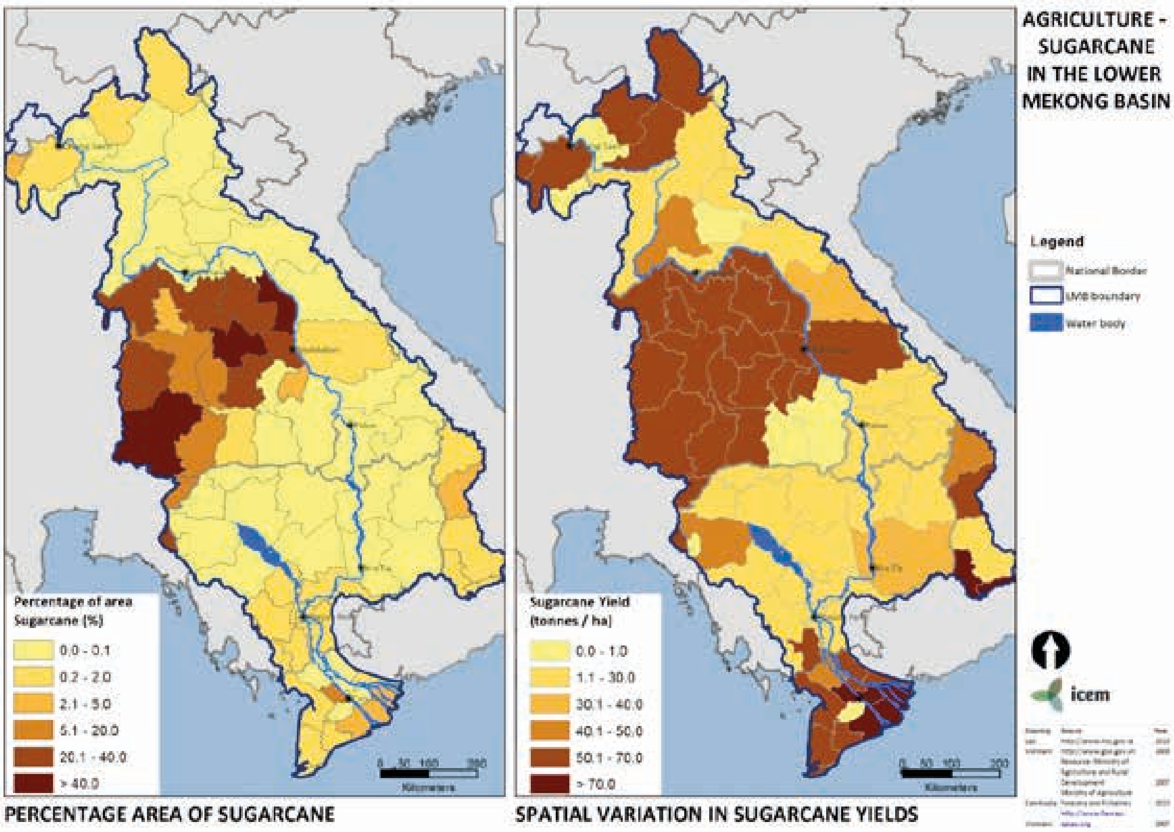
Source: a) Belfield et al. 2011; b) MAFF 2011, Oddar Meanchey and Bantheay Meanchey Provinces; c) FAO 2008 (examples of Sakeo and Nakhon Phanom Provinces in Thailand and Oddar Meanchey in Cambodia)

Maize, soybean, and cassava have the same type of cropping calendar that they have in *High-* and *Mid-elevation* ecozones (May to August/September for maize and soybean, and March/April to December/January for cassava). Sugarcane's cropping calendar extends beyond the rainy season running from May to February. In Thailand, sugarcane was once previously rainfed, but is now increasingly irrigated. Early wet season rice can be followed with a soybean crop in some cases. But, in general, most crops are monoculture and rainfed, which often results in only one crop per year. Rubber is well developed in this zone. In Cambodia and Northeast Thailand, there are large areas of industrial and smallholder rubber plantations (MAFF 2011). The typical yields of these crops are presented in Table 2.

### 4.3.2 Trends, threats and opportunities

The cultivation of commercial crops started in Northeast Thailand and has progressively expanded into Cambodia, first in the Northwest provinces (Pailin, Oddar Meanchey, Bantheay Meanchey, Battambang) and more recently in the eastern provinces (Siem Reap, Ratanakiri). In Thailand, sugarcane expansion can partially be explained by government subsidies. Sugarcane is still prevalent in Northeast Thailand, especially in Sakon Nakhon where more than 30,000 ha is planted. Yields in Thailand are generally higher than those found in Cambodia (Figure 9). Cassava, maize, and soybean are also an important part of the agriculture sector in this region of Thailand.

**Figure 9: Yields and relative cultivated area per province for sugarcane in the Lower Mekong Basin**




In Cambodia, large plantations of cassava have been established in Bantheay Meanchey Province and Stung Treng Province with more than 25,000 and 4,000 ha of cassava cultivated in 2008 respectively (MAFF 2011). The recent expansion of cassava in the LMB is mostly driven by market demand; particularly from China. For example, in Thailand, the price charged by producers of cassava increased from US$ 15.7 per tonne to US$ 57.9 per tonne between 2000 and 2008 (FAOSTAT 2012[6]). Cambodia's cassava production is mostly for export to Thailand and Vietnam, where processing factories have generated high demand for the raw product.

Soybean and maize are generally less important in Cambodia due to lower market prices and more restrictive environmental requirements. However, despite this trend, some provinces in Cambodia have witnessed a significant expansion of soybean culture in the last decade, In Battambang, Kampong Cham and Prey Vihear Provinces there was 40,000 ha, 21,000 ha and 20,000 ha of soybean harvested in 2008 respectively.

[6] http://faostat.fao.org/DesktopDefault.aspx?PageID=339&lang=en&country=216

Thailand is the largest rubber producer in the world (FAOSTAT 2012) and rubber plantations are well developed in Northeast Thailand. Provinces in this area, including Ubon Ratchathani and Surin, now have large areas of rubber plantations of 30,000 ha and 14,000 ha respectively (2010). Rubber is also expanding into other parts of the region. Between 2008 and 2011, the area planted of rubber in Cambodia increased 75%, from 108,000 ha to 188,000 ha, which includes both large private concessions and smallholder plantations. Like cassava, rubber plantations are expanding due to international market demand and high prices. In 2011, due to rising foreign demand, Cambodia's rubber export prices grew by 131% (MAFF 2011[7]).

Similar trends are found in southern Lao PDR at lower altitudes found in Champasack and Savannakhet Provinces. International rubber enterprises have been granted 23,000 ha and 43,000 ha respectively for new rubber plantations in these provinces. Foreign investment and development of commercial agriculture based on land concessions is now expanding rapidly in southern Lao PDR and will transform the landscape and local livelihoods. In Savannakhet Province, more than 20,000 ha have been granted for sugarcane culture, 21,000 ha for cassava culture and 30,000 ha for eucalyptus plantations (CRILNR et al. 2009). The rapid expansion of labor-intensive agriculture in this area has raised questions regarding the availability of adequate local labor and potential environmental consequences.

The main climate-related threat to agriculture in this ecozone is prolonged drought during the cropping season. In Battambang and Kampong Cham provinces, 17,000 ha and 4,000 ha of rainfed rice were affected by drought in 2008 respectively. In Thailand, irrigation networks have experienced serious water shortages caused by increasing competition for water between different sectors (industry, agriculture, and urban domestic use). This has resulted in reduced planting of dry season crops in the area (Johnston 2009). Changes in the frequency of rainfall, dry spells during the growing season, and limited access to irrigation are the key future threats to agriculture in this ecozone.

## 4.4 LOW-ELEVATION MOIST BROADLEAF FOREST

### 4.4.1 Farming Systems Profile

#### Important species

This ecozone supports similar crops to the *Low- and Mid-elevation Dry Broadleaf Forest*. Rainfed rice, maize, sugarcane, cassava, soybean, rubber, and eucalyptus are found in this ecozone.

#### Important areas and habitats

Soils in this ecozone are deep and stable with medium texture and no specific toxicity. We can distinguish specific areas in terms of agriculture trends. In western Cambodia (Pailin province) and Xayaburi province in Lao PDR, commercial agriculture is developing fast in response to demand from Thailand's agro-industrial sector. In these areas, maize, soybean, sugarcane, and cassava are replacing

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[7] http://www.maff.gov.kh/en/news/63-ruber2011.html

previously forested areas. Rubber plantations have also been expanding in this area of western Cambodia, the Vientiane plain and the northern lowland areas of Lao PDR.

### Cropping systems

Cropping systems in this ecozone are similar to those in the *Low- and Mid-elevation Dry Broadleaf Forest* ecozones. Rainfed rice is the dominant crop. But, adjustments in the cropping calendar allow for the cultivation of rice, maize, soybean, and cassava in this ecozone where there is more than 1,500 mm of rainfall (for example, the Vientiane plain receives 2,500 to 3,000 mm of rainfall). The growing season generally ranges between 180 and 270 days. Shifting cultivation is found on hills and in remote areas, but it is progressively being replaced by more market-oriented agriculture. In Lao PDR there has been a recent expansion of lowland irrigated rice culture during the dry season and early wet season. In this area, commercial and small-scale agriculture co-exist with similar cropping patterns.

Commercial crops are also cultivated by smallholders, sometimes under a contract with larger agro-industrial companies. Commercial crops are dominated by rainfed maize, sugarcane, and cassava in monoculture. A rotation of maize (or soybean) and cassava is usually recommended. However, this practice depends mostly on market prices and changes in cropping patterns can be observed from one year to the next.

In Lao PDR, and to a lesser extent in western Cambodia, rubber plantations backed with foreign investment and some smallholder operations are replacing forested areas (Douangsavanh et al. 2008; Hicks et al. 2009). A comparison of yields for the main crops is provided in Table 3.

**Table 3: Yield ranges in Lao PDR (Khammouan Province, Vientiane Prefecture) and Cambodia (Pailin Province) for the main crops cultivated in the Low-elevation Moist Broadleaf Forest ecozone**

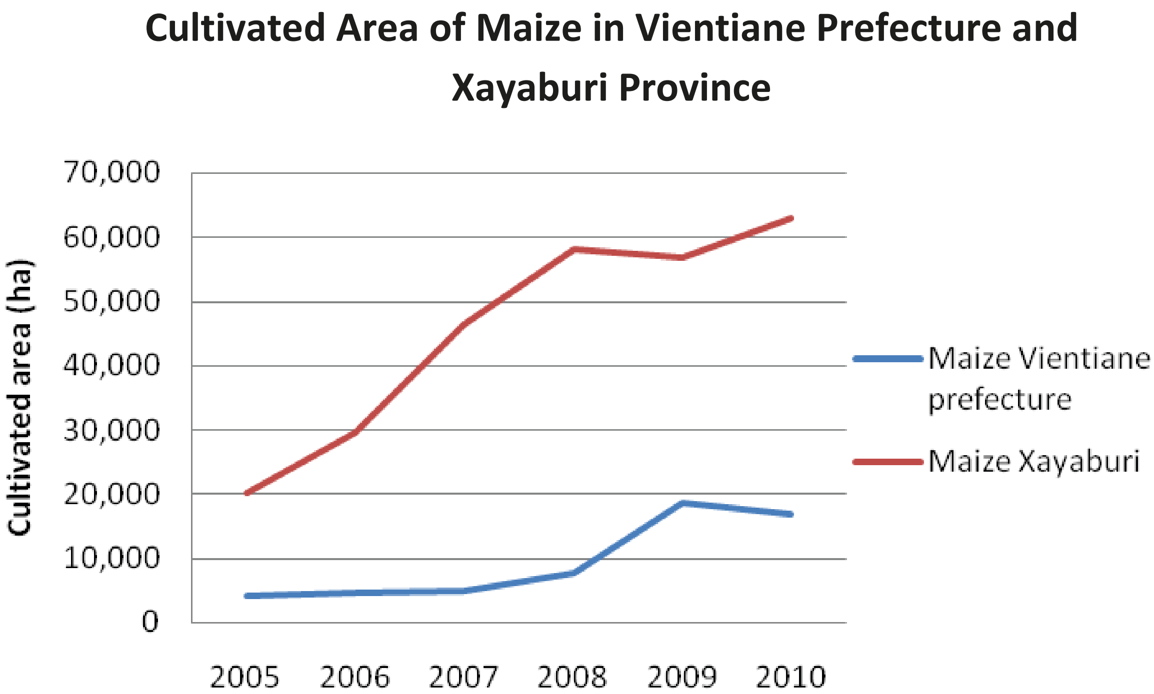
| | Cambodia | Lao PDR |
|---|---|---|
| | tonnes/ha | tonnes/ha |
| **Soybean** | 1.2 | 1.1-1.2[a] |
| **Maize** | 4.5 | 4.8-5.3[b] |
| **Sugarcane** | - | 28-31[b] |
| **Cassava** | - | 9.2-10.2[a] |
| **Rainfed rice** | 3.4 | 3.4-4.3[b] |
| **Irrigated rice** | 3.9 | 5.3-4.1[b] |

Source: MAFF 2011 (2010 data) for Cambodia; and a) FAO 2008 (2005 data) and b) Lao Statistic Bureau 2012 (2011 data)

### Trends, threats and opportunities

This ecozone has experienced a rapid expansion of commercial agriculture in the last decade. In Vientiane Prefecture and Xayabury Province, for example, the cultivated area of maize has grown 42% and 33% per annum respectively between 2005 and 2010 (Figure 10). The cultivated area of cassava in Vientiane Prefecture increased by 23% per annum during the same period. Demand for cassava in this area is being driven by the development of processing factories near the capital. This expansion can induce soil degradation and loss of fertility; especially in areas where cassava is replacing forested areas or in the absence of crop rotation for annual crops.

**Figure 10: Cultivated area of maize in Xayaburi Province and Vientiane, from 2005 to 2010 (Source: Lao Statistic Bureau 2012)**




The area for irrigated rice in Vientiane Prefecture and Xayaburi Province increased by 23% and 22% per annum. Irrigated areas have also expanded in Khammouan Province from 4,000 to 9,000 ha. This province also has small areas of soybean, sugarcane, cassava, and maize. However, there has been a recent expansion of cassava as well as rubber plantations in the southern part of Khammouan Province.

As in the *Low-elevation Dry Broadleaf Forest* ecozone, this ecozone has also been affected by large investment in plantations. By 2007, the Lao PDR government granted more than 150,000 ha of large-scale concessions for plantations. More than 60% of the concession area is found within this ecozone (MPI 2008). These concessions are mostly dedicated to rubber and eucalyptus. However, recent statistics are not available and we base our analysis on national projections cited in Douangsavanh et al. (2008). Statistics or estimates of small- and medium-scale plantation projects are not available and areas of rubber and other plantations are probably under-estimated as mentioned in Hicks et al. (2009).

## 4.5 FLOODPLAIN WETLAND, LAKES

This ecozone combines the *Upper, Mid, and Lower Floodplains* from Chiang Saen to Kratie. From an agricultural perspective these ecozones display relatively similar characteristics.

### 4.5.1 Farming Systems Profile

#### Important species

In keeping with other ecozones, agriculture is generally divided between irrigated rice and rainfed rice and other rainfed commercial crops (maize, cassava, and soybean).

#### Important areas and habitats

The ecozone includes the riverbanks and floodplains along the Mekong River and its main tributaries. Forested areas located in these floodplains were cleared some time ago to make way for agricultural development. The soils, recent alluvial terraces, are fertile and seasonally flooded with sediment deposits. Irrigated perimeters can be found in the Vientiane floodplain, along the Mekong corridor in Lao PDR and in Kratie Province in Cambodia. However, the irrigation is generally limited compared to other ecozones.

#### Cropping systems

This ecozone supports similar cropping systems to those in other *Low-elevation* (both *Dry and Moist Broadleaf Forest*) ecozones. Rainfed agriculture dominates, but irrigated areas have been developed in the floodplain to accommodate a dry season rice crop from December to April. The ecozone has an average annual rainfall between 1,100 and 3,000 mm. The crop calendar ranges from 180–200 days,

In the floodplain, growing conditions depend mostly on water management infrastructure and flood depth. Commercial crops such as cassava, soybean, or maize are not tolerant to submergence in the case of floods.

In the *Mid and Lower Floodplains*, cultivated land is partially flooded during the year and cropping systems have to adapt to this water regime. Recession rice culture (transplanted in December and harvested in April) or early wet season rice cultivation (April to July/August) are employed as options to avoid flood. At higher elevations medium (less affected by the flood) rainfed rice variety can be planted from August to December. These systems take advantage of the fertile sediments that result from flood conditions. Deep water rice, a type of rice crop with a longer growth period and tolerance to long and deep periods of submergence, is also found in this ecozone.

The rice culture techniques and varieties used will depend on the level of water control. In areas without water control, deep water rice (May/June to December/January) is an option. If water management infrastructure is in place, a double rice crop is possible with a first dry season crop followed by an early wet season crop before the peak flood.

### Trends, threats and opportunities

The *Floodplain* ecozone in Lao PDR has experienced an increase in commercial crops and irrigated rice culture. For example, in Champasak Province and Vientiane Prefecture, the planted area of irrigated rice increased 35% and 22% per annum respectively between 2005 and 2010. Growth in irrigated rice culture in Northeast Thailand has been much smaller by comparison. For example, in Roi Et and Ubon Ratchathani Provinces the area dedicated to irrigated rice increased by only 1% to 2% per annum between 1993 and 2006.

In addition to rice, other commercial crops are generally more prevalent in this ecozone. But, agriculture in this ecozone is threatened by flooding during the rainy season which generally corresponds with the cropping calendar for most of the commonly planted crops. In 2011 flood damaged more than 80,000 ha of rice paddy in the Cambodian floodplain (which includes the Tonle Sap floodplain). However, as noted above, flood sediments also improve agricultural productivity in this ecozone by enriching and regenerating soils and soil fertility. Improved water management infrastructure incorporating early flood protection systems and/or irrigation schemes will reduce the risk of crop losses and increase the potential number of crops in this zone beyond one harvest per year.

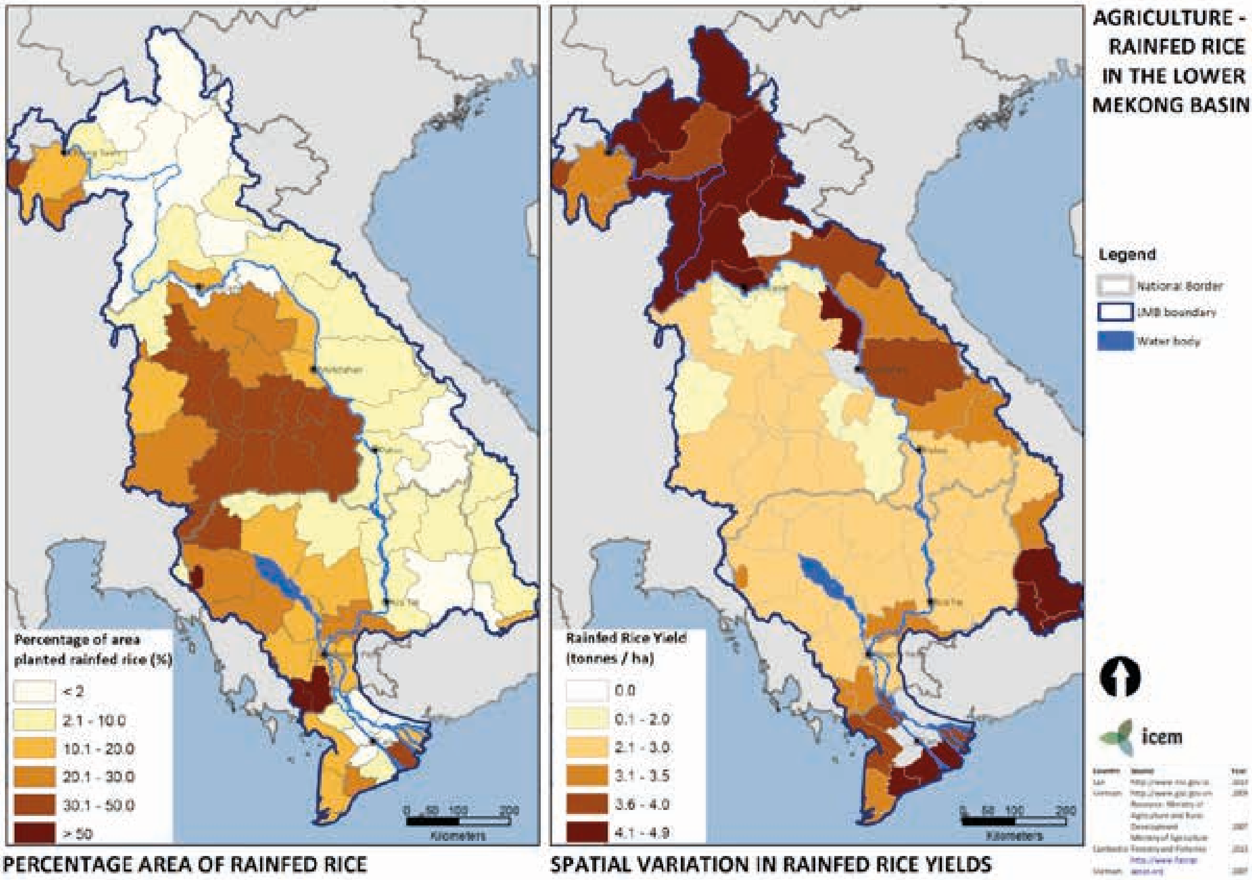
## 4.6 TONLE SAP SWAMP FOREST AND LOWER FLOODPLAIN (KRATIE TO DELTA)

### 4.6.1 Farming Systems Profile

#### Important species

This ecozone includes the Cambodian floodplain and the Tonle Sap Lake. Farming systems in this ecozone are mostly rainfed (Figure 11). There is also limited access to irrigation for either a dry season crop or supplementary irrigation in the rainy season. Most of the irrigated rice in Cambodia is found in this ecozone with 9% of the ecozone covered by an irrigated perimeter. Other crops such as sugarcane or maize are of less importance. Cassava, soybean and maize are also found in some provinces (Figure 5 and Figure 6).

**Figure 11: Yields and relative cultivated area per province for lowland rainfed rice in the Lower Mekong Basin**




## Important areas and habitats

As with the *FloodPlain, Lakes* ecozone, soils in this area are alluvial in nature and subject to seasonal flooding resulting in annual deposits of sediment. Soils have a medium to fine texture, considerable depth and limited toxicity. Soils at lower elevations tend to be distinguished by heavy clay content and higher acidity compared to soils at higher elevations that have shorter inundation periods (Pillot 2007).

The floodplain is seasonally inundated with floods starting in July/August and finishing in November, when the water starts to recede. However, inter-annual variation in the flood level means that the starting time and amplitude of the flood are difficult to predict leading to increased risk of water shortages for farmers. Irrigation systems using reservoirs can be found around the lake, and those using canals directly connected to rivers can be found on the floodplain. These systems allow for recession rice and/or dry season rice crops. However, the Royal Government of Cambodia (RCG) has banned the development of individual, small-scale reservoirs since 2010.

### Cropping systems

Agricultural land in the floodplain is locally classified as upland, medium upland and lowland according to the flood's duration, which determines landuse. In the floodplain, rice is the dominant crop. Around 30,000 ha of irrigated rice and almost 200,000 ha of rainfed rice is planted in Kampong Thom Province. Rainfed rice or vegetables are cultivated on more elevated land and recession rice is planted on lowland areas along with dry season rice where irrigation is available. In 2010, the yield of rainy season rice in the floodplain was between 2.7 and 2.9 tonnes/ha in Prey Veng and Kandal Provinces respectively (MAFF 2011).

The yield of dry season rice was higher ranging from 4.3 and 4.1 tonnes/ha in each province respectively. This is generally due to the higher amount of inputs used and more favorable growing conditions during the dry season. The cultivated area and cropping calendar of dry season crops depends upon flood levels and the recession of the Mekong River.

Recession rice can be found around the lake and in the floodplain. Land preparation for recession rice is usually done in May and farmers start broadcasting rice in November/December when the flood subsides. The harvesting time of recession rice is at the end of February or beginning of March. Floating rice in deeply flooded areas is increasingly uncommon with only 200 ha found in Takeo Province.

Cassava, soybean, and rubber cultures are also prominent with around 8,000 ha, 4,000 ha and 15,000 ha respectively of each planted in Kampong Thom Province. Rainfed rice is sometimes combined with soybean in a successive soybean-rice cropping pattern.

### Trends, threats and opportunities

Improving rice culture and developing irrigation is one of the main objectives of the Royal Government of Cambodia in the Rectangular Strategy (RCG 2004). Between 2001 and 2010, the harvested area of dry season rice increased by 5% per annum in Cambodia to reach 404,800 ha in 2010. Around 77% of this dry season rice is located in the floodplain and the Tonle Sap Lake area. In comparison, rainy season rice culture increased by 3.6% per annum to reach more than 2.3 M ha (MAFF 2011). Threats to rice culture in the floodplain are largely climate related resulting from unpredictable droughts and floods. In 2010, more than 34,000 ha of agricultural land in the floodplain were affected by both drought and flood. In Takeo Province, 5,411 ha of rainy season rice was affected by drought and more than 3,000 ha by floods (MAFF 2011). Dry season rice, where the water supply is secure, is less affected by such climatic events.

# 4.7 DELTA FRESH WATER SWAMP FOREST

## 4.7.1 Farming Systems Profile

### Important species

This ecozone has the highest density of irrigation canals in the LMB and is characterized by intensive rice production including double and triple rice cultures. The irrigation infrastructure includes flood protection embankments and a dense network of irrigation canals, which cover more than 90% of the ecozone. Rice production in this ecozone has intensified steadily since the early 1990s. Meanwhile, the rice growing area has remained relatively stable since the early 2000s.

Between 1990 and 2000, the Vietnamese government planned and constructed new dikes and embankments in the upper Mekong Delta to control flooding and increase rice productivity by facilitating two or three crops per year. New irrigation and flood control infrastructure resulted in the planted area of floating rice decreasing by 80% between 1975 and 1994. Since this time the area of irrigated rice has increased from 35,000 ha to 175,000 ha. In 2009, around 45% of the planted rice area in An Giang Province had a rice cropping pattern of eight crops every three years—one year with double rice cropping, followed by two years of triple rice cropping in three consecutive years (An Giang Statistical Office 2011). By 2010 the provincial government was expecting to intensify production further forecasting that 40% of the rice area in the province would produce three crops per year (Kakonen 2008).

The other crops found in this ecozone are fruits produced in orchards by smallholders in the central part of the Mekong Delta (Xuan and Matsui 1998).

### Important areas and habitats

The majority of this ecozone is located in the central part of the delta at higher elevation and not subject to saline water intrusion. As a result, this ecozone is well suited for agriculture with secure water supplies and fertile soils (Le Coq et al. 2004). Soils in this ecozone are alluvial in nature and dominated by the Gleysol type with limited sulfur toxicity (less than 25% of the ecozone area).

### Cropping systems

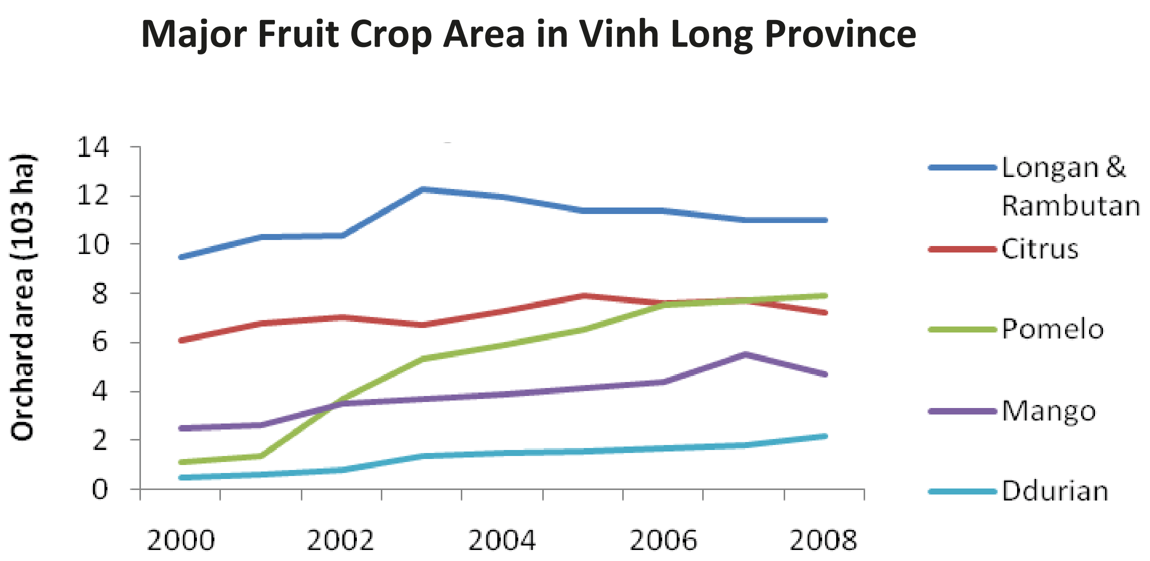
As rice production in the ecozone has intensified, rice production systems have shifted from a flood-prone rainfed system to a flood-protected, irrigated cropping system. As a result, the rice crops cultivated in much of the ecozone are no longer flood tolerant anymore and thus dependent upon flood control. In these areas three rice crops are cultivated per year. While flood control systems are able to protect the rice fields from flooding for the entire year, annual siltation and thus fertilization by sediment deposits is reduced, increasing the need for chemical fertilizers (Howie 2011). In the case of triple rice cropping, the succession of crops is as follows:

- Nov/Dec to Feb/March: Dry Season crop (Winter–Spring crop);
- March/April to June/July: Early Wet Season crop (Spring–Summer crop); and
- June/July to September/October: 2nd Wet Season Crop (Summer–Autumn crop).

In some areas, an early flood protection system has been developed to protect the rice crop during the early flooding periods reducing the risk of crop damage or loss during the harvest of the second crop in July/August. In these areas only two rice crops per year are possible—a dry season crop followed by an early wet season crop from April/May to July/ August. During flood periods, farmers can harvest one crop of aquatic vegetables (e.g., water mimosa or water lettuce) or fish/prawns/crabs.

Direct broadcasting of High Yielding Rice Varieties is now the main technique used. The crop duration is 88 to 95 days per crop, for a yield ranging from 4.5–5.5 tonnes/ha for wet season crops and from 6.0–7.0 tonnes/ha for dry season crops. Maximum water use occurs during the dry season. In the case of orchards, production occurs in raised beds with connected parallel canals in between. The main fruits cultivated in this area are mango (*Mangi feraindica*), longan (*Dimocarpus longana*), rambutan (*Nephelium lappaceum*), citrus (orange – Citrus *sinensis* and mandarin – *Citrus reticulata*), pomelo (*Citrus grandis*) and durian (*Duriozi bethinus*). In Vinh Long, the cultivated area of fruit grew more than 7% per annum between 2000 and 2008 reaching 33,000 ha (Figure 12).

**Figure 12: Cultivated area of major fruit in Vinh Long Province 2000-2008 (Source: General Statistic Office of Vietnam)**




## Trends, threats and opportunities

As noted above, this ecozone is generally not yet affected by saline intrusion. However, in the future as the possibility of SLR grows, some areas (closest to the coast line) might be affected by salinity intrusion in the dry season from January to April. Such a change will require the use of saline-tolerant rice varieties or a reduction in rice production from three to two rice crops per year. Without saline-tolerant varieties, rice yields could decrease by almost 50% in the case of mild saline water intrusion (less than 4 ppt) (Ayers and Westcot 1985). In addition, there is a risk that an increase in the cultivated area during the dry season will result in a lack of water to irrigate crops; particularly if the river flow is reduced.

During the rainy season from September to November, extreme flood events can flood the polders damaging rice crops. Increased incidence of flood may pose particular risks to agricultural producers in the region without adaptation.

Orchard production systems are found outside deeply flooded areas and perversely may be more at risk due to the effects of SLR and increased saline intrusion.

## 4.8 DELTA PEAT SWAMP FOREST

### 4.8.1 Farming Systems Profile

#### Important species

This ecozone is dominated by rice culture supplemented by some areas of sugarcane and pineapple production. These cash crops tend to be dependent on market demand and production areas can vary from year to year.

#### Important areas and habitats

This ecozone is characterized by shallow and deep acid sulphate soils with more than 60% of the ecozone subject to soil sulfur toxicity. This constrains agriculture production in some lowland areas. The development of irrigation systems in these areas has led to the oxidation of acid sulphate soils. Leaching of these soils during the rainy season can cause acidification of the canal water and increased incidence of aluminum and ferric toxicity in the soils (Tuong et al.2003). Most of those lowland areas were previously deeply flooded swamps or flooded forests of *Melaleuca sp*. Therefore, this zone is prone to flooding and farming systems have had to adapt to local constraints associated with this seasonal flooding and soil acidity.

This area also includes a buffer zone between saline and freshwater environments. Saline water intrudes from January to April creating a brackish water environment that influences the types of agriculture that is practiced. Irrigation covers 90% of the ecozone.

#### Cropping systems

The rice cropping system found in this ecozone is similar to the *Delta Freshwater Swamp Forest* ecozone with both double and triple rice culture.

However, the presence of acid soil requires specific technical skills for irrigation management and acidity control. Rice can tolerate acidity to 4.5 pH. Below this threshold rice culture is strongly affected (Sys et al. 1993). Pineapple can grow in soil where pH is as low as 4, but requires more than 600 mm of rainfall with an optimum range between 1,000 and 1,600 mm (Sys et al. 1993). Pineapple is a perennial crop and farmers renew the crop after harvesting fruits for 2–3 years.

In brackish water areas of the ecozone, a rotational rice-shrimp culture is possible and is becoming more popular among farmers. Shrimp culture (*Penaeus monodon,* and *Penaeus vannamei* to a lesser extent) is practiced in the rice fields during the dry season when irrigation is impeded by saline water intrusion. After the shrimp harvest in May/June, the salinity is flushed with the first heavy rain and a rainfed rice crop is grown from August to December (Joffre and Bosma 2009).

### Trends, threats and opportunities

In both Long An and Kien Giang Provinces, the rice culture area has been relatively stable since 1995, with around 250,000 ha and 278,000 ha of dry season rice in each province respectively. During the same period, the area of the second rice crop increased slightly from 172,000 ha to 201,000 ha in Long An Province and 267,000 ha to 282,000 ha in Ken Giang Province. Between 2000 and 2010, rice yields also improved from 3.5 tonnes per ha to 4.7 tonnes per ha in Long An Province and 4.2 to 5.5 tonnes per ha in Kien Giang Province (General Statistic Office of Vietnam 2012).

Sugarcane cultivation is driven by market prices and the cultivated area depends on the market more than the local environment. For example, sugarcane cultivation in Long An has fluctuated from 11,000 ha in 1993 to 15,000 ha in 2003 and more recently 13,000 ha in 2010. In Can Tho Province a more dramatic decline has been observed from 28,000 ha in 1995 to 13,000 ha in 2010.

The alluvial *freshwater* area of the ecozone is prone to flooding and as such can be affected by saline water intrusion. Saline water intrusions are common in Kien Giang, Bac Lieu and Ca Mau Provinces. In these provinces, salinity control infrastructure (embankments and sluice gates) have been developed along the delta to protect rice crops in the freshwater area. With increasing SLR (World Bank 2011), this ecozone will be more affected by saline intrusion possibly requiring a shift in the cropping system and cropping calendar and a switch to brackish water aquaculture.

In addition to saline water intrusion, the SLR will affect the duration and amplitude of the flood. Extreme flooding events or early flooding in August has been known to affect the harvest of the second wet season rice crop. Rice production will be affected through excessive flooding in the tidally-inundated areas and through longer flooding periods. These adverse impacts could affect all three cropping seasons (Wassmann et al.2004)

## 4.9 DELTA MANGROVES AND SALINE WATER

### 4.9.1 Farming Systems Profile

#### Important species

In contrast to other ecozones in the delta, most of the rice crop in this ecozone is rainfed—sometimes in rotation with a shrimp crop. Early wet season and dry season crops are not as common. Sugarcane is the main cash crop and is usually cultivated in elevated areas and/or acid soils.

#### Important areas and habitats

This ecozone is characterized by seasonal saline water intrusion due to a general lack of flood control infrastructure. The cropping calendar employs a saline or brackish water phase during the dry season from December to June/July and a freshwater phase from July/August to November/December. Soil types are dominated by Gleysol and Fluvisol soils with some saline and acidic layers (less than 30% of the ecozone area contains sulfur toxicity). As a result, these areas are less fertile than the alluvial fresh water areas of the delta.

## Cropping systems

Rice culture in this ecozone is mostly based on a rotational rice-shrimp system, with rice culture from August/September to December/January and one or two shrimp crops from January/February to June/July. The rice variety used in this area needs to be saline tolerant. Generally, tolerance is limited to a salinity level of 4 ppt (Ayers and Westcot 1985). Above this level, the rice culture is impeded and a shift to brackish water aquaculture is required.

Rice yields are generally lower than in other parts of the delta due to the use of low-yielding traditional rice varieties and the salinity intrusion. Yields range from 3.5 tonnes per ha in Ca Mau to 4.1 tonnes per ha in Tra Vinh (FAO 2007). When the plots can be protected from saline water intrusion and fresh water is available, double rice culture is possible with a dry season crop followed by an early wet season crop.

Sugarcane is grown in monoculture as an annual crop with planting in the early wet season (April–May) and a growth period of about 10–14 months.

## Trends, threats and opportunities

Since the early 1990s, rice culture has faced competition from aquaculture development with the spread of shrimp farming. Between 2000 and 2009 the planted area of rice decreased by 6.2%, 0.2% and 2.5% per annum in Ca Mau, Tra Vinh and Ben Tre respectively. With the introduction of shrimp farming driven by market demand and high prices (Vo 2003), rice culture has become less attractive to farmers. Continuous shrimp monoculture could pollute soils and the water environment, which could eventually undermine shrimp production systems. Rotational rice-shrimp systems may prove to be more sustainable over the long term.

# 5 CROP TOLERANCE AND GROWTH CONDITIONS

## 5.1 RUBBER

This crop is found mostly in *High-, Mid- and Low-elevation* ecozones, but with some restrictions in dry broadleaf forest due to lower average rainfall. It is not found in the *Floodplains and Delta* ecozones. For rubber, optimal growth conditions are within 27°C and 28°C with average annual rainfall between 1,250 and 4,000 mm. Rubber requires deep, well aerated and structured soil. According to Johnston et al. (2012), new rubber plantations in Northeast Thailand and Lao PDR are more constrained in terms of rainfall and yields are lower compared to more traditional plantation areas. Rubber's minimum temperature for optimal growth is 20°C. In Lao PDR, eastern Cambodia and the Central Highlands the main constraint is low temperatures below this optimum. Cold-tolerant varieties are best suited in these areas.

## 5.2 COFFEE

Coffee is found in *High- and Mid-elevation* ecozones, with adequate rainfall and average temperatures. The main restriction in these areas is the presence of adequate soil characteristics. Like rubber, coffee (*C. canephora*) cultivation requires deep, well aerated and structured soil. Optimal growing temperature ranges between 20°C and 30°C, while annual rainfall requirements are between 1,000 and 2,500 mm per year. The trees tolerate a drought of 21–30 days, while with too much rainfall the plant tends to develop wood at the expense of flowers and fruits. One to two months of less than 50 mm rain facilitates uniform flowering, while heavy rain during and after harvest is not desirable. The maximum altitude for coffee is 1,300 m, which can be a constraint in the *High-elevation* ecozone.

## 5.3 RICE

Rice culture is suitable in all the ecozones. The traditional shifting cultivation system is based on natural fertility of the soil and no or low inputs are used by farmers.

Upland rice is found mostly in the *High- and Low- elevation Moist* ecozones and enjoys monthly rainfall ranging between 100 to 650 mm per month (Sys et al.1993). Lowland rainfed rice requires about 200 mm of rainfall per month and a minimum temperature of around 15°C (Yoshida 1981). Rainfed rice is highly sensitive to drought and a lack of rainfall during the second half of the vegetative stage can greatly affect rice production.

In the floodplain environment, which is seasonally flooded, the growing conditions are more specific. Rice varieties are tolerant to anoxia and flooding. The level of tolerance and the growth characteristics depend on the species of rice.

Optimum soil pH is between 5.5 and 7.5. Precipitation during the growth cycle needs to be between 100 to 750 mm per month. Outside these limits, rice yield can be affected. Water stress during flowering can affect the crop yield of more than 50% depending on the stress severity.

Traditional rice, grown in flooded areas with photoperiod varieties and a long cycle (180 days), is usually cultivated without any inputs (fertilizers, pesticides or herbicides). These varieties are still popular in the Cambodian floodplain. Short-term varieties are commonly used in irrigated areas and involve the use of fertilizers, pesticides and herbicides. In brackish water environments, the tolerance to salinity for rice culture is limited to 4 ppt (Ayers and Westcot 1985). Above this level, the rice culture is impeded.

## 5.4 CASSAVA

Cassava is found in almost all ecozones within the LMB, but dominant in *Mid- and Low-elevation* ecozones with a larger presence in Northeast Thailand and the Central Highlands (*Mid-elevation Dry Broadleaf Forest* zone) as well as *Low-elevation Moist Broadleaf Forest* in Cambodia (Figure 5).

Cassava is a robust crop, well suited to sandy soils and areas with high rainfall variability. Optimal growing temperature is between 20°C and 29°C and optimal rainfall is between 1,000 to 1,500 mm per year (Ecocrop 2012). In the northern part of the LMB, low temperatures might be a limiting factor and cold tolerant varieties may perform better. Rainfall can also be a limiting factor. For example, the dry zone in Northeast Thailand is not particularly well suited for cassava cultivation due to low rainfall. Despite low suitability and yields, strong demand and high prices have resulted in Northeast Thailand remaining one of the main cassava production areas in the LMB.

## 5.5 MAIZE

Maize is found in most all ecozones across the LMB, but is most prevalent in *High- and Mid-elevation* ecozones and some specific points in the *Low-elevation* and *Delta* ecozones (Figure 6).

According to Johnston et al. (2012), the suitability of maize in the region is highly dependent on precipitation. Optimal rainfall is between 500 and 1,200 mm per year. One of the main constraints for maize producers is its poor tolerance to drought. As a result, low soil water storage can result in low yields. The optimal temperature range of maize is between 18°C to 32°C. Temperatures at or above 35°C are considered inhibitory. Yield reductions are observed for each day spend above 30°C and this effect is exacerbated under drought conditions (Lobell et al. 2011). Maize can grow with as little as 300 mm but with a 40% to 60% lower yield compared to optimum conditions. The growth cycle in this region is about 125 days, starting around May (Belfield and Brown 2009). Maize is relatively well adapted to a wide range of soils but prefers fertile, well-drained loamy soils. The sandier soil in Northeast Thailand results in a lower yield compared to northern Thailand or Lao PDR.

## 5.6 SUGARCANE

Sugarcane is found in *Mid- and Low-elevation Dry Broadleaf Forest* ecozones mostly in Northeast Thailand (Figure 9). Rainfall requirements are restrictive, with more than 1,300 mm or 110–180 mm per month required during the growing period. These rainfall requirements can be constraining in several ecozones (such a *Low-elevation Dry Broadleaf Forest*) if irrigation is not possible. Temperature can also be a constraint. Optimal growing temperature is between 24°C and 32°C.Very little growth occurs under 20°C and above 34°C (Sys et al. 1993). Sugarcane has a growth cycle of about 280 days in this region, but the growth cycle can exceed 14 months. Sugarcane is relatively tolerant to saline and acid soil and prefers well-drained, well-structured and aerated loam that is more than 1 m deep to clay soils. Coarse and fine textured soils can be problematic.

## 5.7 SOYBEANS

Soybean is found mostly in the *Low-elevation* ecozone and to a lesser extent in the *Mid-elevation* ecozone. The optimal temperature for soybean growth is 20°C to 30°C. Temperatures of 35°C and above limit growth. Early wet season crops might be affected by high temperatures (above 38°C) in March/April.

Soybeans can grow to maturity (90–120 days) with as little as 180 mm of in-crop rain, but this would reduce yield by 40% to 60% compared with optimal conditions. The ideal rainfall for soybeans is 500–1,000 mm. Drought (more than 5 days without rain) can cause plant death and reduced yields. Rainfed crops require planting during the main wet season, from the end of June, and harvesting in July/August. Planting dates should be chosen to avoid the wettest month during harvest. When irrigation is available, a dry season crop is possible from March to May. Soybeans prefer fertile, well-drained, loamy soils. Soybeans are not well suited to sandy soils or soils with low water storage capacity, such as gravelly or shallow soils.

## 5.8 ADDITIONAL PERENNIAL CROPS: LITCHI, MULBERRY, TEAK AND EUCALYPTUS

Litchi (*Litchi chinensis*) requires 1,000 to 1,700 mm of rainfall per year and temperatures between 20°C to 35°C with a chilling period (20°C to 22°C) before flowering. Litchi trees can grow at up to 2,000 masl, but the optimum elevation is at 300 masl. The tree is sensitive to strong winds. But the main threats are lower temperatures in winter and higher temperatures shifting the blooming period to later in the year.

Mulberry trees (*Morus alba*) are used as feed for silk worms and silk production and also timber. Rainfall requirements are between 700 and 2,500 mm per year. Optimal temperature ranges between 20°C to 28°C. Mulberries grow better in a well-drained neutral soil; preferably a deep loam. Shallow soils are not recommended. The tree is considered susceptible to drought.

Teak trees (*Tectona grandis*) grow in areas with 1,200 to 3,000 mm of rainfall and deep soils. The trees have been known to withstand a dry season of 4-6 months. Optimal temperatures are between 22°C to 32°C. Plantations can last between three and 60 years in areas below 1,200 masl. The trees tolerate mild frost, but young trees need to be protected from high winds.

*Eucalyptus globulus* is a widely used species for plantations. Optimal rainfall is between 700 to 1,500 mm per year. Optimal temperatures range between 14°C and 23°C. The trees prefer well-drained and deep soil with good water holding capacity. The growing period is short—between 5 to 15 years.

# 6 RICE CULTURE IN THE LMB, DIVERSITY OF PRACTICES

## 6.1 IRRIGATED AND RAINFED RICE

Rice is cultivated in the LMB in many different conditions. We distinguish between rainfed and irrigated rice. However, the boundary between these two systems can be unclear as described in Jonhston et al. (2012).

Rainfed agriculture is defined as "*agricultural systems that are not irrigated and rely solely on rainfall (both directly and indirectly as stored soil moisture) for their water supply*" (Johnston et al. 2012). These systems are sensitive to climate variability and even if the amount of rainfall in the year is often adequate, rainfed systems are affected by intra- and inter-season variations in rainfall that can generate drought and water stress for crops.

In the LMB, more than 75% of the paddy rice cultivated area is rainfed. The rest of the production is irrigated. However, the level of irrigation varies encompassing fully irrigated, irrigated by supplementary systems, and other types of additional rainwater storage techniques such as bunds or reservoirs. However, even in irrigated systems a significant proportion of the water demand for the rice crop is provided by rainfall.

In drawdown areas, receding rice culture takes advantage of residual moisture from the wet season. This system is popular in Cambodia's floodplain where the rice is planted after the water recedes from December to January and harvested later in the dry season. Similar conclusions can be made with early rainy season rice, which uses a large amount of rain water.

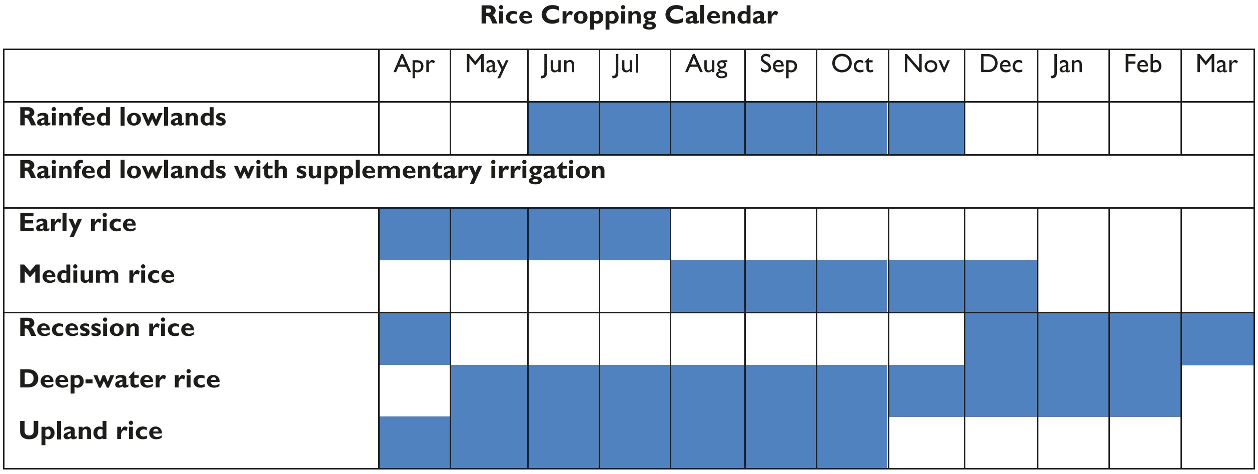
In northern Thailand most of the irrigated area is used in the rainy season as supplementary irrigation while dry season crops account for only 10% to 15% of the irrigated area (Johnston et al. 2012). In Lao PDR, 40% of the total irrigated area corresponds to land irrigated only during the rainy season (or supplementary irrigation). The irrigated area in the dry season corresponds to 60% of the total irrigated area.

## 6.2 CROPPING CALENDAR

The cropping calendar for rice culture across the LMB depends on irrigation facilities, rainfall, and flooding. An example of this diversity is presented in Figure 13.

The upland rice calendar is generally found in *High- and Mid-elevation* ecozones in Lao PDR and the Vietnamese Central Highlands. Rainfed lowland rice, with or without irrigation, is found in almost all ecozones, while recession rice is found in *Floodplain* and *Tonle Sap* ecozones.

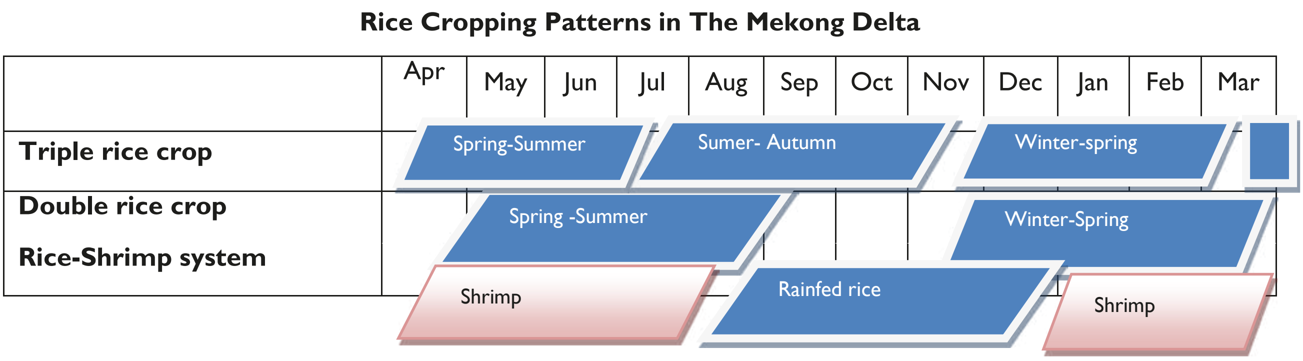
**Figure 13: Different rice cropping calendars**




Deep-water rice is a type of lowland rainfed rice that was a traditional crop in the Cambodian floodplain and cultivated in lowland areas.

In the Mekong Delta, where irrigation is well developed, rice cropping patterns are double or triple rice crop or rotational rice-shrimp systems (Figure 14). Double and triple rice cropping can be found in the *Freshwater Swamp Forest* and *Delta Peat Swamp Forest* ecozones, while the rice-shrimp system is found in the *Delta Mangroves and Saline Water* and *Delta Peat Swamp Forest* ecozones in areas not protected against saline water intrusion in the dry season. Differences between cropping intensity depend on flood protection systems and protection against saline water intrusion. In some cases, one rice crop can be replaced by a commercial crop (watermelons or vegetables) in the case of triple rice cropping. In recent years, more variable rainfall patterns and a need to save on the pumping cost of irrigation, have prompted farmers in irrigated areas to shift their calendar toward an intermediary calendar with both dry season and rainy season crops in between the season. The dry season crop will be shifted a few weeks to benefit from the early rain at the end of the crop. The rainy season crop start later and benefit from the early dry season at the end of crop for a higher yield. Both of the crops use supplementary irrigation (R. Lefroy, pers. comm.).

**Figure 14: Main rice cropping calendar in the Mekong Delta.**



## 6.3 RICE YIELDS

Rice yields vary across ecozones and countries according to many different factors, including climate, soil, cropping patterns, and rice varieties. In the text we described the rice yield for each ecozone as well as the rice yield variation within each ecozone. In Table 4, we summarize these examples for each ecozone.

**Table 4: Rice yields in different ecozones. Range of rice yield based on provincial statistics in 2010 for Cambodia, Lao PDR, and Vietnam, and 2006 for Thailand provinces**

| | Upland Rice (t/ha) | Lowland Rice (t/ha) | Irrigated Rice (t/ha) |
|---|---|---|---|
| **High-elevation Moist Broadleaf Forest**[a] | 1-2.5 | 3.7-4.6 | 3.8-4.5 |
| **Mid-elevation Dry Broadleaf Forest**[b] | 1-2.5 | 1.7-3 | 4.6 |
| **Low-elevation Dry Broadleaf Forest**[c] | - | 1.7-2.7 | 3-4.7 |
| **Low-elevation Moist Broadleaf Forest**[d] | - | 3.1-4.3 | 3.5-5.3 |
| **Tonle Sap and Lowland**[f] | - | 2.7-2.9 | 4.1-4.3 |
| **Mekong Delta Freshwater**[g] | - | - | 4.5-7 |
| **Mekong Delta Peat Swamp**[i] | - | - | 3.5-5.5 |
| **Mekong Delta Coastal**[j] | - | 3.6 -4.6 | - |

a) Phongsaly, Hoauphanh, and Lam Dong Provinces; b) Chaiyaphum and Gia Lai Provinces; c) Battambang, Sa Kaeo, and Nakhon Phanom Provinces; d) Khammouan Province and Vientiane Prefecture; e) Bokeo, Ubon Ratchathani, Roi Et, Champasak and Stung Treng Provinces; f) Kandal and Prey Veng Provinces; g) An Giang and Vinh Long Provinces; i) Kien Giang, Long An Provinces; j) Ben Tre, TraVinh, and Ca Mau Provinces

Upland rice has a lower yield compared to lowland rainfed and irrigated rice. Low rice yields in the *Low-elevation Dry Broadleaf Forest* ecozone reflect low soil fertility in Northeast Thailand. In the *Tonle Sap & Floodplain* ecozone, low rice yields reflect poor soil fertility and traditional rainfed practices using traditional deep water varieties without many inputs. In the Mekong Delta, yield differences in irrigated rice can be observed between the *Mekong Delta Peat Swamp* and *Mekong Delta Freshwater* ecozones, which also reflect different soil conditions.

According to Mainuddin and Kirby (2009), economic and physical water productivity in rice culture is higher in Vietnam than in any other country of the LMB, showing that irrigation is more efficient in Vietnam. Northeast Thailand and Cambodia have the lowest water productivity.

Rice yields in the last 20 years have increased in all countries of the LMB. For example, in Lao PDR the average rice yield was less than 2.5 tonnes per ha in 1990 and reached more than 3.5 tonnes per ha in 2009. A similar trend can be found in Cambodia (Johnston et al. 2012).

Johnston et al. (2012) highlighted that yield improvements for all rice types (upland and lowland rainfed, and irrigated) are possible and that the yield gap is large; 3–4 tonnes per ha for upland rice and 10 tonnes per ha for irrigated. These yields can be only be achieved with careful water management and input management.

# 7 COMMERCIAL CROPS, YIELDS AND CROPPING PATTERNS

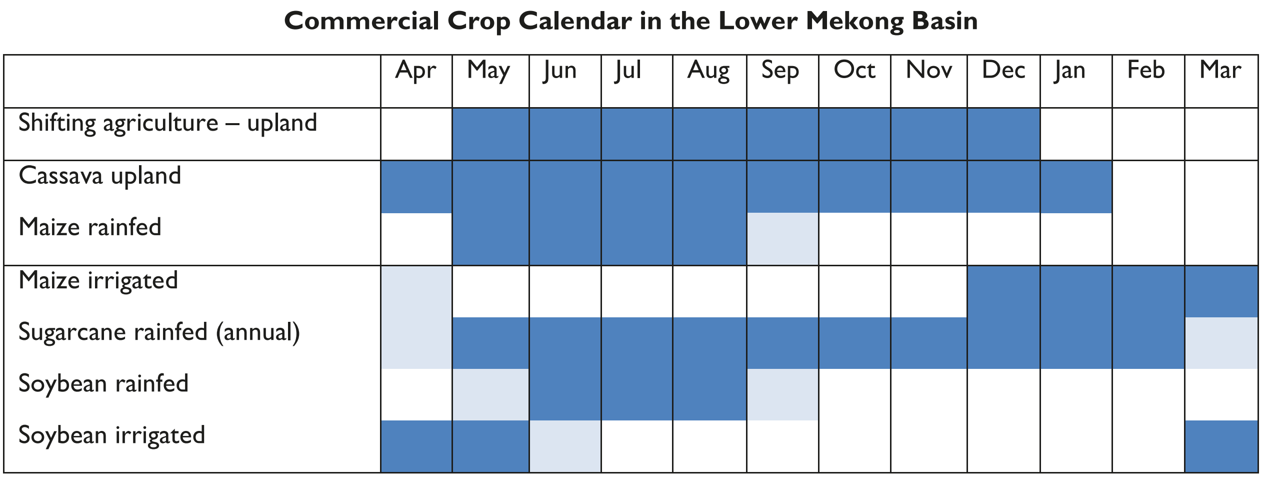
In this section, we summarize the review of cropping patterns and of the productivity of the different crops across the ecozones.

During this study, it was difficult to estimate the proportion of commercial crops that are irrigated. In some specific areas in northern Thailand sugarcane and maize are irrigated. Similar observations can be made about Cambodia and the Mekong Delta region in Vietnam. However, this is not reflected in the provincial and national statistics used in this study.

## 7.1 CROPPING CALENDAR

Figure 15 presents the cropping calendar for commercial crops across the LMB. Some differences between ecozones can be observed. However, most of those crops are rainfed and planting and harvesting seasons are within the period from May to November.

**Figure 15: Cropping calendar of the main commercial crops (except rice) in the Lower Mekong Basin**




Annual variability in the cropping calendar is triggered by the timing of the first rains. Choice of the cropping system is mostly based on access to irrigation and the choice of crops between soybean, maize, or sugarcane depends on market prices. However, in the case of irrigation, maize-rice or soybean-rice or early wet season rice followed by soybean or maize is possible. Both cassava and sugarcane are cultivated in monoculture. Considering their growing periods, no crop succession is possible in a year. In a rainfed situation, annual rotation of maize, cassava, or soybeans is recommended if possible for better soil management. Shifting agriculture includes several crops (upland rice but also maize or cassava) and starts with the clearing of the plots in the dry season.

## 7.2 CROP YIELD

In the following table (Table 5), the examples of crop yields for the different ecozones and main crops are presented. Crop yields are affected not only by the bioclimatic and soil conditions but also by farming practices. Also, the influence of the ecozones on major crop yields is reduced with new varieties (e.g., cold tolerant and drought tolerant), use of fertilizers, and other inputs such as access to irrigation.

**Table 5: Examples of crop yields in the different ecozones**

| | Maize (t/ha) | Soybean (t/ha) | Sugarcane (t/ha) | Cassava (t/ha) | Rubber (t/ha) | Coffee (t/ha) |
|---|---|---|---|---|---|---|
| **High-elevation Moist Broadleaf Forest**[d] | 4.5-5.2 | - | 55.8 | 4-17.5 | 1.-2[b] | 2[a] |
| **Mid-elevation Dry Broadleaf Forest**[e] | 1-3.3 | 1.4 | 60 | 4.5-22 | 1.-2[b] | 2[a] |
| **Low-elevation Dry Broadleaf Forest**[f] | 3.7-5 | 1.5-3.7 | 15-63 | 20-24 | 1[c] | - |
| **Low-elevation Moist Broadleaf Forest**[g] | 3.9-5.3 | 1.1-1.5 | 28-31 | 9-10 | 1-1.5 | - |
| **Mekong Delta Peat Swamp**[h] | 4.0-5.3 | - | 39-59 | - | - | - |

a) clean bean, source WASI; b) dry latex, source WASI; c) dry latex, source MAFF 2011. d) Phongsaly, Hoauphanh, and Lam Dong Provinces; e) Chaiyaphum and Gia Lai Provinces; f) Battambang, Sa Kaeo, and Nakhon Phanom Provinces; g) Khammouan Province and Vientiane Prefecture; h) Kien Giang and Long An Provinces.

*Low-elevation Dry Broadleaf Forest* ecozone has low yields for most crops due to poor soil fertility and drought. Cassava is generally a more favorable option in this zone as it is a robust species. The wide range of cassava yields in *Mid-* and *High-elevation* zones results from smallholder production and the shifting agricultural system. The cassava yield could potentially be higher than 25 tonnes/ha in some specific areas of the *Low-elevation Dry Broadleaf Forest* and *Low-elevation Moist Broadleaf Forest* ecozones.

Soybean yields are variable depending on climate and harvesting periods. Large differences are also found between countries with higher yields found in Northeast Thailand and in *Mid and Low Dry Broadleaf Forest* ecozones where more intensive methods are used.

Sugarcane yields vary by a wide margin depending on the availability of irrigation. Low yields are country specific with lower yields generally found in Lao PDR and Cambodia (around 30 tonnes per ha) than in Vietnam and Thailand (59 and 72 tonnes/ha respectively).

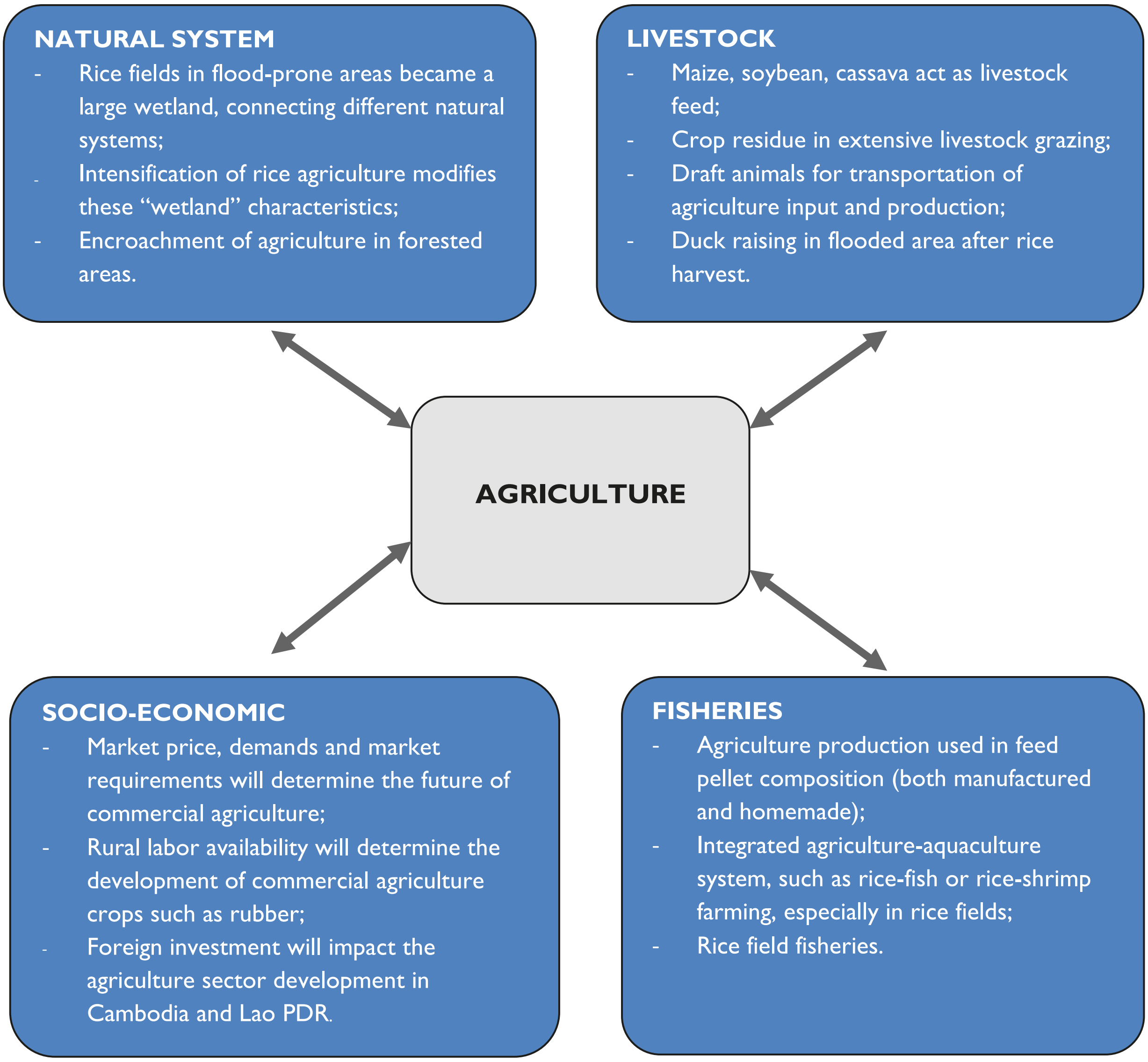
Coffee yields generally reflect the situation amongst Vietnamese coffee producers. Although average yields are around 2 tonnes/ha, the maximum potential yield in the two ecozones where coffee is mostly found (*High and Mid-elevation Moist Broadleaf Forest*) can reach a maximum of 6 tonnes/ha.

Rubber yields are generally lower in the *Low-elevation Dry Broadleaf Forest* ecozone due to the different practices used there. Higher yields are observed in Vietnam and Lao PDR, while the average yield is lower in Cambodia (1 tonne/ha).

# 8 LINKS BETWEEN AGRICULTURE AND OTHER SECTORS

Agriculture is a key productive sector in the LMB and interacts with a range of other sectors in the basin including livestock and fisheries. Developments in the agriculture sector also result in socio-economic outcomes and changes in natural systems that can feedback into and drive new developments in the sector. These interactions are summarized in Figure 16 and discussed briefly below.

**Figure 16: Links and interactions of agriculture systems with other sectors**



***Livestock and agriculture***

- Maize, soybean, and cassava are agriculture products that have a significant importance for livestock feed. Even if in subsistence and small-scale livestock farming, these crops do not have major significance at the basin scale, maize, soybean, and cassava are major components of livestock farming.
- Fallow periods both in lowlands and upland shifting cultivation systems provide grazing lands for large livestock. In Cambodia, a large area of the floodplain is used as grazing land for cattle in the dry season. In the meantime, livestock manure is used as an organic fertilizer. This includes manure deposited during grazing as well as manure collected in livestock barns for large livestock but also for pigs and poultry.
- Large livestock in agriculture are used as draft animals for transportation of inputs and harvest, but also for land preparation, even if this practice is less frequent with the spread of mechanic tillers.
- In flooded and irrigated rice fields, duck-raising is a common practice after the rice harvest in Cambodia and in the Mekong Delta. In addition, integrated rice-duck farming is also observed in rice plots as an Integrated Pest Management practice.

***Agriculture and fisheries (including aquaculture)***

- As for livestock, soybeans, maize, and rice bran are ingredients of pellets used in aquaculture. Rice bran is used both in small-scale low-input and high-input aquaculture farms in Cambodia.
- Integrated agriculture-aquaculture systems are found in the LMB mostly in the Mekong Delta, with rice-shrimp and rice-fish (or freshwater prawn) systems, depending on the water quality such as the presence or not of brackish water. A rice-shrimp system is an alternate system, with a rice crop followed by a shrimp crop, while rice-fish (and/or prawn) is a concurrent system, with fish culture benefiting from the rice field ecosystem. This practice requires special rice plots (ditches and fish refuges) and input management.
- Flooded rice fields are a favorable environment for fisheries and other aquatic animals. In Cambodia, the catch from these rice fields was estimated to be around 110,000 tonnes in 2008 (FiA 2010). A recent MRC study reported yields in Cambodia's rice fields ranging from 42–165 kg/ha/yr (Hortle 2007).

***Agriculture and Natural Systems***

- Flooded rice fields can be considered wetlands during the flood season. Wetlands in Cambodia are connected to a vast network, where fish and aquatic organisms can migrate, from the flooded forest to rice fields, deep pools and refuge ponds in the floodplain.
- However, intensification of agriculture and development of irrigation canals modifies this environment. The spread of Rice Intensification Technique, labeled SRI, modifies the ecosystem of the rice field, making it less favorable for aquatic organisms. In the meantime, use of chemicals such as herbicides and pesticides affect ecosystems and especially aquatic ecosystems.

- Monoculture affects the biodiversity of agro-ecosystems. In the region, the spread of industrial crops and especially coffee, rubber, eucalyptus, cassava, and cashew plantations has strongly encroached on forested areas in Cambodia, Vietnam, and now in Lao PDR.

***Agriculture and socio-economic component***

Besides socio-economic indicators, specific economic drivers will have a large influence on the agriculture sector in the LMB such as:

- Market demand and market prices for industrial crops such as sugar, soybean, maize, cassava, and rubber;
- Rural labor availability for industrial plantations, specifically for rubber plantations in Lao PDR;
- Foreign investment in industrial plantations in Cambodia and Lao PDR.

# 9 INSTITUTIONAL AND POLITICAL FACTORS

Agriculture in the LMB is rice based, with a large degree of diversity in terms of technique and cropping calendar. Current farming systems are mostly rainfed. Irrigated agriculture areas are found in the Mekong Delta mostly, Northeast Thailand, and the Cambodian floodplain. Recently, the agriculture sector, driven by regional and international markets has been shifting from subsistence farming to the production of commercial crops with the emergence of rubber, cassava, maize, soybean, and sugarcane production.

Conflict for water resources between sectors and wide differences in access to knowledge and agricultural inputs are observed throughout the LMB, from farmers in upland Lao PDR to Vietnamese farmers in the Mekong Delta. Conflict for land and the expansion of agriculture in new areas in Cambodia, the Central Highlands in Vietnam, and Lao PDR has now been observed with the emergence of commercial agriculture.

This review showed the diversity of cropping systems in various ecozones, from areas of high elevation to coastal zones and from rainfed subsistence systems without input to intensive triple rice cropping systems dependent on synthetic fertilizers and pesticides. Trends in agriculture show that the Central Highlands is already devoted to commercial agriculture with the expansion of maize, cassava, and rubber plantations and a mature coffee sector. Similar trends are now found in northern and central Lao PDR, with the influence of foreign investment from China, Thailand, and Vietnam. Cambodia shows an intensification of its agriculture where forest is being converted to cassava, soybean, or rubber plantations. However, new producers are not always large investors using contract farming. For example, most cassava production remains in the hands of smallholders.

The intensification of agriculture systems faces sustainability issues, with erosion and loss of fertility due to the use of monoculture. A changing climate and higher climate variability will increase the vulnerability of this dynamic sector. Not all the cropping systems will have the same vulnerability to increased temperature, increasing storms and extreme rainfall events, and high variability of rainfall patterns. Building more resilient and sustainable cropping systems will be necessary to allow the agriculture sector to grow.

# SECTION 2
# VULNERABILITY ASSESSMENT

- APPROACH AND METHODS
- CLIMATE SUITABILITY
- CROP YIELD MODELING
- CAM ANALYSIS
- CONCLUSION

# 10 APPROACH AND METHODS

After describing and analyzing the main agriculture production systems, we developed a vulnerability assessment of the main crops across the entire LMB using a combination of quantitative and qualitative methods.

The vulnerability assessment involved a three-step approach based on the climate modeling results of the Integrated Water Resources Management (IWRM) watershed model for the whole Mekong Basin, developed by the Environmental Impact Assessment Centre of Finland (EIA Ltd), MRC, World Bank, Aalto University, and ICEM. Climate modeling within the A1 climate scenario was used.

The climate modeling results were used as inputs for the three tools used to assess the vulnerability of the main crops within the whole basin. These tools are as follows:

- The Land Use Suitability Evaluation Tool (LUSET), developed by IRRI, was coupled to the IWRM model to assess the suitability across the basin for a range of crop species, including rainfed rice, soybean, maize, cassava, Robusta coffee, and rubber.
- The AquaCrop yield model, developed by FAO, was also coupled to the IWRM model to estimate the impact of climate change on rice and maize yields in eight locations (or "hotspots") across the basin.
- The vulnerability-adaptation CAM matrix was used in the eight hotspots across the basin to assess the level of exposure, vulnerability, and adaptation required for each crop, based on local and international expertise.
- As with the baseline section, the CAM assessment focuses only on the biophysical changes, threats, and opportunities to farming systems in the eight hotspot provinces. It does not account for political and institutional factors that could influence the climate vulnerability of agriculture in these hotspots.

The eight case study hotspots represent areas most exposed to changes in climate, including: Chiang Rai and Sakon Nakhon (Thailand); Champasak and Khammouan (Lao PDR); Mondulkiri and Kampong Thom (Cambodia); Gia Lai and Kien Giang (Vietnam).

## 10.1 CLIMATE SUITABILITY

To evaluate the possibilities for agriculture development within the catchment area, we used the LUSET model, which was developed by IRRI (CGIAR-CSI 2006) and previously used in Vietnam (Yen et al. 2006). The model is based on two input interfaces (or modules): the crop requirement module and the land unit information module. For each Land Unit (LU), the suitability of the area for growing particular crops is calculated using the unique characteristics of the land unit in question and the crop's specific requirements.

The output of LUSET consists of a table in which a suitability class is assigned for each LU by crop combination. In the second stage, each LU is geo-referenced in the catchment to enable GIS analysis.

Crop requirements are based on the predefined crop requirements found in Sys et al. (1993). These crop requirements are modified over time with local expert knowledge and other data and stored on the FAO Ecocrop database (http://ecocrop.fao.org/ecocrop/srv/en/home). For the purpose of this study the analysis is limited to climate suitability as there is no detailed soil survey of the LMB to accurately incorporate soil characteristics into the assessment. Climate characteristics used in the analysis included rainfall (average monthly and annual rainfall), temperature (average monthly and mean minimum temperature of the coldest month), and drought length (month where precipitation is below 50% of all potential evapotranspiration). In some cases, crop requirements were adjusted based on local expertise and a weighting was assigned to each of the factors for each crop according to its importance.

Each LU corresponds to a grid cell of 1 km x 1 km. The same parameters as for crop requirements were used, such as climate data (average monthly rainfall, average monthly temperature, etc.). For climate data, we used average monthly rainfall, annual rainfall, and the minimum and average monthly temperatures from the past 25 years.

The Integrated Water Resources Management (IWRM) watershed model for the whole Mekong Basin, developed by EIA Ltd, MRC, World Bank, Aalto University, and ICEM was used to generate the necessary climate data.

For each characteristic of the LU (i.e., temperature and water), the suitability class and weighting factors were combined to produce a suitability value ranging from 0 to 100 (Yen et al. 2006). Subsequently an *Overall Suitability Value* (OSV) (combining the temperature and water characteristics) was obtained after a two-step calculation and was then transformed into an *Overall Suitability Rate* ranging from 1 (not suitable) to 100 (highly suitable). The OSV was then categorized into seven classes of suitability that are described in Table 6.

Crops selected for suitability analysis were lowland rainfed rice (*Oryza sativa*), maize (*Zea mays*), cassava (*Manihot esculenta)*, soybean (*Glycine max*), rubber (*Hevea brasiliensis*), and Robusta coffee (*Coffea canephora*). Sugarcane (*Saccharum officinarum*) and other forestry species such as eucalyptus, mulberry, or teak were not tested due to a lack of data.

Table 6: Land suitability classes definition

| Suitability Classes | Definition |
|---|---|
| **0-10: Not suitable** | The crop cannot grow or complete its life cycle |
| **10-25: Marginal suitability** | There is a high risk of crop failure |
| **25-40: Low suitability** | Crop can grow but cannot achieve an average yield due to water and/or temperature constraint |
| **40-60: Moderate** | Slight constraint of temperature or water stress and optimum yield is not achieved due to non-optimal growth conditions |
| **60-75: Good suitability** | No water or temperature stress, but optimal conditions are not achieved and crops cannot achieve maximum yield |
| **75-85: High suitability** | No climate-related stress and almost optimum climate conditions throughout the cycle, leading to high yield if crop management is adequate |
| **85-100: Very high suitability** | Optimum climate conditions throughout the growth cycle leading to maximum achievable yield if crop management is adequate |

## 10.2 CROP YIELD MODELING

Climate suitability modeling was supplemented with crop yield modeling for both rice and maize. This modeling was based on the AquaCrop model developed by FAO coupled with the IWRM model. The model used daily projected climate data, including temperature and rainfall, from six global models and crop yield was calculated by integrating AquaCrop into the IWRM model. More detail on the crop modeling is provided in the Main Report for the USAID Mekong ARCC Climate Change Impact and Adaptation Study.

Rice and maize yield predictions were calibrated using the average provincial yield of the selected provinces (or hotspots). We present only the average crop yield modeling based on the six global models used.

## 10.3 CAM MATRIX

This approach is based on expert knowledge, where each crop was assigned a sensitivity level (very low, low, medium, high, and very high) for different selected threats[8]. The sensitivity level was based on a literature review. For each threat and crop, the sensitivity level is related to an exposure level, which is based on climate modeling in each of the hotspots. The combination of sensitivity and exposure gives the "Impact Level" of the crop for each threat. This Impact Level is then assessed against the adaptive capacity (based on expert knowledge) of the crop in question to derive the "Vulnerability Level" of the crop to a particular threat. This approach has been conducted for the main crops in all of the eight hotspots.

As with the baseline report, the CAM assessment focuses only on the biophysical changes, threats and opportunities to farming systems in the eight hotspot provinces. It does not account for political and institutional factors that could influence the climate vulnerability of agriculture in these hotspots.

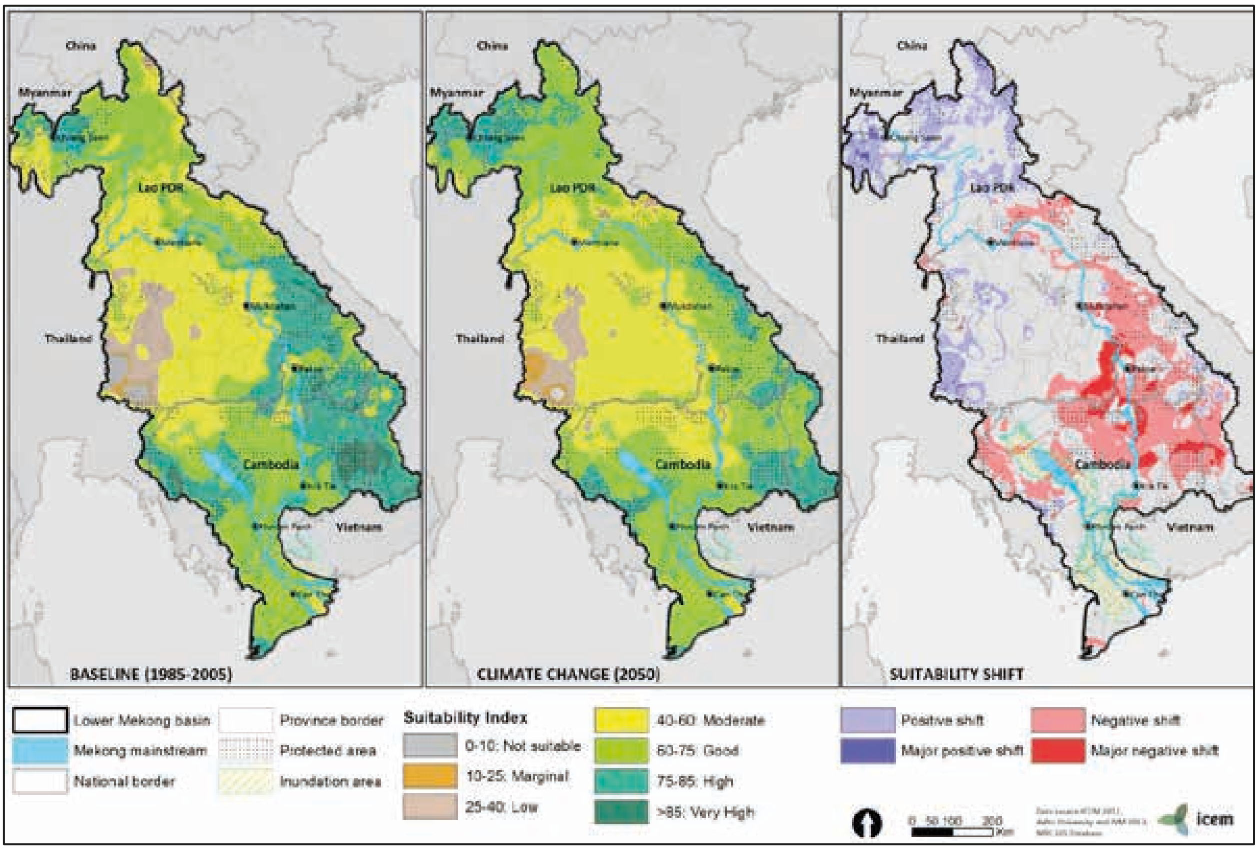
[8] Threats selected: increase of temperature; decrease of temperature; increase of precipitation; decrease of precipitation; decrease in water availability; increase in water availability; storm; flash flood; flood; increase in $CO_2$.

# 11 CLIMATE SUITABILITY

## 11.1 RUBBER

At present, rubber displays higher suitability in eastern Cambodia, the Central Highlands of Vietnam and southern Lao where large rubber plantations are already present (Figure 17).

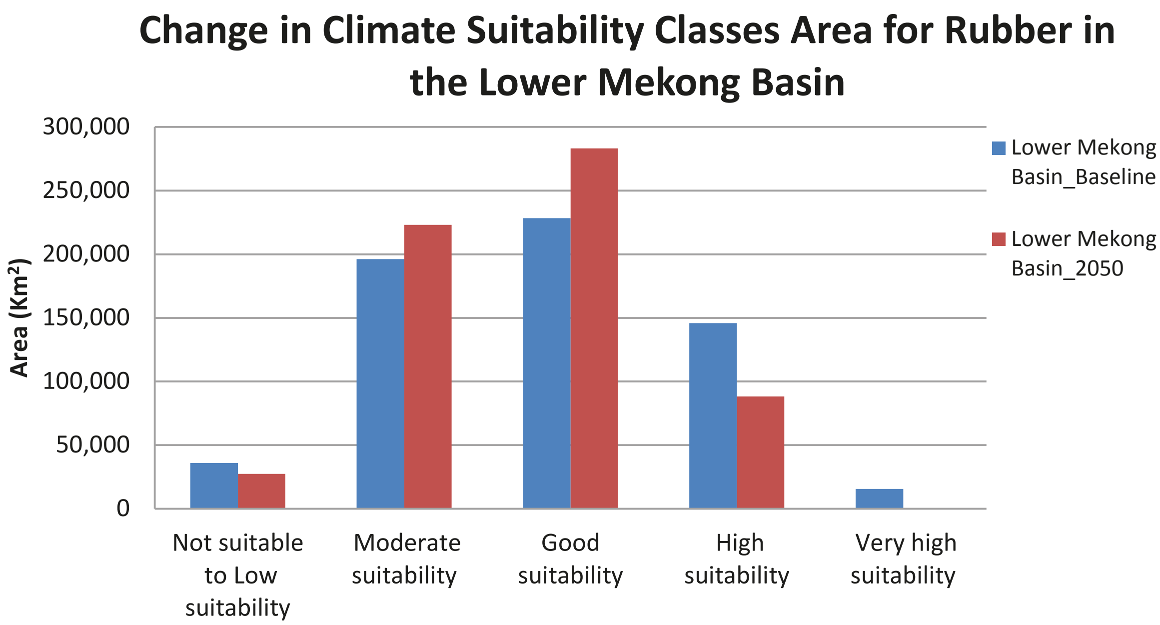
**Figure 17: Baseline and 2050 land suitability for rubber in the Lower Mekong Basin**




Northeast Thailand is less suitable for rubber due to drought and lack of rainfall. Cambodia and most of Lao PDR are suitable in terms of rainfall. As the model does not take in account floods or soil conditions the floodplains in Cambodia and in the Mekong Delta are also considered suitable for rubber plantations. In reality, these areas are prone to flooding and are not suitable for such culture. A significant portion of northern Lao PDR is also well suited to rubber culture although some areas are not suitable due to lower temperatures.

At the basin level and regarding climate suitability for rubber in 2050, the area of high and very high suitability will decline resulting in increased area of moderate and good suitability compared to the baseline (Figure 18). The area of high and very high suitability will decrease by 57,000 km$^2$ and 15,000 km$^2$ respectively.

**Figure 18: Change in climate suitability area from baseline to 2050 for the entire Lower Mekong Basin for rubber culture**




Major negative shifts are noted in Champasak (Lao PDR), Kratie (Cambodia), Preah Vihear (Cambodia) and Ubon Ratchathani (Thailand) Provinces with 1,000 km$^2$ to 5,000 km$^2$ of land moving from highly to moderately suitable.

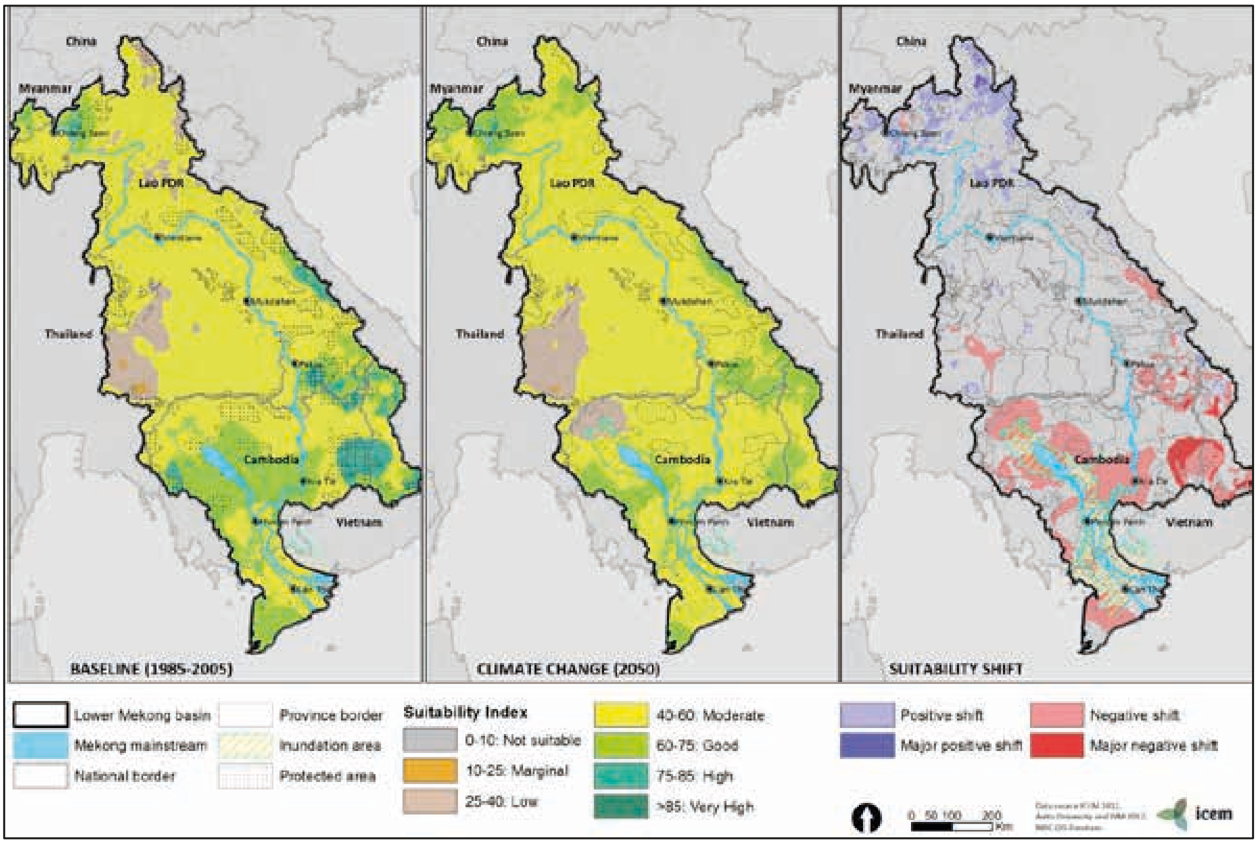
In 2050, projected increases in rainfall in central and southern Lao PDR and the Chi-Mun Rivers Basin in Thailand will lower the suitability of rubber crops in these areas. While overall suitability will remain good or high in eastern Cambodia and the Central Highlands, it is projected to be lower than present due to drought. Higher projected temperatures in northern Lao PDR and northern Thailand will result in improved suitability for rubber in these areas. While areas in North and Northeast Thailand that are currently prone to drought will see improved suitability from greater rainfall, increased rainfall in low- and mid-elevation ecozones in Lao PDR will result in slightly reduced suitability for rubber.

## 11.2 ROBUSTA COFFEE

Under current conditions, the area of highest suitability for Robusta coffee is found in the Central Highlands of Vietnam and the Bolaven Plateau in Lao PDR (Figure 19). A large part of the Cambodian floodplain, the Mekong Delta and the Cardamom Mountains also appear to be suitable for Robusta coffee. However, as noted above the model did not take in account flooding nor soil quality, which might be limiting factors for coffee culture in these areas as soil properties are very important in determining land suitability of coffee. Areas of low suitability are found in areas of low annual rainfall such as Northeast Thailand.

In 2050, changes in suitability vary across the basin. Positives changes are projected in northern Lao PDR, while negative changes are projected in eastern Cambodia (Mondulkiri and Ratanakiri Provinces), the Central Highlands of Vietnam, and the Bolaven Plateau in Lao PDR.

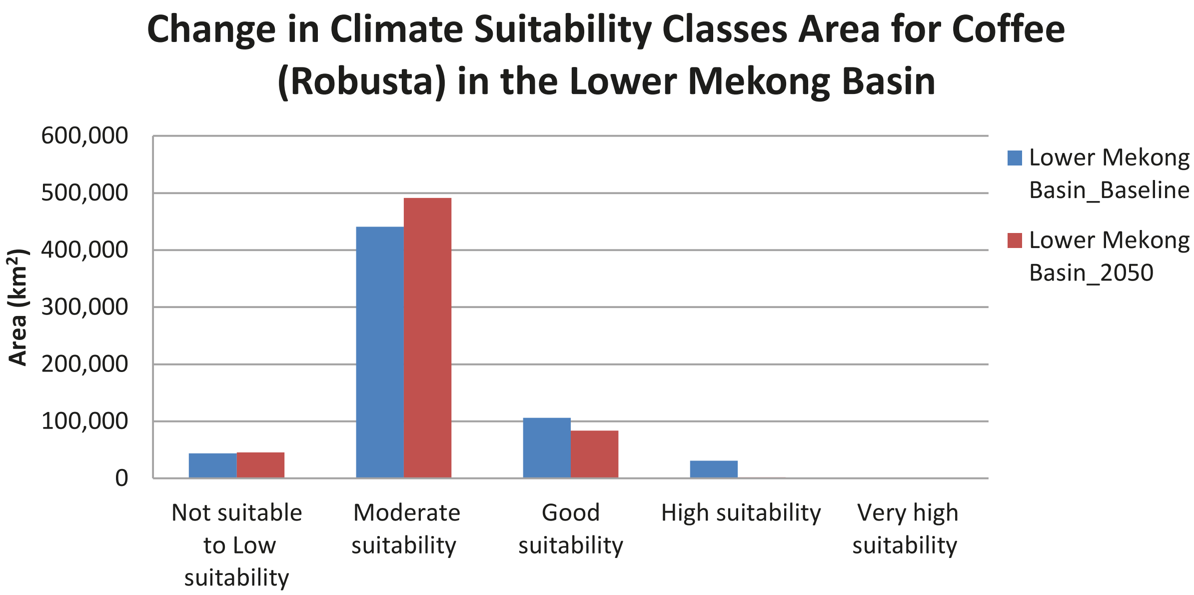
**Figure 19: Baseline and 2050 land suitability for Robusta coffee in the Lower Mekong Basin**




Specifically, projected changes in temperature and rainfall will increase suitability in areas of high elevation such as in northern Lao PDR. In contrast, more rain and warming in eastern Cambodia and the Vietnamese Central Highlands are projected to reduce the suitability of Robusta coffee culture in these areas, although they will continue to have moderately suitable growing conditions.

About 30,000 km$^2$ of very high and high suitability area for Robusta coffee, mostly in the eastern region of the LMB in Cambodia, southern Lao PDR, and Vietnam, are projected to shift to moderate suitability in 2050 (Figure 20). Areas of good suitability are projected to decrease by more than 20,000 km$^2$ in the same regions. Lao PDR is predicted to see the largest negative shifts in coffee suitability with a decrease of 9,000 km$^2$ of highly suitable land and 180,000 km$^2$ of land of good suitability.

**Figure 20: Change in climate suitability area from baseline to 2050 for the entire Lower Mekong Basin for Robusta coffee**




## 11.3 LOWLAND RAINFED RICE

The suitability of rice was found to be good, high, or very high across the LMB (Figure 21). However, the model did not take into account flooding and its impact on the rice crop and rice calendar. Therefore, deep water rice or recession rice are not accounted for in this analysis. Temperature suitability is homogeneous across the basin and only high elevation areas were found to have a lower suitability. In these areas, upland rice with tolerance to a cooler climate is cultivated. Higher suitability in Cambodia's floodplain and the Mekong Delta was found when the planting date is delayed until June.

In 2050, the land suitability will remain high across the LMB despite some negative changes predicted in Northeast Thailand. At the basin scale, more than 70,000 km$^2$ of land is projected to shift to the high suitability class, while the area of very highly suitable land is projected to decrease by 11,000 km$^2$.

Bolikhamxay and Xaisomoun Provinces in Lao PDR are projected to see a sharp shift of 1,000 km$^2$ of area with good suitability to the moderate class. In other parts of Northeast Thailand (Ubon Ratchathani; Amnat Charoen) highly suitable areas are projected to decrease by more than 8,000 km$^2$.

These negative shifts will be offset to some extent by positive changes in suitability in other areas. In Cambodia 36,000 km$^2$ is project to shift from good to high levels of suitability. In Lao PDR more than 19,000 km$^2$ will undergo a similar shift.

**Figure 21: Baseline and 2050 land suitability for lowland rainfed rice (planted date in May, 150 days) in the Lower Mekong Basin**

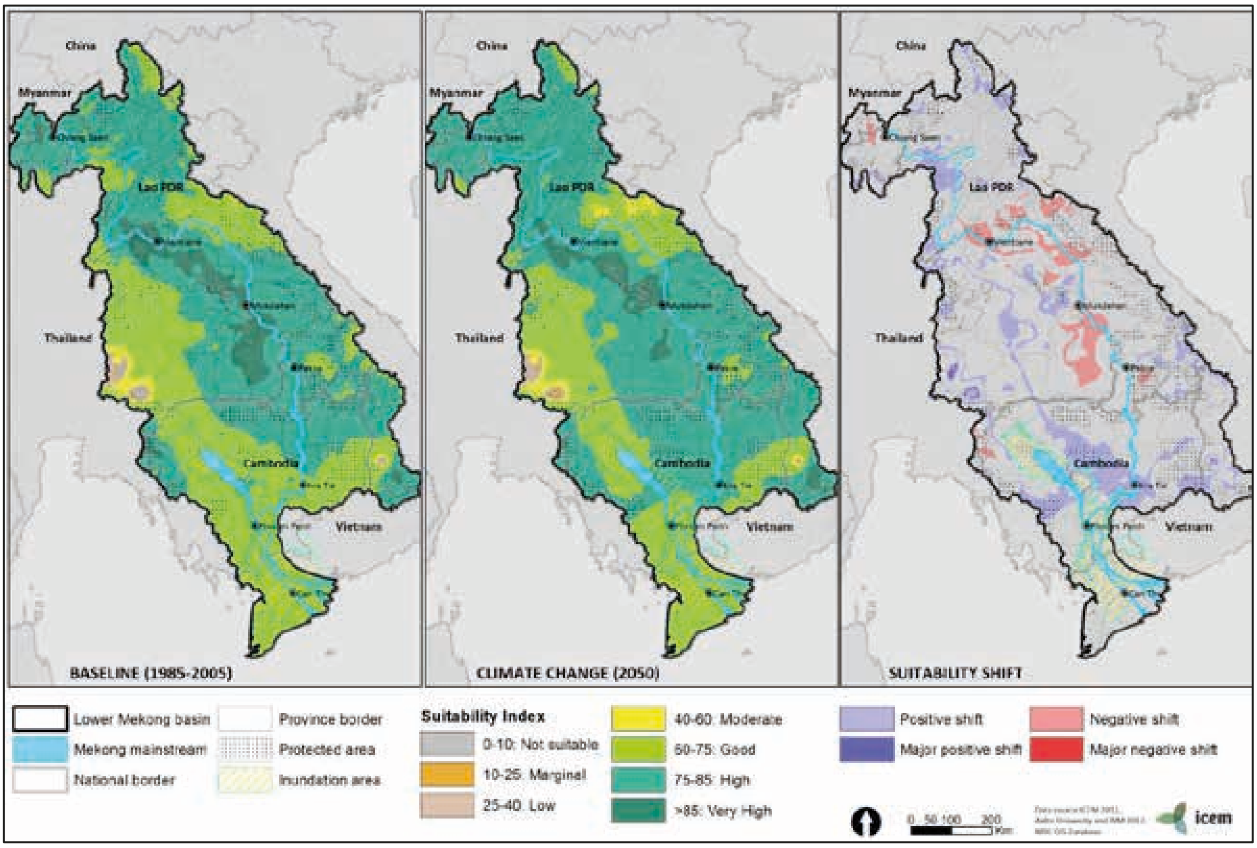
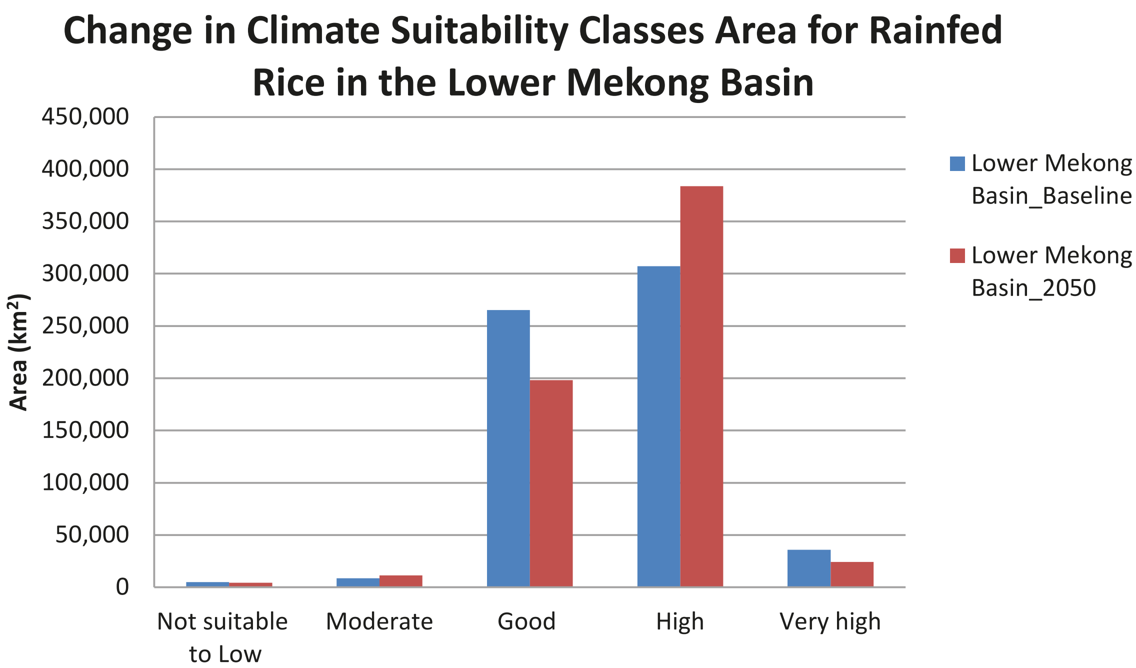



**Figure 22: Change in climate suitability area classes from baseline to 2050 for the entire Lower Mekong Basin for rained rice**

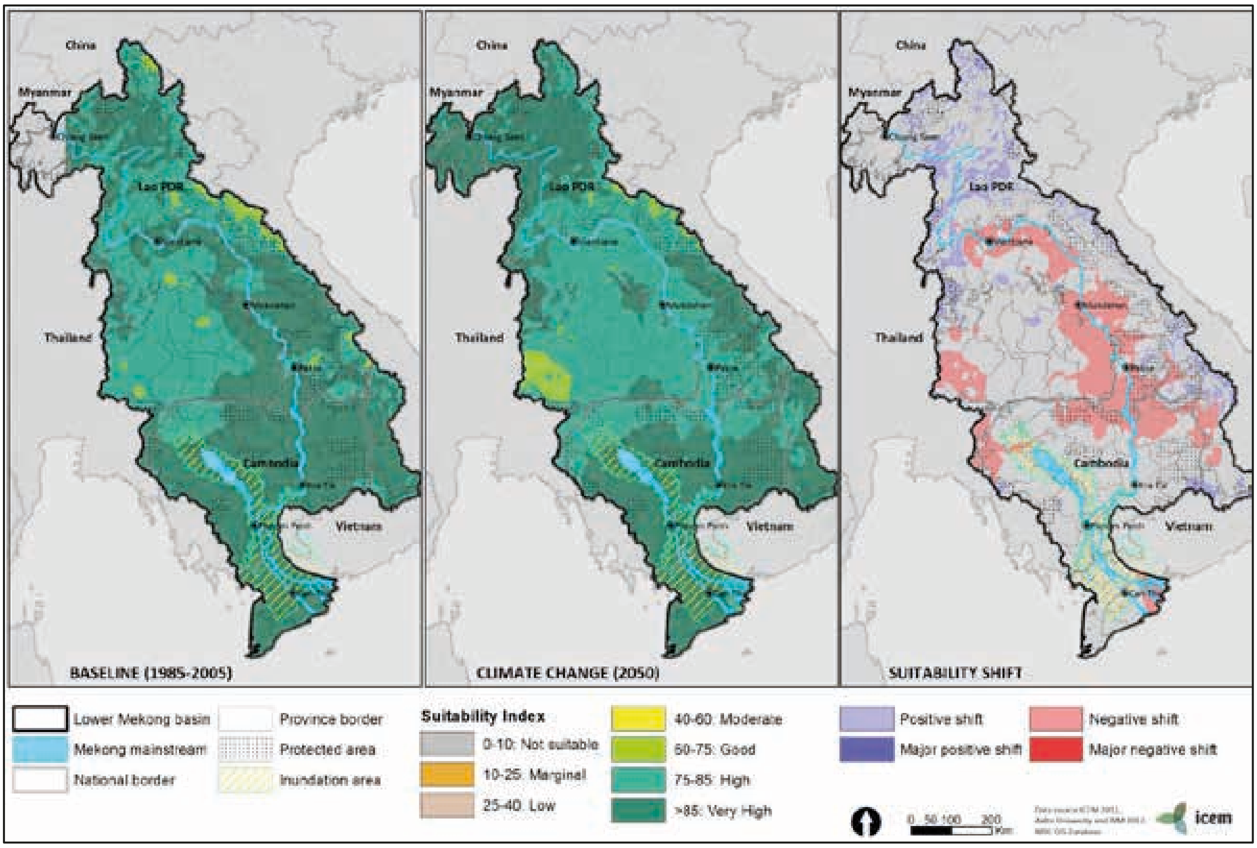


## 11.4 CASSAVA

Overall, cassava suitability in the LMB is high. Lower suitability is found in the Khorat Plateau due to low rainfall and long drought (Figure 23). Lower suitability is also found in high elevation zones such as the Central Highlands of Vietnam and northern Lao PDR, due to cold temperatures. Flood-prone areas in Cambodia and the Mekong Delta should also not be considered suitable for cassava. Provinces with high levels of yearly precipitation such as Bolikamxay and Champasack (Bolaven Plateau) in Lao PDR, are less suitable for cassava cultivation.

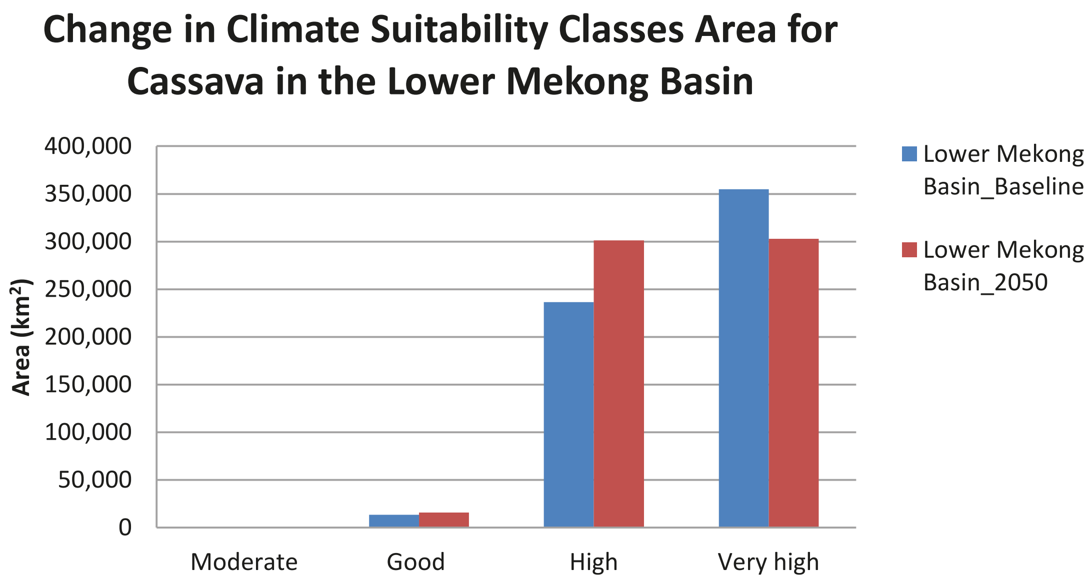
In 2050, the model predicts a general increase in suitability in highly elevated areas due to higher temperatures. Higher rainfall slightly reduces the suitability in areas with already sufficient amounts of rainfall such as southern Lao PDR, eastern Cambodia and the Central Highlands.

**Figure 23: Baseline and 2050 land suitability of cassava in the Lower Mekong Basin**




At the basin level, most of the shifts projected will be from very high to high suitability classes. These shifts will not significantly affect the crop's growth in these areas. Increasing temperatures is projected to shift more than 1,000 km$^2$ of land from good to highly suitable in the upland areas of Bolikhamxai and Phongsali Provinces in Lao PDR and 2,000 km$^2$ to very highly suitable in Xayaburi and Luang Prabang Provinces in Lao PDR and Kon Tum Province in Vietnam. Shifts from high to good suitability are projected in Nakon Ratchasima Province in Thailand (8,000 km$^2$), Chaiyaphum (700 km$^2$), and Bui Ram (400 km$^2$) Provinces.

**Figure 24: Change in climate suitability area from baseline to 2050 for the entire Lower Mekong Basin for cassava culture**




## 11.5 MAIZE

Under current conditions the suitability of maize in the LMB is largely determined by rainfall. Temperature suitability was found to be homogenously low across the basin, in part due to the restrictive parameters used in the model for this analysis. Suitable areas include Northeast Thailand and Cambodia, as well as areas around the Vientiane floodplain and Xayaburi Province in Lao PDR; particularly if a planting date in May is used. The Bolaven Plateau and Champasack Province have the lowest levels of suitability for maize in the LMB due to excessive rainfall during the planting season (Figure 25).

In 2050, the changes in suitability for maize across the LMB are not predicted to be significant. Areas with high rainfall will be less suitable in Central Lao PDR and increased temperature and rainfall will reduce suitability in northern Lao PDR, patches of Northeast Thailand and the Central Highlands of Vietnam. At the basin scale, about 40,000 $km^2$ of land is projected to shift from a good suitability to a moderate or low suitability (Figure 26). In Thailand and Lao PDR, 3,000 $km^2$ and 8,000 $km^2$ respectively of low/marginal land is projected to shift to the not suitable category.

Increases in temperature are projected to be beneficial in highly elevated zones in northern Lao PDR leading to slight increases in suitability. The Vietnamese Mekong Delta is also projected to become more suitable for growing maize with 18,000 $km^2$ of land shifting from moderate to good suitability. Although, this projection does not take into account potential detrimental effects related to flooding.

Figure 25: Baseline and 2050 land suitability for maize in the Lower Mekong Basin with planting date in May and crop duration 120 days

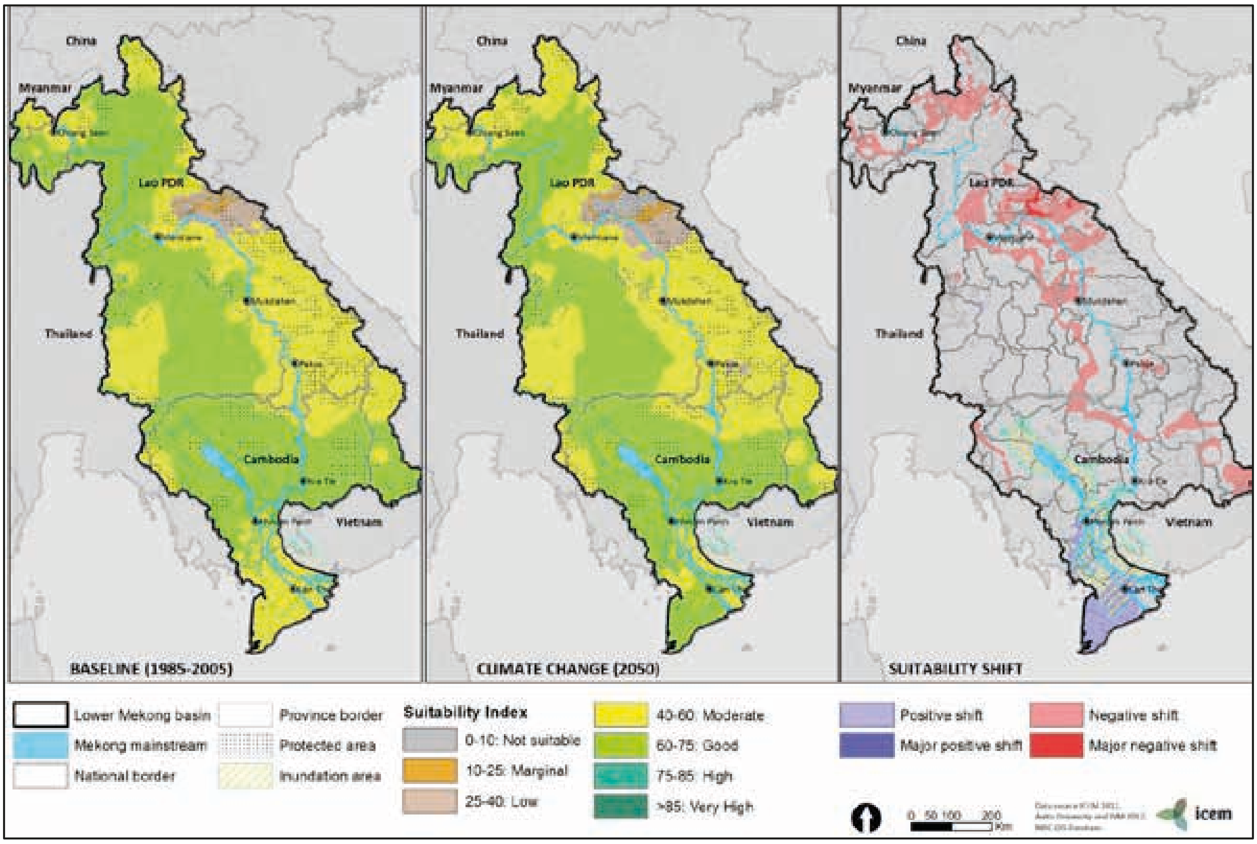
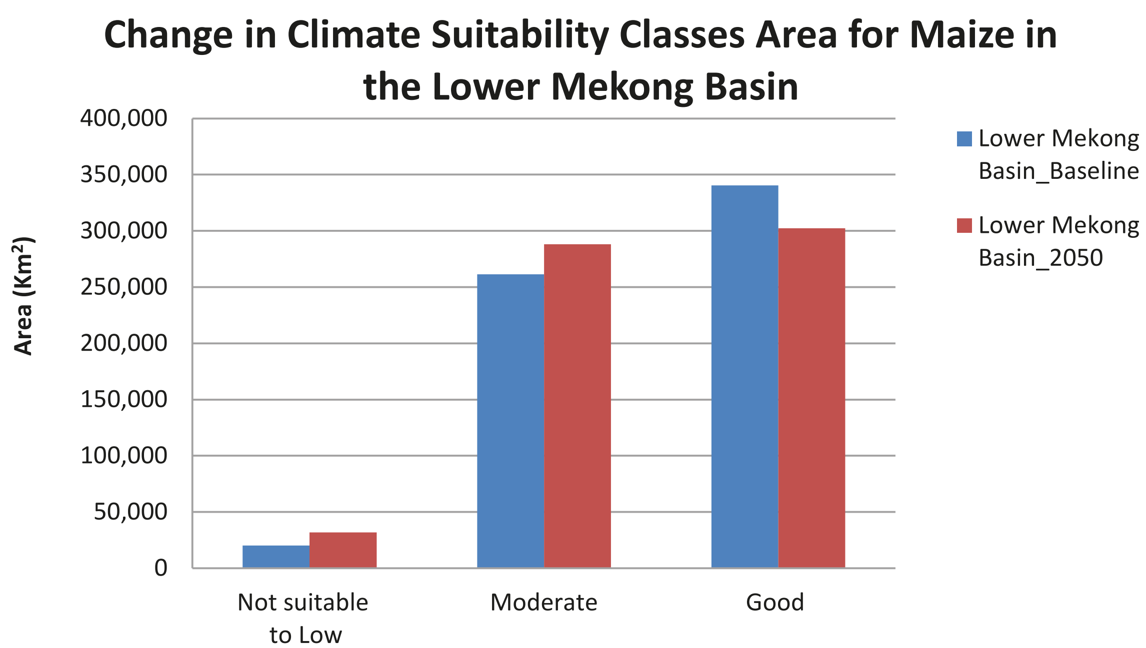



Figure 26: Change in climate suitability area from baseline to 2050 for the entire Lower Mekong Basin for maize cultivation (planting date in May)

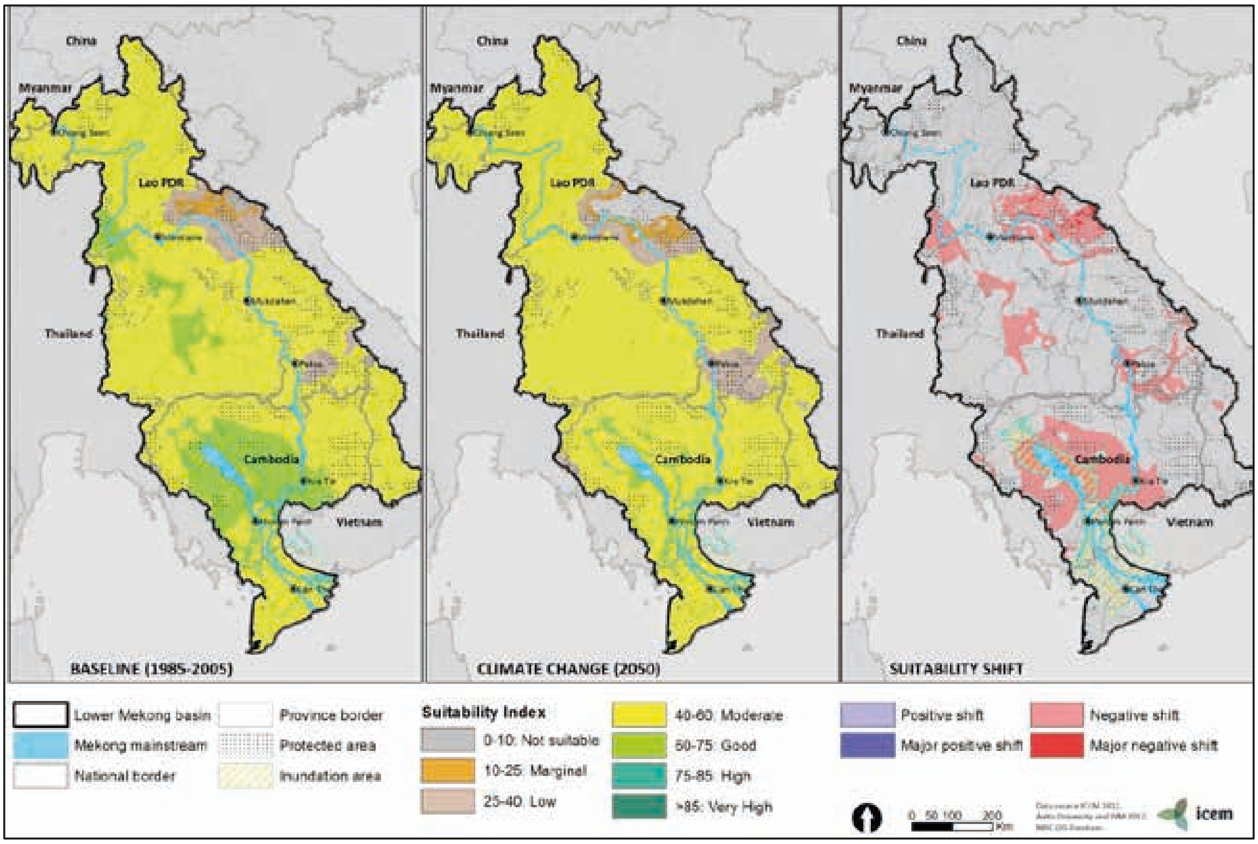


## 11.6 SOYBEAN

Soybean is not well suited to the current conditions in the LMB; particularly in areas with high precipitation. Suitability is moderate to good in in Northeast Thailand and the Cambodian plains. Temperature suitability is lower in highly elevated zones such as the Central Highlands and northern Lao PDR due to low temperatures during the growth cycle.

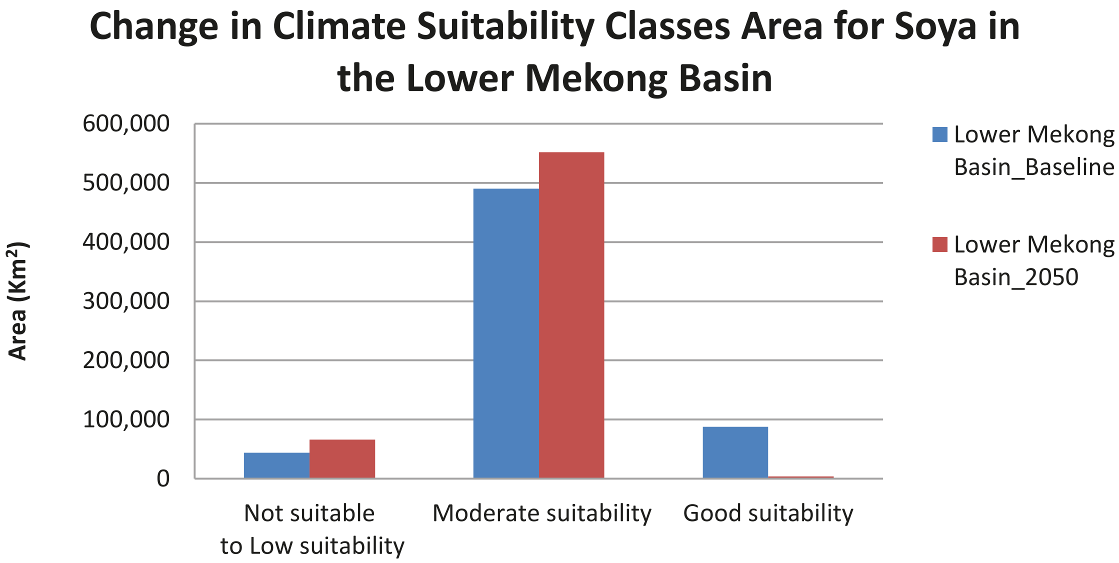
In 2050, a general decline in suitability is predicted. At the basin level, more than 83,000 km$^2$ of land is projected to shift from good to moderate suitability (Figure 28) including more than 60,000 km$^2$ in Cambodia alone. The provinces of Kampong Chhnang, Battambang, Preah Vihear, Pursat, Kampong Cham, Siem Reap, Kratie and Kampong Thom have areas ranging from 4,000 to 12,000 km$^2$ where the suitability for soybean cultivation will decrease to a moderate level. These provinces are currently producing soybean in rotation with cassava or maize.

**Figure 27: Baseline and 2050 land suitability for soybean in the Lower Mekong Basin with planting date in May and crop duration 120 days**




Shifts are projected to be less important across southern Lao PDR, Northeast Thailand, and eastern Cambodia. Changing the planting date to avoid periods of heavy precipitation may mitigate shifts that result from projected changes in rainfall.

**Figure 28: Change in climate suitability area classes from baseline to 2050 for the entire Lower Mekong Basin for soybean cultivation (planting date in May)**




## 11.7 SUMMARY OF FINDING AND LIMITATIONS

The main projected changes in terms of climate suitability for each crop are summarized in Table 2. The relevance of these findings to the actual agro-system depends on a range of factors including whether crops are currently being grown in areas of high or low suitability, or in areas on the cusp of a particular suitability class; the importance of the crop to farmer income and likely trends in demand for the crop over the long term; and the extent to which suitability influences farmer decisions about cropping patterns.

Positives shifts were found for several crops with higher suitability projected for rubber, Robusta coffee, and rice in a number of areas in the LMB. Suitability of soybean, maize, rubber, cassava, and coffee crops is projected to decline in specific areas of the LMB due to increased precipitation. In contrast some higher altitude areas of the basin are projected to be more suitable for cassava and rubber cultivation due to temperature increases. These projected changes in climate suitability are relevant for future planning.

Rainfed rice culture is too diverse to be assessed in detail. However, our results show that increased precipitation in the rainy season will increase the suitability for lowland rainfed rice culture. The model does not take into account floods or flash floods related to increased rainfall. The negative impact of increased temperature might have been underestimated due to the model specification which takes into account monthly average temperatures and not maximum temperatures. In addition, an increase of temperature might affect upland rice in areas of mid and high elevation. Upland rice and sugarcane was not incorporated into this analysis due to data restrictions.

**Table 7: Summary of findings per crop and ecozone and relevance for current agro-system**

| | Main change in suitability | Location | Relevance to actual agro-system |
|---|---|---|---|
| **Rubber** | Increased suitability due to increased precipitation | Northern Thailand (Chiang Rai) and Northern Lao PDR (Luang Namtha, Phongsaly; Oudomxai) | High |
| | Decreased suitability due to increased rainfall | Cambodia (Kratie, Preah Vihear) and Central and Southern Lao PDR (Champasack) and Chi Mun Basin in Northeast Thailand (Ubon Ratchatani) | Medium |
| | Increased suitability due to higher temperature | High elevation areas: Northern Thailand (Chiang Rai), Lao PDR (Luang Namtha, Phongsaly; Oudomxai), Central Highlands (Kon Tum) | High (more area to cultivate) |
| **Cassava** | Increased suitability due to higher temperature | High and mid elevation ecozones (Northern Lao PDR in Luang Prabang, Luang Namtha, Xyaburi and Central Highlands, Kon Tum) | High |
| | Decreased suitability due to higher temperature | Low elevation ecozones (Lao PDR, Cambodia and Central Highlands) | High |
| | Increased suitability due to increased precipitation | Northern Thailand (Chiang Mai, Chiang Rai) | High |
| | Decreased suitability due to increased precipitation | Low moist ecozone, mid and high elevation ecozones (Lao PDR in Champasack) and Cambodia (Stung Treng, Preah Vihear, Battambang); and Central Highlands (Gia Lai) | High |
| **Maize** | Decreased suitability due to increased precipitation | Luang Namtha; Vientiane, Khammouan and Phongsaly Province (Lao PDR), Dak Lak in Central Highlands (Vietnam) | Low |
| **Soybean** | Decreased suitability due to increased precipitation | Low elevation (moist and dry) ecozone: Kampong Chhnang, Battambang, Preah Vihear, Pursat, Kampong Cham, Siem Reap, Kratie, and Kampong Thom (Cambodia) | Low in moist ecozone; Medium in dry ecozone (Cambodia and Northeast Thailand) |
| **Robusta Coffee** | Increased suitability due to higher temperature | Medium and high elevation ecozones: Chiang Mai, Chiang Rai, Northern Lao PDR | High for Lao PDR (Northern regions) |
| | Increased suitability due to increased precipitation | Medium and high elevation ecozones: Chiang Mai, Chiang Rai, Northern Lao PDR | High for Lao PDR (Northern regions) |
| | Decreased suitability due to higher rainfall and temperature | Medium and high elevation ecozones: Lao PDR (Champasack and Attapeu) and Western Cambodia (Mondulkiri, Ratanakiri) and Central Highlands (Dak Lak) | Low / Medium |
| **Lowland Rice** | Increased suitability due to increased precipitation | Across the LMB | Low/medium |
| | Lower suitability due to increased precipitation | Northeast Thailand (Nakhon Ratchasima) and Lao PDR (Xaisomoun, Bolikhamxay) | High |

While different planting dates were assessed for lowland rainfed rice, no significant differences were found in terms of climate suitability. In addition, for the rice culture climate suitability model, we selected only one crop duration, which may be extremely variable. For other crops like soybean, maize or even cassava, the planting date varies across the basin and suitability may be different as a result. Therefore, it should be noted that the results presented here are based on a single planting date and do not take into account the diversity of the cropping calendar. New crop varieties and the development of specific varieties tolerant to low or high temperatures or resistant to drought were also not taken into account.

This basin-wide approach gives a snapshot of the change in terms of climate suitability for the main crops cultivated within the LMB. Suitability levels are based a priori on an international database and local knowledge, but no calibration was done. The effects of soil, slope, flood, salt intrusion and pest incidence were not taken into account and would modify the findings regarding the specific areas of suitability for each crop.

The use of LUSET provides not only a global picture of suitability changes within the LMB but helps to screen and select specific areas where the suitability of the current crops will be affected by climate change in the future. Specific vulnerability assessments at the provincial level will be performed based on local climate projection and level of sensitivity.

# 12 CROP YIELD MODELING

## 12.1 RICE

Based on the crop yield modeling, predicted changes in rainfed rice yield are extremely variable by location (Table 8). Changes in yield are variable, but a slight decrease is expected in 2050 due to higher projected temperatures during the crop season. Decrease in average rice yield of just a few percent per hectare may have tremendous impact in terms of food security and food production since rainfed rice is the most important crop in the LMB. A significant increase in the yield of rainfed rice yield in 2050 is projected in Northeast Thailand (Figure 29). This change in crop yield is due to increased rainfall during the cropping season and the reduction of water stress.

The decline in yields observed in the crop yield model is driven by increased temperature, which is a finding consistent with other studies (Groenigen et al. 2012; World Bank 2011, Welch et al. 2010). The increased yield modeled in Northeast Thailand is in line with the findings of Mainuddin et al. (2010), which estimated a yield increase between 7% and 26%. This study, under the A2 and B2 climate change scenarios, also estimated an increase of rice yield in northern Lao PDR.

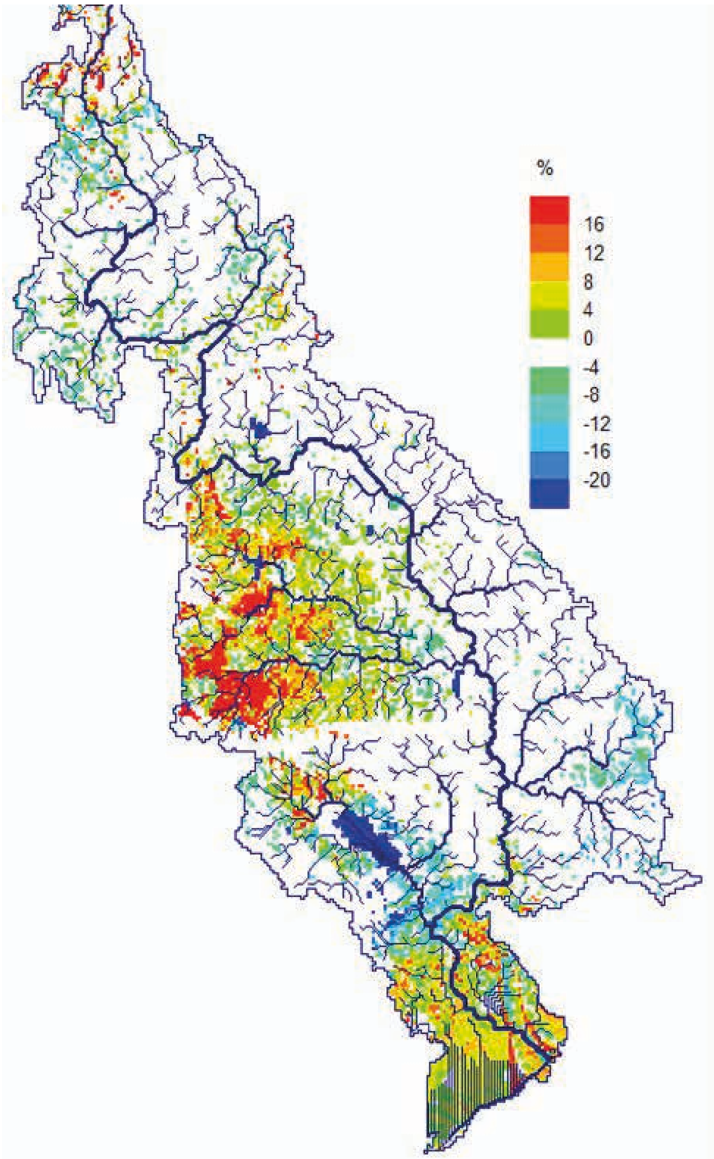
However, there are a number of limitations with this analysis that should be taken into account when considering these results.

**Table 8: Crop yield modeling for rainfed rice baseline and in 2050**

| | Baseline (tonnes/ha) | Change by 2050 (%) |
|---|---|---|
| **Chiang Rai** | 3.4 | -4.8 |
| **Sakon Nakhon** | 2.1 | 4.6 |
| **Khammouan** | 3.4 | -0.1 |
| **Champasack** | 2.9 | -5.6 |
| **Gia Lai** | 3.3 | -12.6 |
| **Mondulkiri** | 2.1 | -3.0 |
| **Kampong Thom** | 2.2 | -3.6 |

The type of modeling employed does not take in account extreme events such as floods or storms. Some of the results presented here also do not align with the climate suitability results presented earlier. For example, this model shows a yield increase in Sakon Nakhon, while the suitability modeling projected that climate suitability in 2050 would decrease compared to the baseline. Similarly this model projects a significant decline in rice yields in Gia Lai, while the suitability modeling implied a much more moderate decline in general suitability. These variances arise due to differences in the models themselves including the use of different time frames and the fact that the crop yield model manages to integrate soil parameters. As a result, the climate suitability model presented earlier is less precise than the crop yield modeling.

Figure 29: Change in rainfed rice yield in 2050 compare to current baseline




Similarly, the yield changes projected above in the Mekong Delta are not relevant as farmers have access to irrigation and crop yields were estimated without consideration of access to supplementary irrigation. Yield increase is attributed to $CO_2$ fertilization and higher rainfall. The negative impact related to the increase of temperature is offset by $CO_2$ fertilization. However, recent studies suggest that the combined effect of increased temperature and $CO_2$ fertilization will be detrimental to crop yield (Groenigen et al. 2012). Welch et al. (2010) highlighted the importance of the increased diurnal temperature on rice yield in Asia. Ultimately multiple, interacting climate-related parameters will significantly influence rice yields. As noted by Mainuddin et al. (2010), planting date and crop duration will have an important impact on rice yield.

## 12.2 MAIZE

Based on the crop yield modeling, predicted declines in maize yield across the LMB range from 3% to 12% by 2050 due to increased rainfall or temperature (Table 9). The results of the maize crop modeling are more consistent with the results of the climate suitability modeling when compared to the case of rice with predicted declines in maize yield generally matching up and with areas where a decline in suitability was projected.

**Table 9: Crop yield modeling for maize baseline and in 2050**

| | Baseline (tonnes/ha) | Change by 2050 (%) |
|---|---|---|
| **Chiang Rai** | 4.22 | -3.13 |
| **Khammouan** | 4.74 | -5.03 |
| **Champasack** | 5.08 | -5.55 |
| **Gia Lai** | 3.54 | -12.09 |
| **Kampong Thom** | 3.06 | -5.97 |

These results presented above are similar to the World Bank (2011) estimation for the Mekong Delta and the Central Highlands, with a yield drop higher than 3.4%.

A key limitation of the approach employed is that it does not account for any change in agricultural practices in response to climate phenomena such as modifying the fertilization levels.

# 13 CAM ANALYSIS

In the following section, we present the results of the vulnerability assessment for the eight hotspots studied. For each location, the main crops' vulnerabilities were analyzed based on the climate modeling results. The full CAM analysis is presented in the Annex 1, while this section presents a summary of the main vulnerabilities.

## 13.1 CHIANG RAI

Changes and shifts in regular climate will affect lowland rice culture, litchi, and rubber due to an increase in temperature (Table 10).

**Table 10: Main threats and vulnerabilities in Chiang Rai Province, Thailand**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability |
|---|---|---|---|
| **Lowland rice** | Increased temperature | 10% to 12% of the days above 35°C. High temperature in October during ripening stage. Temperature above 35°C induces sterility and reduces the number of grains. | High |
| **Litchi** | Increased temperature | Litchi trees requiring temperature below 15°C for at least 100 hours to flower during the winter months from November to December. Relative minimum temperature will increase by 20% in December. | High |
| **Rubber** | Increased temperature | Maximum temperature over the optimum in both dry and wet seasons. | High |

Farming systems in Chiang Rai are based partially on lowland rice cultivation. The climate suitability projection indicates that lowland areas will have lower climate suitability by 2050 for lowland rice, while upland areas will show a slight increase in suitability. Lowland rice will be more affected by changes in climate such as increased temperature than upland rice due to the fact that it is generally grown at lower elevations and is a less robust rice variety. A drop in the yield of lowland rice would be detrimental to the agriculture sector, for both the economy and for household food security. The crop yield modeling estimates a drop of 4.8% of rainfed rice yield, corresponding to an average yield of 3.2 tonnes/ha instead of 3.4 tonnes/ha. Projections based on 2006 statistics estimate that a decrease of 4.8% in the rice yield would generate a decrease of about 30,000 tonnes of rice at the provincial level. However, our estimation takes into account the entire area in which the main rice crops are cultivated and predicted increases in temperature are variable across the province.

Litchi production is one of the key products of the agriculture sector in Chiang Rai. Production takes place in monoculture on sloped, upland areas. The product is exported. A decrease in production would affect the local economy including waged laborers employed for harvesting and packaging. Increased temperature will affect the flowering of the tree. In 2009, the average low temperature was over 20°C and affected more than 50% of the crop's productivity.

Rubber production will also suffer from increased temperature, with more days above the optimum temperature of 29°C. In the meantime, new areas of up to 1,000 km² in higher altitudes will become more suitable for rubber plantations as a result of increasing temperatures.

An increase in rainfall during the rainy season will most likely affect crops other than rice, such as maize or soybean, especially at their harvest times. However, some areas of the province suffer from a lack of rainfall and increased precipitation during the cropping season will be beneficial. Maize will be more negatively affected by the expected increase in temperature, as will other crops such as soybean, coffee, pineapple, and rubber. Chiang Rai Province is not located in a storm prone area and changes in specific events will mostly concern flash flooding with more days of precipitation levels above 160 mm projected. Flash floods will affect mostly lowland culture such as rice, maize, and soybean.

## 13.2 SAKON NAKHON

Increased temperature and rainfall will affect lowland rainfed rice, cassava, and rubber (Table 11). Increased precipitation will affect rainfed rice yield. The crop yield modeling shows an increase in rice yield by 4.6%. This result is probably due to the predicted increase in rainfall during the cropping season, which may offset the effect of increased temperature.

However, changes in rainfall, particularly increased rainfall in August, may negatively impact rice culture if it reaches above the rice crop's upper limit of tolerance. Climate suitability modeling estimated a decrease in suitability for more than 1,000 km² of rice land in the province due to increased rainfall and temperature during the growing season. Lowland rainfed rice is the second largest crop in the province after sugarcane with more than 280,000 ha cultivated. A decrease in productivity will affect the food security of farmers throughout the province.

**Table 11: Main threats and vulnerability for crops in Sakon Nakhon, Thailand**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability |
|---|---|---|---|
| **Lowland rice** | Increased temperature | The increase in temperature will be by 5% to 9% during the wet season, equivalent to an increase of 10% of days above 35°C | High |
| **Cassava** | Increased precipitation | Total precipitation during the growth cycle will be above the upper limit (>2,300 mm), with total precipitation 50% higher in the dry and rainy seasons compared to the baseline | High |
| | Flooding | Increased rainfall from May to November may increase flood intensity and frequency | High |
| **Rubber** | Increased temperature | Average maximum temperature will be above the optimum for more than 10 months (90% of the days) | High |

Cassava covers almost 10,000 ha of the province and is generally cultivated by smallholders. An increase in rainfall is projected to reduce the suitability of cassava over more than 2,000 km² of land in the province. Water logging and the increased presence of pests and fungal disease will lead to lower rates of production. Cassava has a low tolerance to water logging and rainfall increased to more than 2,300 mm during the growth cycle will affect the crop's productivity, as predicted in the climate suitability model. The vulnerability of the crop will also depend on the location of the plots (lowlands, plains, or hills) and the soil type present because these factors will determine water logging duration.

Increased temperatures will be a threat to the 37,000 ha of rubber plantations in the province with more than 50% of daily maximum temperatures expected to be above the maximum optimal temperature for growth from March to May.

Sugarcane is the main crop produced in the province, with more than 290,000 ha cultivated and, as it is more resistant to high temperatures, it is considered a less vulnerable crop compared to rice or cassava. Sugarcane can endure water logging. However, since the exposure level for both threats will be high, productivity may be affected. Increased water consumption due to higher temperatures in late dry season or during droughts may be an issue that generates conflict between different water users.

In general, rainfed crops are expected to be subjected to an increasing number of days with abundant precipitation, with 11 events per year projected to be above 100 mm. Rainfall, especially at the harvest time of rice, maize, or soybean, may affect yields and the occurrence of pests and diseases.

## 13.3 KHAMMOUAN

The vulnerabilities of the main crops cultivated in Khammouan are related to effects from extreme rainfall events and increased precipitation, as well as increased temperature (Table 12). In Khammouan Province, the farming system in upland areas will be strongly affected by the increase in rainfall and extreme events, lowering yield and increasing rates of erosion. The absence of fertilization will limit the response to yield drop. In lowland areas, access to irrigation and to agriculture inputs will mitigate the impact on the yield. However, this specific agro-ecosystem will face higher incidences of floods and flash floods. The recent development of cassava culture will likely stop as the province will be less suitable for its cultivation and a shift of crop cultivation will probably be observed.

**Table 12: Main threats and vulnerability for crops in Khammouan Province, Lao PDR**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability |
|---|---|---|---|
| **Lowland rainfed rice** | Increased temperature | Less than 30% of the daily maximum temperatures within the optimal zone. Increased temperature will induce sterility and lower yield. | High |
| **Lowland rainfed rice; Cassava, Maize, Sugarcane** | Flooding, flash flooding, and storms | 15 days per year with 100 mm of rainfall or more, with a maximum of 200 mm, and high storm frequency will increase the threat from rain events. | High |
| **Cassava, Maize** | Increased precipitation | Increased precipitation of 5% to 27% between April and November, maximum precipitation above 800 mm in June, July, and August. Threat will be accentuated on heavy soil prone to waterlogging. | High |

Increased temperature will have a greater impact on rainfed rice than irrigated rice; particularly because of higher temperature increases during the rainy season. Due to the topography of the province, with both mountainous areas and floodplains, extreme climatic events that involve storms and heavy rainfall above 100 mm per day will increase the threat for lowland rainfed rice, maize, cassava, and sugarcane.

Climate suitability was found to be lower for these crops by 2050 as a result of projected increases in precipitation.

Despite these threats and the projection that the suitable areas for rice production will decline by more than 2,000 $km^2$ in the province by 2050, the crop yield modeling found no significant change in rice yield. Maize yields are expected to decline by 5.3% compared to the 2010 baseline. However, maize production remains a limited percentage of the agriculture sector in Khammouan Province and this change in yield will not drastically affect the sector.

Cassava cultivation is now expanding with the development of processing factories, as is sugarcane. These crops will be threatened by increases in precipitation and higher incidences of extreme climatic events. Meanwhile, sugarcane will be less affected by water logging compared to cassava. Rubber will be less affected by the predicted increase in temperature and will benefit from higher rainfall due to a shortened drought period. Rubber plantations are usually located on slopes, which are less exposed to flood.

## 13.4 CHAMPASAK

Crops in Champasak Province will face threats from increased precipitation and temperature that will affect several crops' yields. Farming systems in the province for both smallholder and commercial plantations will face radical changes in terms of climate suitability in their production systems. Commercial crops for both exportation and subsistence for food security will be affected with high vulnerability for smallholders working with predominantly rainfed farming systems. Agriculture will also have to cope with increased incidences of extreme climatic events (Table 13).

The province is characterized by a specific agro-system, including the Bolaven Plateau that supports smallholder rainfed Robusta coffee culture and the Mekong corridor where there is development of commercial agriculture. The rubber concession covers a large area and cassava culture has expanded in the recent years based on smallholder and contact farming, both on the Plateau and along the Mekong corridor. Climate suitability for rubber will decrease in more than 6,000 $km^2$ of land within the province, due to increased rainfall and temperature.

Irrigated rice is cultivated by 20% of the farmers in this region and this crop will face a critical period at the end of the dry season, with a significant increase in temperature. Lowland rainfed rice will also face increased temperatures; especially early wet season rice. The crop yield model estimated a decrease in yield of about 5.6%, corresponding to a drop of more than 11,000 tonnes of the annual provincial production.

Table 13: Main threats and vulnerability for crops in Champasak Province, Lao PDR

| Vulnerable Crop | Threat | Impact Summary | Vulnerability |
|---|---|---|---|
| **Lowland rainfed rice, Irrigated rice, Robusta coffee** | Increased temperature | Critical period in March, April, May with more than 50% of daily temperatures above 35°C. Daily maximum temperature above rice optimal zone during the wet season Extreme maximum temperatures above 36°C from January to October | High to Very High |
| **Cassava, Robusta coffee, Lowland rice** | Storms (flashflood) | Extreme events with more than 250 mm/day of rainfall will occur, with more than 7 events per year with more than 100 mm/day. | High |
| **Cassava, Maize, Robusta coffee** | Increased precipitation | Total precipitation during the growth cycle will be below the upper limit (>2,300 mm) for cassava. Precipitation above suitable range (>400 mm) in July and August for maize. Wet years will be above suitable range with increased rainfall in wet season (above optimal zone). | High |

Robusta coffee, traditionally cultivated on the Bolaven Plateau, will face serious threats with temperatures above 36°C from January to October. Coffee will also face the threat of more recurrent storms and heavy rainfall that may lead to flashfloods. About 2,000 km$^2$ of land is predicted to have lower climate suitability for Robusta coffee.

Cassava culture will face water logging if planted on soil that does not drain well and maize crops will have reduced yields due to heavy rainfall at the end of the crop season. The crop yield model estimated a drop in yield of about 5.5% compared to the baseline resulting in a decrease of 2,000 tonnes of maize. The combined effect of increased precipitation and temperature may lead to an increase in pest occurrence and crop disease, especially for coffee culture.

## 13.5 KAMPONG THOM

Kampong Thom Province is affected by flooding in the Tonle Sap in the southern region. The central region of the province is also highly vulnerable (WFP 2008). The northern part of the province supports smallholder agriculture with rainfed rice, as well as soybean in rotation with cassava crops. Lately, there has been an expansion of rubber cultivation in both industrial concessions and smallholder farms. The province is also characterized by the rapid expansion of smallholder cassava culture.

Floods may affect lowland rainfed rice at the end of the crop cultivation before harvesting, leading to total loss of the culture. Late crops of soybean may be affected by flooding, especially during the harvest period as they require dry conditions. More than 12,000 km$^2$ of land within the province will see a decline in soybean's climate suitability by 2050. Cassava culture will also be threatened by flooding and increased rainfall and subsequent water logging that reduces yield and facilitates the spread of disease.

Table 14: Main threats and vulnerability for crops in Kampong Thom Province, Cambodia

| Vulnerable Crop | Threat | Impact Summary | Vulnerability |
|---|---|---|---|
| **Lowland rainfed rice** | Increased temperature | More than 75% of the maximum daily temperatures above the optimal zone for lowland rainfed rice. | High |
| **Irrigated rice** | | More than 50% of maximum daily temperatures above 35°C in March and April for irrigated rice. | High |
| **Soybean** | | Extreme maximum temperature (<25% of frequency) higher than 35°C during soybean crop growth. | High |
| **Lowland rainfed rice, Cassava, Soybean** | Flooding | Flood prone area around the Mekong and Tonle Sap lake in the southwestern part of the province. Precipitation above 500 mm per month in October and total precipitation in the wet season above 1,700 mm. | High |
| **Soybean** | Decrease in water availability | Decrease in water availability will be between 10% and 4% during the crop growth period. | High |

Increased temperatures will affect both dry and rainy season rice crop and coupled with an increase in rainfall, the decline in yield is estimated to be about 3.6%. Yield decreases under current conditions could result in reductions of output of up to 15,000 tonnes of rice compared to the 2010 baseline. Increases in temperature will also affect soybean culture, leading to a drop in yield. The increase in rainfall and temperature will also reduce the suitable areas of rubber, which has recently expanded in the province.

## 13.6 MONDULKIRI

Mondulkiri is a forested area, traditionally cultivated by local communities in a subsistence system based on rainfed rice and the traditional Khmer "Chamkar system." This system includes rainfed cultivation of root crops (taro and cassava), sweet potato, maize, and mung bean. Recently, industrial plantations and contract farming of rubber, cashew, soybean, and cassava have expanded in the province.

Crops in Mondulkiri will be highly exposed to storms and increased rainfall, as well as decreased water availability in the soil. The exposure to heat and higher temperatures during the rainy season will be at a medium level (Table 15). Crop yield modeling estimates a decrease of 3% in rainfed rice yield in Mondulkiri. Although yields are generally already low, the change in yield will result in a lower rice production of about 1,114 tonnes per year for the province. The climate suitability modeling showed a decrease in suitability for all the crops assessed in Mondulkiri; particularly the industrial crops including cassava, rubber, coffee, and soybean. This could potentially strain the expansionary trend of agriculture in the province and impact on opportunities for the improvement of livelihoods. Decreases in suitability will affect significant areas available for soybean (400,000 ha), rubber (more than 5,000 ha), and coffee (more than 6,000 ha).

Table 15: Main threats and vulnerability for crops in Mondulkiri Province, Cambodia

| Vulnerable Crop | Threat | Impact Summary | Vulnerability |
|---|---|---|---|
| **Cassava, Soybean, Lowland rainfed rice** | Storm and increased precipitation | 21 days with more than 100 mm, including 1 day above 160 mm per year. Precipitation above 500 mm per month in October and high frequency of storms, which may damage crops and create water logging in lowland areas that are more exposed. | Medium to High |
| **Soybean** | Decreased water availability | Decrease in water availability will be between 18% and 20% during the crop season creating water stress. | High |
| **Rice** | Increased temperature | Increase in maximum temperature will fall between 12% and 17% compared to baseline during growth period. More than 50% of the maximum daily temperatures will be above the optimal zone for rainfed rice. | Medium |
| **Cassava** | Increased temperature | Around 15% of the days will be above 35°C during the growth cycle of cassava. | Medium |
| **Rubber** | Increased temperature | Dry season (March to May) will have more days above 35°C as daily maximum temperatures, with temperature increases of 17% in May | Medium |
| **Soybean** | Increased temperature | Higher maximum temperature below 35°C in the rainy season will create a stress and limit yield. This might be a stress for soybean in the case of the early wet season crop, in April or May. | Medium |

## 13.7 KIEN GIANG

Kien Giang Province, a coastal province in the Mekong Delta, is characterized by two main agro-ecosystems. The first is based on alluvial soil that supports two to three rice crops per year, as well as vegetable production. The second system involves cultivation in acidic soils and is influenced by saline water intrusion during the dry season. In this zone, rice-shrimp farming is dominant and sugarcane or pineapple cultivations are of minor importance. There are multiple threats to agriculture in the coastal zone, with SLR and saline water intrusion in addition to increased temperature and changes in rainfall pattern (Table 16).

Saline water intrusion will be more severe and will encroach further inland with SLR without the use of sluice gates or embankments that can contain the seawater. Rice yield in Kien Giang in dry season will face the threat of more intense and longer lasting salinization along with increases in temperature. As a result, rice yield will also depend on the availability of fresh water from upstream sources, which remains uncertain depending on hydropower and other sector developments (industrial, irrigation, population growth, etc.) in upstream countries.

**Table 16: Main threats and vulnerability for crops in Kien Giang Province, Vietnam**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability |
|---|---|---|---|
| **Irrigated rice** | Increased temperature | About 50% of days in March-May have a maximum temperature exceeding 35°C. About 50% of days of maximum temperature are expected to exceed the optimal zone in both wet and dry season. An increase in temperature in early rainy season may cause heat stress, reducing rice tillering and yields. The effect of increased temperature will be more severe with droughts in early rainy periods | High |
| **Rainfed rice, Irrigated rice** | Sea Level Rise & saline water intrusion | Sea level will rise about 30 cm by 2050. Sea level rise causes saline water intrusion inland through canal systems in the dry season and increases flood severity in the rainy season.<br>Rice suffers a significant yield loss with a salinity concentration above 4%. Yield losses depend on the location, time and duration of the stress. | High to very High |

The results of the climate suitability model did not take into account SLR parameters and therefore showed an increase in climate suitability for the rainy season rice, when increased temperature is not as significant as in the dry season.

Double and triple rice crop culture systems will face threats in both the rainy and dry season and will require the use of additional saline water intrusion protection systems. In coastal areas, saline water intrusion may be longer lasting and may constrain the rotational rice-shrimp culture with a shorter period for rice cultivation. This will necessitate greater investment in embankments and flood protection systems.

## 13.8 GIA LAI

Gia Lai Province in the Central Highlands has a dynamic agriculture, with both a traditional farming system based on upland rice farming and a more recent industrial agriculture based on rubber, cassava, maize, sugarcane, and Robusta coffee production. Within the province, there will be cumulative threats for agriculture including increased temperature in the late dry season and early wet season and a high incidence of storms and high rainfall during the rainy season, leading to more floods and flash floods (Table 17).

Both the industrial and traditional production systems will be vulnerable to extreme climate events. Rice culture and Robusta coffee culture will face severe threats from high temperatures during their growth cycle. Increased temperatures for irrigated crops like coffee and rice will induce higher water demands for the agriculture sector. Yield will be affected, both in dry and rainy season, for rice and coffee. Significant areas are predicted to be less suitable for cassava (3,000 $km^2$), Robusta coffee (more than 1,000 $km^2$) and rubber (more than 4,000 $km^2$) culture.

**Table 17: Main threats and vulnerability for crops in Gia Lai Province, Vietnam**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability |
|---|---|---|---|
| **Rainfed rice**<br><br><br>**Irrigated rice** | Increased temperature | About 50% of days of maximum temperature are expected to exceed the optimal zone for rice in the rainy season.<br>About 50% of days in April and May will have maximum temperatures exceeding 35°C.<br>High temperature will cause direct heat stress or indirect water stress through high evapotranspiration on rice crops, resulting in low rice yields. | High |
| **Robusta coffee** | Increased temperature | More than 50% of days in February–October are expected to have maximum temperatures exceeding 32°C, sub-optimal condition for Robusta coffee.<br>Production might be affected in the dry season with high temperature through direct heat stress and indirect water stress. | High |
| **Cassava, Maize** | Storms, floods and flash floods | The central highlands are vulnerable to flash floods (World Bank 2011). Increase in precipitation, from June to November (5% to 15%), compared to baseline with 10 days with more than 100 mm and 2 days of more than 140 mm of rain. Flash floods are related to storms or heavy rains in upland and/or upstream areas in July-September with high rainfall in narrow valleys, which create a sudden water level rise (rivers, stream) and which carry debris. | High |

Facing high temperatures and change in rainfall patterns, rainfed rice yield is expected to drop by 12.6% and maize by 12%, according to the crop yield modeling. This will lead to a drop in rice and maize[9] production by 20,000 and 24,000 tonnes respectively. Coffee yield changes are estimated to be lower (-1%) in 2050 according to a World Bank study (2011) for the Central Highlands.

Rice and other annual crops grown on lowlands will face higher incidence severe flooding and flash flooding in the rainy season. In addition, the recent expansion of cassava culture on slopes combined with the effect of higher storm frequency and rainfall will contribute to more erosion, leading to more severe flash floods. Maize and cassava are classified as highly vulnerable to these types of events. However, other crops such as sugarcane, rice, coffee, and rubber will also be vulnerable.

[9] Estimation is based on 2011 production.

# 14 CONCLUSION

This comprehensive approach, which uses three different assessment tools, provides us with the opportunity to assess in both quantitative and qualitative manners the vulnerability of the main subsistence and commercial crops cultivated in the LMB.

Climate suitability modeling highlighted the altitude shift for rubber, cassava and coffee crop cultivation, with newly suitable land in higher altitudes following the expected increase in temperature. Changes in climate suitability are negative for most of the studied crops, with large areas of rubber, coffee, and maize crops demonstrating lower suitability in 2050 with an increase in temperature and/or precipitation. The suitability of commercial crops (rubber, cassava, and maize) will change in newly cultivated areas in Cambodia, the Central Highlands, and Lao PDR where agriculture trends are currently shifting from traditional, subsistence-based systems to commercial, economic-based systems for distribution to international or regional markets.

Climate suitability will not change for lowland rainfed rice, according to our modeling, with higher suitability in current water-deficient areas. This result shows some of the limitations of the climate suitability model, where a diversity of practices (crop duration and planting date) cannot be taken into account for the entire basin. The crop yield modeling was more precise and found an overall decrease in yield for rice cultivated in rainfed conditions except in drought prone areas, especially in Northeast Thailand, which will benefit from increased precipitation.

Diversity of cropping systems and crop management was approached by using a qualitative method to assess the vulnerability for each of the crops in the eight hotspots. This method allowed us to highlight the most vulnerable crops and give a hierarchy to the threats for each crop, according to current management practices. Increased temperature and increased occurrence of extreme events were found to be a common threat across the basin. Soybean, rice, maize, and coffee are vulnerable to increased rainfall. The higher incidence of extreme events such as storms and heavy rainfall will increase the vulnerability of the most productive agro-ecosystem in the region, the lowlands. The combination of poorly planned agriculture practices and lack of soil conservation considerations, will lead to an increase in soil erosion and loss of fertility in uplands areas.

This vulnerability assessment will contribute to designing some adaptation options for the agricultural systems in the different hotspots selected. These options will give a general framework for improving the resilience of agricultural systems and for reducing the vulnerability of farming systems.

# SECTION 3
# ADAPTATION OPTIONS

- OPTIONS FOR DEVELOPING MORE RESILIENT AGRICULTURE
- ADAPTATION OPTIONS
- CONCLUSION

Section Three is structured in two sub-sections. First, we present some adaptation options for agriculture that are already implemented in the region. These options consist of technical changes that result in improved rice-based culture, water management, and soil fertility. In the second part, we use a vulnerability assessment of the eight hotspots across the LMB and, based on this assessment, we proposed some adaptation options according to the main threats and vulnerabilities identified in previous sections.

As with the baseline and vulnerability assessment reports, the adaptation options presented focus on addressing the biophysical changes, threats, and opportunities to farming systems identified in the eight hotspot provinces. The options presented do not account for the political and institutional dimensions of adaptation in the agriculture sector. These considerations are taken up in the final synthesis report.

# 15 OPTIONS FOR DEVELOPING MORE RESILIENT AGRICULTURE

Adapting the agriculture sector to climate change in the LMB will involve a mix of strategies such as:

- Strengthening the resilience of both rainfed and irrigated rice-based systems through adoption of improved varieties and better management practices and reducing vulnerability to extreme climate events. This could include the use of specific varieties to mitigate the impact of flood and drought and integrating "System of Rice Intensification" (SRI) techniques into general management practices.
- Adopting/improving water efficiency and water management practices (water harvesting, small–scale irrigation, etc.) in drought-prone areas in order to alleviate the impacts of water shortages.
- Improving soil fertility and soil management of both cash and subsistence systems in plains, plateaus and uplands.
- Promoting agriculture techniques that reduce greenhouse gas (GHG) emissions.
- Promoting agricultural diversification and mixed farming systems to mitigate current reliance on monocultures.

The following section discusses some of these options in more detail in the context of the specific conditions and risks observed in the LMB in previous sections.

## 15.1 RICE-BASED SYSTEM

### 15.1.1 New Varieties and Risk Management Strategies

Experience with improved varieties in the LMB is growing, which allows governments and farmers to anticipate some of the benefits and challenges associated with adopting new resilient varieties as an adaptation measure. New flood-tolerant and submergence-tolerant rice varieties[10] ("Scuba rice") developed by IRRI are now available and can help mitigate flood uncertainty. In areas where flood amplitude is too extreme for rice culture during the wet season, measures to store water for access during the dry season should be investigated to allow a shift from dependence on a rainfed crop to an irrigated dry season crop.

In areas where the variability of rainfall in the rainy season generates dry spells, drought resistant varieties will allow for better flexibility and reduce the gaps in seasonal yields. On average, a drought

[10] http://www.irri.org/index.php?option=com_k2&view=item&id=9148:climate-ready-rice&lang=en

resistant variety has a yield of 0.8 to 1.2 tonnes/ha higher than non-drought resistant varieties[11] under stressed conditions.

To address the uncertainty of drought, flood and rainfall patterns, farmers in Kandal Province, Cambodia, use a number of different management approaches such as planting rice varieties of different maturation periods. Resurreccion et al. (2008) describe a similar risk management strategy where farmers use conventional rice culture for a section of their rice field while using drought resistant rice varieties in an SRI system in a fraction of the field.

A short-term crop that draws upon residual water in the soils is capable of growing after a rainfed rice crop. This technique also uses the crop residue as mulch in order to limit transpiration. In Vietnam, the planting of a double rainfed rice crop (short-term varieties) followed by a potato crop was found to be technically efficient and plantings were up scaled at the provincial level.

The local diversity of agro-ecological conditions and farming practices is important. Research and extension work that identifies the appropriate rice variety (or varieties) and measures for a specific community and agro-ecological context will be necessary.

### 15.1.2 System of Rice Intensification

SRI offers a new opportunity for increasing the production value of rice per drop of water and for reducing agricultural water demand. Such a strategy may be particularly important in the context of a changing climate, increasing rainfall variability, and growing competition for water and land. Put simply SRI aims to improve rice yield while reducing inputs. The technique is based on several principles and farmers can choose to apply the entire process or to select specific steps according to their particular capacity and situation. The selective approach has proven successful in Vietnam, which is described further below. Specific SRI practices can include a mix of the following practices.

SRI encourages the use of fewer seedlings (one instead of several), which are transplanted earlier in the season and at a lower transplanting density. A lower density of seedlings promotes less competition for resources, which in turn encourages the formation of elongated roots and improved plant growth when compared to conventional rice culture. SRI also involves a succession of flooded and dry periods that increase soil aeration, facilitate root elongation and promote nutrient assimilation. SRI water management practices have been found to reduce overall water requirements by 20% to 50%. Weed control is completed manually and pest control involves the use of an Integrated Pest Management Approach.

SRI is applicable to both irrigated and rainfed systems, but generally requires considerable water management capacity. Increased root growth and elongation makes rice plants more resistant to drought, water logging and typhoons[12]. Compared to conventional technique, the SRI approach has lower production costs, using fewer seeds (80% to 90% less) and fertilizers, but labor requirements

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[11] http://www.irri.org/index.php?option=com_k2&view=item&id=9148:climate-ready-rice&lang=en

[12] http://info.worldbank.org/etools/docs/library/245848/overview.html#

were found to either increase or decrease according to the location. In Northeast Thailand, farmers' evaluations of SRI systems intercropped with mung bean returned higher yields compared to SRI plots that were not intercropped[13].

Commonly cited constraints in adopting SRI include an unwillingness to modify traditional rice cultivation techniques, lack of water management capacity, increased labor requirements for weeding, and, in some cases, increased labor input due to the use of organic fertilizers.

In the context of climate change SRI can deliver a number of adaptation benefits such as:

- Sustained rice yields despite higher temperatures;
- Reduced demand for water;
- Reduced GHG emissions and use of nitrogen fertilizer[14]; and
- More robust plants and reduced loss from climatic events such as drought, flood, and storms. (Africare 2010)

There have been a number of successful SRI pilots in North and Central Vietnam. These pilots have displayed increased yield, reduced urea and pesticide use and reduced irrigation expenses compared to conventional rice culture. These benefits have led to a significant improvement of household incomes (Africare 2010). In the context of climate change, where Vietnamese farmers face higher storm frequency and heavy rainfall, it was found that plots using SRI practices are more resilient to harsher climate conditions due to their stronger tillers and deeper roots. Introduced in 2003 in North Vietnam, SRI techniques are now used by more than 260,000 farmers in 21 provinces in North and Central Vietnam.

## 15.2 IMPROVEMENT OF WATER USES IN AGRICULTURE

IWMI (2006) notes that improved water management can involve a range of different practices, the most important of which are:

- *"In-situ soil and water conservation technologies, including conservation agriculture (e.g., planting pits, infiltration ditches, mulching, contour banks)*
- *Ex-situ rainwater harvesting and water storage technologies (e.g., small earth dams, tanks, hand-dug shallow wells, runoff harvesting)*
- *Water-lifting technologies (e.g., treadle pumps, hand pumps) for transferring water to fields and/or removing water from fields*
- *Technologies for efficient application of water to plants (e.g., clay-pot subsurface irrigation, bucket irrigation, direct application by hose)"*

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[13] http://ciifad.cornell.edu/sri/countries/thailand/index.html

[14] However, GHG reductions are only possible in systems where improved water management is also possible. SRI technique can also be considered as an improved practice for soil management.

Basic technology for adaptation to drier conditions and uncertain rainfall conditions are listed in AIT UNEP (2011). For example, percolation tanks are used in India to capture runoff water and to improve percolation in order to regenerate shallow water tables[15] (IWMI 2007). Community-based responses can be developed, with mini-ponds used for supplemental irrigation in Bangladesh[16] (FAO 2008). In Northeast Thailand, tests are being conducted that add green mulch with combinations of clay and organic additions to the soils in order to increase fertility and water storage capacity[17].

Rainwater harvesting can be used for agricultural purposes in the case of small-scale horticulture or vegetable production. This technique can be applied in dry or wet areas and has multiple purposes. In Cambodia, this approach has been developed for drinking water and sanitation with collection in cement or metal tanks[18]. Examples of rainwater harvesting also include runoff water collection in small-scale dams or ponds, which can be used in both plains and upland areas. In areas with more rainfall, rainwater harvesting can be used to support a second crop at the end of the rainy season and reduces the risk of a water shortage. In areas with dry spells during the rainy season, rainwater harvesting can be used to limit the impact of water stress for the main crop planted in the rainy season.

Water saving techniques for small-scale farmers also includes drip irrigation. Bucket drip irrigation is a low cost technology that can help to diversify agriculture. This technology involves a raised bucket that supplies water to pipes with emitters alongside plots. Water is regulated through a slow release mechanism. The system requires an investment of only US$5 and allows farmers in water-scarce areas to produce good harvests using the appropriate amount of water (CGIAR 2007). An example in the Cambodian floodplain shows that drip irrigation for vegetable production can save water, can improve yield and labor efficiency, and can be financially sound (Roberts and Long 2006, Palada et al. 2010). This technique could be attractive to farmers in areas well connected to markets and where freshwater shortages might be an issue. It can be coupled with water harvesting techniques.

In addition to improving the resilience of crops to weather extremes, access to irrigation with groundwater, rainwater collection, and small-scale water storage can also provide opportunities for dry season crops or diversification for intensive home gardening. This diversification strategy in areas that are well connected to markets can provide a new source of income. In Cambodia facilitating access to dry season irrigation with the building of small-scale dams and a shift to a double rice crop system, has been shown to have tremendous positive impact on community livelihoods (UNDP 2011).

Farming practices that can be implemented to increase the water holding capacity of soil include conservation tillage, mulching, and compost or manure use. More generally, soil management techniques to improve water holding capacity and to reduce erosion are needed and can be considered climate change adaptation techniques.

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[15] http://www.iwmi.cgiar.org/assessment/files_new/synthesis/Summary_SynthesisBook.pdf
[16] ftp://ftp.fao.org/docrep/fao/010/i0481e/i0481e.pdf
[17] http://www.cgiar.org/csos/cso_cgiar_grant_program.html
[18] www.rainwatercambodia.org/

## 15.3 SOIL MANAGEMENT AND FERTILITY

As mentioned by Jonhston (2009), maximum yield is far from being reached in most of the agricultural land of the LMB. Yield gaps are a persistent challenge and both fertility management and the use of fertilizer are partially responsible for this gap. Yields of the main crops show large variations across the LMB. For example, lowland rainfed rice yields are below 2 tonnes/ha in several provinces in Cambodia, Lao PDR, and Thailand while yields reach 5 tonnes/ha in the Mekong Delta. Similar gaps can be found for soybean or maize between Cambodia and Thailand. While such gaps are based on a range of factors including the suitability and productivity of specific ecozones, much could be done to try and narrow this gap; particularly in terms of improved soil management.

The use of synthetic fertilizers will be required to fill the yield gap. Improving fertilizer use efficiency is essential through better application, by fractioning the amount of fertilizer used into several doses or by using other techniques such as "*Urea Deep Placement*" (UDP). In this technique, developed by IRRI and the International Fertilizer Development Center (IFDC), fertilizers are placed in the soil next to the root, instead of being broadcast (an inefficient technique, which indirectly leads to more GHG emissions). The UDP technique increases urea efficiency by 50%, decreases nitrogen loss and urea use, and significantly improves yield. This technique is now used in 500,000 ha of rice in Bangladesh (Roy & Misra 2003, Ladha et al. 2000, IFDC 2011). However, in Cambodia, the adoption of such technique was found to be very low due to the additional workload, cost of labor, and technical issues.

The growing prevalence of monoculture commercial crops in Thailand and later in Vietnam, Lao PDR, and Cambodia has raised questions about the sustainability of these systems often based on increased mechanization and increased use of inorganic inputs. Absence of a fallow period, the removal of crop residue, and the removal of organic matter weaken the farmed ecosystem. One option to reverse this trend is to promote cropping systems such as conservation agriculture that involve the rotation of crops, permanent vegetal covers, direct mulch seeding, and reduced tillage to improve the quality of soil organic matter and to promote nutrient availability for the crop. This system is flexible and can include the integration of pastureland in plains and the integration of local traditional crops in rotation with grains and/or forages.

Conservation agriculture (CA) has been successfully adapted in different environments, including upland farming systems, lowland areas in rice-based systems, and in commercial crop systems. In Lao PDR, improved pasturelands have been promoted based on planting *Brachiaria ruziziensis* in rotation with upland rice or soybean (NAFRI 2011). This system was later adopted in Xayaburi Province in Lao PDR where land preparation has been traditionally based on plowing and the burning of crop residues. Elsewhere in Lao PDR, Job's tear (*Coix lacryma-jobi*) and rice bean (*Vigna umbellata*) are used in rotation with rice or maize and help control weeds, limit erosion, and improve the physical and chemical properties of soil[19]. CA practices have also been successfully introduced into commercial and rice-based systems in Cambodia. Here CA cropping systems include a short term "bio pump" crop before the main crop is planted. The main crop can be rice, soybean, or maize, while the bio pump can be *Eleusine* or

[19] http://agroecologie.cirad.fr/pampa_et_projets/laos

*Cajanus*, which can be later used as pig feed. In western Cambodia the rotation of maize with *Stylosanthes* cover, followed by a rotation of *Stylosanthes* with soybean or cassava is found to be both successful and economically profitable. According to CA practitioners these methods can be applied and adopted by medium- to large-scale farmers.

The impact of herbicide use to create the mulch cover in CA systems is not well known. However, farm experiments and farm-based trials have tended to show that the volume of herbicides used in conservation agriculture is lower than in conventional practices. Additionally, the vegetal cover captures most of the herbicide's active substance before it percolates into the soil.

In the context of climate change, the development of CA is an option to improve the resilience of farming systems by integrating forage and grain production for livestock, by improving soil quality for sustainable agriculture, by reducing $CO_2$ emissions (with the absence of burning crop residue), and by promoting carbon sequestration into the soil (Corsi et al. 2012). With increased extreme rainfall events and storms, a permanent vegetal cover will help limit the loss of soil fertility and limit the degradation of the physical properties of the soils due to erosion. CA can help design sustainable production systems that are resilient to changing environmental conditions and extreme events.

## 15.4 REDUCING GHG EMISSIONS

Methane gas is an important GHG in agricultural systems coming largely from inundated rice fields and ruminant animals, which together produce almost half of human-induced methane emissions. Methane is produced by anaerobic microbes in soils that are deprived of oxygen due to continuous flooding. Increased atmospheric $CO_2$ and increased temperature both increase the amount of GHG emissions from rice fields (van Groenigen et al. 2012). It is estimated that rising $CO_2$ levels and warming will approximately double the GHG emissions from rice crops by the end of the twenty-first century. As suggested by van Groenigen et al. (2012), mid-season drainage of rice fields and replacing urea with ammonium sulfate can significantly reduce methane emissions. Based on this assessment and given the prevalence of rice in the LMB, reducing emissions from rice systems through improved water management and supplementary practices could be an important, integrated climate change adaptation and mitigation strategy.

SRI practices such as making paddy soils intermittently and mostly aerobic substantially reduces methane emissions (Nguyen et al. 2007). Nitrous oxide emissions (another GHG) related to organic fertilization will be limited in the case of SRI (Africare 2010) and will not offset the benefits from methane reduction. Mitigation of climate change using SRI also comes from the reduction of synthetic fertilizer use, which generally contributes to increased $NO_2$ (nitrous oxide) emissions during their manufacturing and transportation. The use of fewer manufactured fertilizers and/or improving the efficiency of fertilizer use at the field level (using UDP, for example) can reduce GHG emissions.

# 16 ADAPTATION OPTIONS

This section attempts to match the adaptation options discussed in the previous section to the specific conditions and requirements of the eight hotspots, based on the results of the CAM exercise and the use of the LUSET approach. Adaptation responses are proposed for the most vulnerable commodities highlighted in the CAM exercise for each hotspot. For each response, we define a timeframe, a possible interaction (positive or negative with other sectors) and the geographic scope. A tentative extrapolation at the ecozone level is given, based on the results of the Land Use Suitability Evaluation Tool results.

The adaptation options presented here are generic and not detailed. Before preparing on-farm trials, a precise and detailed diagnostic of the farming system will be required, as will an evaluation of the needs and capacity of the targeted communities in order to fine-tune the field level approach. Past experience with related interventions in the target communities have to be assessed as well in order to understand underlying drivers of success and failure.

## 16.1 KAMPONG THOM, CAMBODIA

Rice, soybean, and cassava are the most vulnerable commodities in Kampong Thom due to increased temperature and higher incidences of flood. A decrease in water availability will only severely threaten soybean crops.

**Table 18: Threats, vulnerabilities, and adaptation options for rice culture in Kampong Thom, Cambodia**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability | Adaptation Options |
|---|---|---|---|---|
| **Lowland rainfed rice and Irrigated rice** | Increased temperature | Higher temperatures will reduce yield and offset $CO_2$ fertilization | High | Heat-tolerant varieties<br>Shifting calendar to avoid the highest temperature peak in dry season<br>SRI techniques |
| **Lowland rainfed rice** | Flooding | Flood prone area around the Tonle Sap lake and central part of the province | High | Short term variety (early maturing) to avoid peak floods and to shift to double rice cropping<br>Drought-tolerant varieties<br>Shift to dry season crop<br>Dry season fish refuge in rice fields |

Adaptation options for rice at the farm level (Table 18) include access to heat tolerant seeds developed by IRRI[20] (an improved variety that can tolerate higher temperature) and a shift to a double rice cropping systems to avoid floods in the lower floodplain (Roth et al. 2012). The aim of this approach is to shift from traditional, deep-water rice cultivated during the flood period to double rice crops of shorter periods that avoid the peak flood. Using SRI techniques can improve yield and develop rice crops that are more resilient to extreme events. Introducing submergence-tolerant varieties might not

[20] http://www.irri.org/index.php?option=com_k2&view=item&id=9148:climate-ready-rice&lang=en

be a realistic option in all locations because the level of flooding will exceed the level of tolerance in some cases. The presence of frequent destructive floods will require a shift from a rainy season crop to a dry season crop when irrigation is possible. In addition, farmers are currently facing dry spells during the rainy season and the use of drought-tolerant varieties will help to reduce yield gaps due to severe drought.

**Table 19: Threats, vulnerabilities, and adaptation options for soybean and cassava in Kampong Thom, Cambodia**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability | Adaptation Options |
|---|---|---|---|---|
| **Soybean** | Increased temperature | Higher temperature will reduce yield | High | Adaption shift to other more heat-tolerant crops (e.g., maize)<br>Develop conservation agriculture |
| **Cassava and Soybean** | Flooding | Flood prone area around the Tonle Sap lake and central part of the province | High | Short term variety (early maturing) to avoid peak flood for cassava or shift to maize.<br>Shift cropping calendar for soybean or dry season crop |

Other threatened crops are soybean and cassava, which face the same threats of increased temperature and flooding (Table 19). Pilot testing of short-term varieties of cassava culture (7–8 months) has shown that such varieties can be planted in order to avoid periods of flooding. This approach will generate a lower yield and growth period might be too short to achieve an economically attractive yield. In order to avoid floods, the cropping system could also shift to the use of other crops, such as maize, which have a shorter growth cycle.

Soybean will face a decline in yield due to high temperatures and a late crop in the rainy season (after a first crop of maize or rice) will be at risk from flood. In addition, higher precipitation in the rainy season might jeopardize the harvest and increase the presence of pests. Shifting the cropping calendar to have an early soybean season in May would reduce potential losses from flood. Shifting to the use of more heat-tolerant crops like maize or cassava might be an option. Development of conservation agriculture with rotations of soybean, maize, or cassava with a plant cover (e.g., *Arachis pintoi* or *Stylosanthes* sp.) may also be a feasible option for medium-scale farmers that would improve the soil quality and diversify the cropping system. However, this option may require mechanization and increased use of herbicide.

Vegetable production in peri-urban areas or in areas well connected to markets can be supported with water saving and storage techniques like drip irrigation and water harvesting. These techniques can be implemented in small areas, like homestead gardens, for intensive farming in the dry season. Farmers could be able to learn from successful experiences with these approaches in other provinces of Cambodia including Svay Rieng and Prey Veng.

A potential benefit of these types of approaches is that investment requirements would be relatively small and implementation lead times would be relatively short when compared to other adaptation measures such as upgrading or installing new irrigation infrastructure. More detail regarding the expected timeframes for specific adaptation responses in Kampong Thom is provided in Table 20.

**Table 20: Adaptation planning for Kampong Thom, Cambodia**

| Level of Response | Short Period (next five years) | Medium Period (5 to 10 years) | Long Period (more than 10 years) |
|---|---|---|---|
| **Adaptation deficit** | On-farm initiatives, introduction of new short-term varieties<br>Introduction of drought-tolerant varieties | Introduction of heat-tolerant varieties | |
| **Additional adaptation** | Introduction of conservation techniques and SRI<br>Drip irrigation<br>Water harvesting | | |
| **Adaptation to induce system shift** | | Development or rehabilitation and improvement of irrigation schemes for a shift to dry season crop (rice, maize, soybean, etc.) | |

Shifting the cropping calendar to avoid floods will not affect other sectors, while the shift to conservation agriculture might reduce the area available for grazing. Shifting from soybean culture to maize or cassava will reduce soil fertility without further nitrogen fixation over the medium to long-term period. By providing access to water, the development of irrigation systems will create opportunities for integrated rice-fish culture. This development will increase wage labor availability in the dry season, which will give new opportunities to households that seasonally migrate for casual labor. To enhance rice-fish systems, flooded rice fields should include dry season refuges that work to increase fish stocks in rice fields during the flood season.

The geographical scope of the suggested adaption options is small. On-farm and community trials for the introduction of new varieties, cropping techniques, and water management practices should be designed for the community or commune level.

Up-scaling adaptation deficit responses could also be trialed at the ecozone level where similar threats and similar cropping systems exist. Climate suitability modeling shows similar responses for soybean, cassava, and maize within the ecozone. Shifting the cropping calendar or introducing heat-tolerant and/or drought-tolerant rice varieties are generic measures that are not geographically specific and could be considered for application in several ecozones.

## 16.2 MONDULIKIRI, CAMBODIA

In Mondulkiri, the main threats to the agriculture sector are increases in temperature in both the dry and rainy seasons and an increase of precipitation especially in October (Table 21). Adaptation measures similar to those suggested for Kampong Thom Province to cope with increased temperature and flooding could be tested. These include using heat-tolerant varieties, using short-term varieties to avoid the storm season, and adopting a double rice crop in the rainfed lowlands. The introduction of drought-tolerant varieties can help farmers cope with dry spells during the dry season.

At the household level, small-scale vegetable production can be integrated with water harvesting programs to diversify food production and improve food security. Access to the required inputs may be a constraint for communities in remote areas.

Water logging and local floods will necessitate improved drainage systems in rice-based systems. The SRI technique should be tested to improve the resistance of rice plants to storms. For upland rice, increased rainfall and storms will increase erosion rates. Direct seeding mulch-based cropping (DMC) is a potential option to limit erosion and increase soil quality. Examples of the successful application of these techniques can be found in Vietnam and the uplands of Lao PDR.

Soybean will become less suitable in this area due to higher temperatures and increased rainfall. Soybean monocultures could be adapted by incorporating the DMC technique with a cover crop or rotation based on conservation agriculture. Maize –*Eleusine* rotations, maize-*Cajanus* rotations, or planting of *Brachiaria sp*. are options for new cropping systems. Intermediary crops can also provide additional forage and grain for livestock. Both soybean and maize require harvesting before the peak rainfall in October. Similar adaptation measures are adequate for cassava monoculture crops, with diversified rotations over the years. Cash crops such as cassava, maize, and soybean can be rotated with a dry season forage crop. These techniques have been widely tested in Vietnam, Lao PDR, and other provinces of Cambodia and can be replicated in Mondulkiri.

Rubber suitability will be lower, and threats due to higher temperatures might generate an altitude shift requiring new plantations at higher altitudes. Diversifying to include Robusta coffee will not be possible due to low rainfall.

**Table 21: Threats, vulnerabilities, and adaptation options for rice culture in Mondulkiri, Cambodia**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability | Adaptation Options |
|---|---|---|---|---|
| **Rainfed rice** | Increased temperature<br><br>Storms and increased precipitation | Reduce yield with higher maximum temperature<br><br>More frequent storms and extreme precipitation can create waterlogging and damage crops | High | Heat-tolerant rice varieties<br>Early-maturing varieties, and double rice crop<br>Improving drainage systems<br>Erosion control and vegetal covers in uplands and slopes<br>SRI technique, multiple varieties<br>Drought-resistant varieties |
| **Soybean** | Increased temperature<br><br>Decreased water availability<br><br>Storms and increased precipitation | Water stress due to lower water availability<br>Reduced yield due to temperature higher than 35°C<br>More frequent storms and extreme precipitation can create waterlogging and damage crops | High | Shifting to temperature-tolerant and water stress-tolerant crops<br>Diversifying system with conservation agriculture |
| **Cassava** | Storms and increased precipitation<br><br>Increased temperature | | Medium to High | Improving drainage systems<br>Erosion control systems on slopes |
| **Rubber** | Increased temperature | More days above 35°C reduce growth and yield | Medium | Heat-tolerant variety |

As in Kampong Thom, the investment requirements of the adaptation strategies identified here would be relatively small and implementation lead times would be relatively short (Table 22).

**Table 22: Adaptation planning for Mondulkiri, Cambodia**

| Level of Response | Short Period (next five years) | Medium Period (5 to 10 years) | Long Period (more than 10 years) |
|---|---|---|---|
| **Adaptation deficit** | Introduction of new varieties (early maturing) and drought-tolerant varieties | Introduction of heat-tolerant varieties | |
| **Additional adaptation** | Introduction of the conservation technique and DMC with new crops and new crop rotation<br>Rainwater harvesting for small-scale vegetable production | Improving drainage systems in specific (waterlogged) lowland areas | |
| **Adaptation to induce system shift** | | | Altitude shift for rubber |

A longer process of planning and implementation will be required to improve the drainage systems in waterlogged areas, to introduce heat-tolerant varieties, and to shift the altitude for rubber plantations. However, the effect of increased temperature will not be immediate.

The introduction of forages within the crop rotation in DMC systems will benefit livestock. For example, cajun can be used as pig feed. Improving pastureland with *Brachiaria ruziziensis* provides pasture for cattle and buffalos. Improving the drainage capacities of rice fields will reduce the duration of floods and thus reduces the potential for rice-fish fishery. However, this type of fishery is uncommon and not economically important in this province. Drainage improvements will require scoping for the selection of specific highly vulnerable areas.

The introduction of new cropping techniques, crops succession, and crop rotation should be done at the farm and/or the community level. These technically oriented approaches can be later up-scaled at the ecozone level (mid-elevation and low-elevation ecozone).

## 16.3 KHAMMOUAN, LAO PDR

In Khammouan, increases in rainfall and flood will heighten the vulnerability of commercial and rice crops. Projected increases in temperature will affect rainfed rice culture (Table 23).

Increases in temperature will require the use of heat-tolerant rice varieties. The increase of temperature will be more important in lowland areas than in upland systems. For upland systems, increases in rainfall will lead to erosion, but DMC techniques could be implemented to reduce negative impacts to upland rice as well as commercial crops such as maize or cassava.

In lowlands, higher incidences of flash flooding will require either investment in a protection system in the most vulnerable areas or a shift to a more robust system such as tree plantations. Community-based forestry practices could be employed as one strategy to improve overall watershed management by encouraging reforestation of upland areas.

**Table 23: Threats, vulnerabilities, and adaptation options for rice and commercial crops in Khammouan Province, Lao PDR**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability | Adaptation Options |
|---|---|---|---|---|
| **Rainfed rice** | Increased temperature<br><br>Flooding, flash floods and storms | Increased temperature will induce sterility and lower yield | High | Heat-tolerant rice varieties<br>Submergence-tolerant varieties<br><br>Early maturing, and double rainfed rice crop in lowland<br>Shifting to dry season crop when irrigation is possible |
| **Cassava**<br>**Sugarcane**<br>**Maize** | Flooding, flash flooding and storms | 15 Days with 100 mm of rainfall or more with a maximum of 200 mm and high storm frequency will lead to floods and flash floods that will damage the crops | High | DMC and conservation agriculture in upland systems to limit erosion<br>Highlighting key vulnerable areas to flooding<br>Shift to more robust crops (e.g., tree plantations) |
| **Cassava, Maize** | Increased precipitation | Increased precipitation from April to November, maximum precipitation above 800 mm in June, July, and August. Threat will be accentuated on heavy soil prone to waterlogging. | High | Improve drainage system<br>Shift to more waterlogging-tolerant crops (sugarcane, rice, or eucalyptus)<br>Shift to early crop in April//May to avoid peak rainfall<br>Introduce DMC technique to increase resilience of cropping systems |

In lowlands, cassava and maize cultivated in the Xe Bang Fai plain and the Mekong Corridor will face water logging and will require improved drainage. Shifting to a dry season crop is recommended where irrigation is available. For maize, shifting the cropping calendar to accommodate an early wet season crop will prevent loss during peak rainfall. Diversifying into crops that are more tolerant to water logging such as eucalyptus plantations, sugarcane, or lowland rainfed rice is also worth considering.

Water management capacity in the Xe Ban Fai plain is stronger than in the rest of the province. In this area, the adoption of SRI techniques that involve the sequential drainage and flooding of rice fields is an option to mitigate GHG emissions and improve plant resilience to storms. Farmers can take advantage of projected increases in precipitation by adopting water harvesting and horticulture practices. Residual water could be employed for use in homestead gardens and market access has already been developed with access to Thailand and Vietnamese markets.

The introduction of the conservation agriculture techniques and short-term rice varieties to avoid peak flood periods could be implemented in relatively short timeframes (Table 24). Introduction of the DMC technique will also improve the natural systems and reduce impacts from erosion. There are successful examples of conservation agriculture in Xayaburi and Champasak Provinces that could inform implementation in Khammouan[21].

Testing of submergence-tolerant and short-term varieties could also be adopted within relatively short timeframes and could yield significant benefits as the area is already being negatively impacted by flood. Adopting new heat-tolerant varieties is not as urgent because the anticipated changes in climate that may necessitate such measures will be progressive and set in over time. Adaptation options that require new infrastructure will require more planning and longer lead times to implement.

These adaptation options could be up-scaled at the ecozone level for the uplands, while adaptation in Xe Ban Fai and the Mekong corridor areas are more limited to this province specifically as the climate change threats in these areas will be more geographically specific.

**Table 24: Adaptation planning for Khammouan, Lao PDR**

| Level of Response | Short Period (next five years) | Medium Period (5 to 10 years) | Long Period (more than 10 years) |
|---|---|---|---|
| **Adaptation deficit** | Introduction of new varieties (early maturing, submergence tolerant) | Introduction of heat-tolerant varieties | |
| **Additional adaptation** | Introduction of conservation technique and DMC with new crops and new crop rotation<br>SRI technique | Improving drainage systems in specific lowland areas (waterlogged regions) and investment in protection systems | |
| **Adaptation to induce system shift** | Shift to non-rice cropping system | Shift to waterlog-tolerant crops, plantations, or new cropping calendar<br>Shift to irrigated system in areas heavily affected by floods | Shift to irrigated system in areas heavily affected by floods |

[21] http://agroecologie.cirad.fr/pampa_et_projets/laos

## 16.4 CHAMPASAK, LAO PDR

Increased temperatures and rainfall will affect coffee plantations on the Bolaven Plateau and irrigated rice in the dry season in addition to maize, cassava, and lowland rainfed rice (Table 25).

**Table 25: Threats, vulnerabilities and adaptation options for rice and commercial crops in Champasak Province, Lao PDR**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability | Adaptation Options |
|---|---|---|---|---|
| **Rainfed rice** | Increased temperature<br><br>Storm | Increased temperature will induce sterility and lower yield<br><br>Increased probability of extreme rainfall events and storms that can damage rice crops and generate flashfloods | High to Very High | Heat-tolerant and submergence-tolerant rice varieties<br><br>Early maturing and double rainfed rice crop in lowlands<br>Shifting to dry season crop when irrigation is possible<br>Diversification to other crops (orchards, bamboo)<br>SRI technique |
| **Irrigated rice** | Increased temperature | Increased temperature will induce sterility and lower yield | High | Heat-tolerant rice varieties |
| **Cassava**<br>**Maize**<br>**Robusta coffee** | Increased precipitation<br><br>Storms (flash flooding) | Increased probability of extreme rainfall events and storms that can damage crops and generate flashfloods and/or waterlogging | High | DMC and conservation agriculture in upland systems which limit erosion, as well as in plain monoculture systems<br>Highlight key vulnerable areas<br>Diversification of monoculture farms |

As in other provinces, increases in temperature by 2050 will require the development and use of heat-tolerant rice varieties. Increased incidence of storms will generate more frequent and intense floods in the lowlands and, as a result, a shift in the cropping calendar to shorter growth periods should be promoted in order to reduce the risk of crop damage. Shifts to dry season crops with supplementary investment in irrigation systems could be considered as an adaptation option, but such farming systems will face high temperatures in the late dry season to which some crops might not be well adapted.

In both upland and plateau regions, increased precipitation and storms will jeopardize the current production systems. In the case of coffee plantations, increased precipitation will lead to increased incidence of water logging and disease necessitating improved drainage capacity. Traditionally, coffee production in Lao PDR is a rainfed, smallholder, and monoculture system. Diversification options could be considered including other types of plantation (cashew or black pepper) or annual crops that can sustain water logging and heavy rainfall. Additional soil management measures to prevent erosion and improve organic fertilization will also be required. Intercropping of legumes, living barriers to flash floods, vegetal cover, and mulching to limit transpiration and increase water infiltration are additional technical options that can be explored in coffee plantations. In the dry season, increases of temperature will require either mechanical shading or biological shading by intercropping with trees. With significant rainfed water resources, rainwater harvesting and water storage ponds for multiple purposes should be explored to facilitate irrigated agriculture.

Conservation agriculture has been tested on the Plain of Jars in Lao PDR (NAFRI 2011) with a rotation of pastureland and upland rice. Other rotations such as Job's tear (*Coix lacryma-jobi*) and rice bean (*Vigna umbellata*) in rotation with rice or maize could be tested to try to improve the yield and soil properties. In the lowlands, which are prone to water logging, cassava can be replaced by crops with great water tolerance such as rice (flood-tolerant varieties, if necessary), sugarcane (mild tolerance), or eucalyptus plantations. These crops could also be considered as alternatives to maize, which is projected to suffer from heavy rainfall and water logging in the late rainy season. A shift in the cropping calendar to avoid the peak rainfall period, as well as shifting to a dry season crop if there is access to irrigation, will reduce the threats related to heavy rainfall and storms.

Rubber plantations, which are now expanding in the province, will be affected by higher rainfall. By 2050, Champasak Province will no longer be a highly suitable area for rubber and, as a result, consideration should be given to other perennial or annual crops.

Specific timeframes for adaptation responses in Champasak Province are presented in Table 26.

**Table 26: Adaptation planning for Champasak, Lao PDR**

| Level of Response | Short Period (next five years) | Medium Period (5 to 10 years) | Long Period (more than 10 years) |
|---|---|---|---|
| **Adaptation deficit** | Introduction of new varieties (short-term rice) | | Introduction of heat-tolerant varieties |
| **Additional adaptation** | Introduction of conservation technique and DMC with new crops and new crop rotation<br>Introduction of soil, shade, and drainage management techniques in coffee production areas | Improving drainage systems in specific (waterlogged) lowland areas and incorporating protection systems | |
| **Adaptation to induce system shift** | Diversification of production from coffee monoculture to more diversified crops<br>Rainwater harvesting and development of vegetable production | Shift to irrigated systems in areas heavily affected by flood | Shift to irrigated systems in areas heavily affected by flood |

The development of irrigation systems and more regular access to water will create opportunities for aquaculture including integrated rice-fish systems. DMC and conservation agriculture can generate high quality pastureland and grain for livestock, depending on the crop rotation chosen. These approaches will also provide higher fauna and flora biodiversity in the soil and will enhance the resilience of the agro-ecosystem.

In general the adaptation measures discussed above could be applied to the whole ecozone. However, measures identified for coffee and rubber are more suited to the specific conditions for these crops in this province.

## 16.5 SAKON NAKHON, THAILAND

In Sakon Nakhon increases in rainfall, temperature and risk of flooding are the key risks to the agriculture sector (Table 27).

**Table 27: Threats, vulnerabilities and adaptation options for rice and commercial crops in Sakon Nakhon, Thailand**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability | Adaptation Options |
|---|---|---|---|---|
| **Lowland rice** | Increased temperature | Increase of temperature (increase of 10% of days above 35°C) | High | Heat-tolerant and submergence-tolerant rice varieties<br>Early maturing and double rainfed rice crop in lowlands<br>Drought-resistant varieties<br>SRI technique<br>Diversification with dry season vegetable crop |
| **Cassava** | Increased precipitation | Total precipitation during the growth cycle will be above the upper limit (>2,300 mm), with total precipitation 50% higher in dry season and higher than the baseline in rainy season | High | Shifting to rice or sugarcane or other more waterlog-tolerant crop |
| | Flooding | Heavy rainfall from May to November can increase flood intensity and frequency | | |
| **Rubber** | Increased temperature | Average maximum temperature will be above the optimum for more than 10 months (90% of the days) | High | Heat-tolerant variety<br>Intercropping with vegetables |

Rice technology to improve yields, including the use of better fertilization practices, the use of heat-tolerant varieties and the use of submergence-tolerant varieties in flood-prone areas could be trialed in place of existing practices. In both rainfed and irrigated areas, early maturing crops can be tested as a way to modify the crop calendar and accommodate a double rice crop. SRI techniques can be used to close yield gaps and offset negative impacts arising due to increased temperature and water scarcity.

Farmers with access to irrigation could also diversify into dry season vegetable crops using residual water and supplementary irrigation. Small-scale water storage techniques, such as percolation tanks, mini-tanks or small-scale dams can also be used to support additional crops in the dry season. Improved access to water in the dry season could facilitate drip and additional horticulture production.

Cassava will be less suitable in this province due to higher rainfall. Shifting to other crops might be necessary in lowlands and poorly drained areas, where water logging will be detrimental to the crops. Shifting to more waterlog-tolerant crops such as rice or eucalyptus plantations can be considered.

Higher temperatures, rainfall, and periods of drought period before harvesting will affect sugarcane yield. Considering the crop's importance to the provincial economy, adaptation measures that involve better fertilization management and improved drainage capacity will be required in order to limit soil-borne diseases. Farms with access to irrigation will suffer less from those threats.

Increased temperature will affect rubber plantation productivity. The development of heat-tolerant varieties will be necessary in the future but soil conservation and water storage techniques involving permanent soil cover can help to reduce impacts from droughts, flooding, and erosion during heavy rainfall episodes. Intercropping with cassava during the first three years of the rubber plantation, and later with vegetable production is an option for productive diversification.

Specific timeframes for adaptation responses in Sakon Nakhon Province are presented in Table 28.

**Table 28: Adaptation planning for Sakon Nakhon, Thailand**

| Level of Response | Short Period (next five years) | Medium Period (5 to 10 years) | Long Period (more than 10 years) |
|---|---|---|---|
| **Adaptation deficit** | Introduction of new varieties (early maturing rice, submergence-tolerant and drought-tolerant rice) | Introduction of heat-tolerant varieties (Rice/Rubber) | |
| **Additional adaptation** | SRI technique<br>Introduction of dry season vegetable crop in rice system<br>Vegetable–forestry system<br>Rainwater harvesting and horticulture/drip irrigation | Improving drainage systems in specific (waterlogged) lowland areas | |
| **Adaptation to induce system shift** | Shift to flood/waterlog-tolerant crops | | |

Development of a water storage system can support small-scale aquaculture production, such as catfish production (which has a short cycle). The SRI and water-saving techniques used in rice cultivation can also support other sectors that use water resources and will reduce conflicts for water resources. The introduction of new vegetable crops in rotation with rice or other inter-cropping techniques will support food security and household diversification of income.

Technical adaptation responses will depend on local agro-ecological conditions. A shift from cassava crops to more waterlog-tolerant crops will be needed in poorly drained areas. Integration of dry season vegetable techniques can be implemented in irrigated areas and in areas with high water retention capacity in the soil. Water storage techniques will be suitable only in specific areas with the appropriate, poorly drained soil. Culture on sandy soils can receive specific treatments of green mulch and clay.

The intercropping technique, the introduction of dry season vegetable crops and techniques related to rice production can be up-scaled to the region in low elevation ecozones, if specific similar characteristics exist (soil, topography, and access to irrigation).

## 16.6 CHIANG RAI, THAILAND

In Chiang Rai Province, projected increases in temperature will constrain rice and rubber cultivation in low altitude areas and litchi orchards in uplands (Table 29).

**Table 29: Threats, vulnerabilities and adaptation options for rice and commercial crops in Chiang Rai, Thailand**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability | Adaptation Option |
|---|---|---|---|---|
| **Lowland rice** | Increased temperature | High temperature in October, during the ripening stage. Temperature above 35°C induces sterility and reduces the number of grains. | High | Shifting calendar<br>Early maturation rice and using residual water for a short crop<br>Developing SRI technique<br>Heat-tolerant varieties |
| **Litchi** | Increased temperature | Relative minimum temperature will increase by 20% in December, limiting flowering. | High | Altitude shift<br>Shifting agro-forestry system to less heat vulnerable trees |
| **Rubber** | Increased temperature | Maximum temperature over the optimum in both dry and wet season | High | Altitude shift<br>Intercropping and improve soil management practices |

Irrigated and rainfed lowland rice culture will require the use of heat-tolerant varieties in the future. For water saving purposes, SRI techniques could be adopted in areas with good water management capacities. In flood-prone areas, early maturing rice can be tested to avoid peak rainfall and flood season. In rainfed systems, early maturing rice in succession with a short crop (peanuts or legumes) that uses residual water can be tested. As in other areas with lowland rainfed systems, testing different duration varieties in different plots can reduce the vulnerability to climate variability and early flooding. The horticulture sector, which is well developed in Chiang Rai, can be supported with rainwater harvesting and drip irrigation techniques for small-scale farmers, if the technology is not yet available.

The province will not be affected by storms but some flood-prone areas will be impacted due to higher rainfall. In these specific zones, submergence-tolerant rice varieties and shifting the cropping calendar of maize and soybean will be necessary in order to reduce vulnerability to flood.

Rubber culture will also face constraints due to higher temperatures. However, with available uplands, rubber culture in this province might shift to higher grounds. In their current location, improved soil and fertilization management of rubber plantations by using vegetal cover will mitigate decline in yield due to increased temperature.

Over the long-term, litchi culture will require an altitude shift to allow flowering. Existing litchi plantations will need to be converted to another production system if no heat-tolerant varieties are found. This conversion or shift of production systems will require additional investigation.

Upland farming systems, which are not as threatened by increasing of temperature and rainfall, can apply soil conservation techniques with vegetal cover to limit erosion. Conservation agriculture practices could also be employed to improve soil quality, improve yield, and contribute to erosion and flash flood control.

An altitude shift in rubber and litchi plantations might encroach on forested areas and contribute to deforestation, increased erosion, and impacts on watershed hydrology. Other measures, like SRI, might limit rice field fisheries in lowlands, but will increase water saving and water efficiency. Dry season crops and additional grain crops in rotation with rice will increase diversification of production but might limit the grazing areas for livestock. The development of conservation agriculture in uplands, however, can improve pastureland and forage production with *Brachiaria ruziziensis* or *Cajanus* integrated into the rotations.

Specific timeframes for adaptation responses in Chiang Rai Province are presented in Table 30.

**Table 30: Adaptation planning for Chiang Rai, Thailand**

| Level of Response | Short Period (next five years) | Medium Period (5 to 10 years) | Long Period (more than 10 years) |
|---|---|---|---|
| **Adaptation deficit** | Introduction of new varieties (early maturing rice, submergence-tolerant rice)<br>Drip irrigation | | Introduction of heat-tolerant varieties (rubber/litchi) |
| **Additional adaptation** | SRI techniques<br>Introduction of dry season vegetable crop in rice system<br>Shifting calendar for maize and soybean in flood-prone areas | | |
| **Adaptation to induce system shift** | | Altitude shift for rubber and litchi<br>Conversion of litchi plantations | |

SRI techniques and lowland adaptation techniques will likely be contained to this specific agro-ecological zone, where the threat from increased temperature will have the highest impact. Altitude shifts and conservation agriculture will be applied on slopes and upland areas. These adaptation techniques can be applied in mid- and high-elevation ecozones in Thailand, Lao PDR, and Vietnam according to the existing threats and existing agriculture systems.

## 16.7 GIA LAI, VIETNAM

Gia Lai is projected to experience increases in temperature and additional extreme rainfall events and storms and, as a result, rice, coffee, and commercial crops will face new threats (Table 31).

With increasing temperatures, integrated adaptive measures need to be identified at the crop, farm, and landscape levels in order to adapt to and to mitigate heat stress and related irrigation water shortages. For coffee crops, the threat of increased temperatures will be more severe due to cumulative impacts resulting from additional problems that farmers will encounter. These include deforestation, ground water over-exploitation, land degradation, and the heavy application of chemical fertilizers from intensive production (Haggar and Schepp 2011).

Adaptation options should focus on water-use efficiency and the mitigation of heat stress. Currently, farmers over use water from both surface and ground resources for irrigating coffee in the dry season by as much as two to three times the recommended rates (D'Haeze 2003 cited in Haggar and Schepp 2011). Therefore, improved irrigation practices are necessary to help farmers mitigate water shortages and high evapotranspiration rates in the dry season. Currently, farmers mostly produce coffee under an intensive monoculture pattern. To improve the sustainability of the production system, soil cover management and inter-cropping with annual crops (e.g., legumes) or fodder grasses can reduce water loss through evaporation, increase water filtration, and maintain soil fertility (Tacio, 1993). Organic fertilization will also be essential for maintaining both the fertility and the water-holding capacity of soils.

**Table 31: Main threats and vulnerabilities and adaptation options for crops in Gia Lai Province, Central Highlands, Vietnam**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability | Adaptation Option |
|---|---|---|---|---|
| **Robusta coffee** | Increased temperature | Maximum temperature exceeding 32°C, which is a sub-optimal condition for Robusta coffee. In the dry season, there will be direct heat stress and indirect water stress, reducing growth and yields. | High | Shading and mulching<br>Inter cropping<br>Altitude shift<br>Improve irrigation efficiency techniques |
| **Cassava**<br>**Maize** | Storm, floods and flash floods | The central highlands are vulnerable to flash floods (World Bank 2011). Flash floods are related to storms or heavy rains in upland and/or upstream areas in July-September with high rainfall. Impacts are water logging and debris that may damage the crops significantly in the early growth, flowering or harvesting stages. | High | Establishment and/or improvement of flash flood management systems<br>Conservation agriculture<br>Shift to rubber plantation or agro-forestry systems |

Shade management for coffee crops can employ a range of shading trees. Shading is usually applied in organic coffee farms where coffee is grown with diverse traditional (leguminous or drought-tolerant) trees that deliver a range of products including medicinal, timber, firewood, fruit, animal feed, and/or green manure. This option will be successful within the Vietnamese coffee sector if the producer targets the organic market, with access to premium prices. Diversification of production for monoculture farmers is a way to reduce their vulnerability to extreme climate events. Intercropping with rubber, black pepper, cashew, or *Eucalyptus acacia* are options for crop diversification that mitigate threats in the future (Marsh 2007).

Upland-based cropping systems with cassava will require conservation methods for erosion, using vegetal cover, or the rotation of legumes to restore soil fertility. Shifting to rubber plantations is also an option on steep slopes, as recommended by The Western Highlands Agro-forestry Science & Technical Institute (*WASI*). It would involve a transition phase of inter-cropping rubber and cassava.

In lowlands threatened by increased temperatures in April and May and potential floods, SRI techniques can be applied to overcome water shortages and reductions in yield due to increased temperature. The SRI technique can be applied to both dry and rainy season crops. Peak temperatures in April–May can be avoided by using early maturing crops in the dry season and delayed rainy season crops. In flood-prone areas, testing the use of either early maturing crops to avoid the flood season or the use of submergence-tolerant rice will depend on the farming system and the preference of the farmer. Additional short-term crops (peanuts or legumes) can be tested in rainfed lowland area, based on the amount of residual water available. Small-scale water harvesting techniques should be tested at the community and individual levels in order to supplement rainfed crops or to promote dry season vegetable production in homestead gardens.

Cash crops such as maize and cassava are predicted to be vulnerable to floods and storms. The vulnerability will be higher in lowlands compared to slopes. Both structural and non-structural measures are necessary for adaptation. Non-structural measures such as new improved varieties with short maturity that have high water tolerance need to be tested and evaluated on farms before scale-up. In addition, no-tillage techniques, vegetal covers and agro-forestry plantations on slopes and on hills will reduce damages caused by extreme climatic events and mitigate their intensity (Tacio 1993). Structural options linked to infrastructure investments will also be necessary to mitigate extreme floods and storms. Specific measures could include contour ditches, dikes, drainage canals, and rainwater capturing reservoirs (McElwee 2010).

In the Central Highlands, livestock is less important than in the other hotspots. Therefore, the integration of pasture and/or grain production within the farming system is not a priority. Similarly, aquaculture and fisheries resources are not essential to local livelihoods in this area. The main impact on other sectors will be the expansion of or the altitude shift in upland rice, coffee, and rubber to higher altitudes, resulting in encroachment on forested areas. The development of water-saving techniques will reduce conflicts over water resources, which are currently rising in this region of the LMB.

Specific timeframes for adaptation responses in Gia Lai Province are presented in Table 32.

**Table 32: Adaptation planning for Gia Lai Province, Central Highlands, Vietnam**

| Level of Response | Short Period (next five years) | Medium Period (5 to 10 years) | Long Period (more than 10 years) |
|---|---|---|---|
| **Adaptation deficit** | Mulching and improved water-use efficiency in coffee production<br>New varieties (coffee, maize, and cassava) with short-term maturity | Organic fertilizer/green manure application<br>New improved varieties of coffee, maize, and cassava | |
| **Additional adaptation** | SRI (lowland)<br>New improved varieties and conservation agriculture techniques in uplands<br>Rice short-crop rotation in rainfed lowland | Shading in coffee plantations (toward organic coffee) and application of soil management practices for maize and cassava crops | Infrastructure to catch and reserve rainwater and to prevent damages from floods at the community level |
| **Adaptation to induce system shift** | Crop diversification and sustainable cultivation practices through agro-forestry systems | Crop diversification by integrating with "climate-tolerant" crops like rubber, cashew, pepper, etc. | Altitude shift for coffee |

After testing, rice-based adaptation options can be extrapolated and adapted to the mid- and high-elevation ecozones. Erosion control techniques can be expanded in farming systems that are based on slopes. New techniques in water management for coffee production will be specific to the Central Highlands. Soil conservation and shading techniques can be applied to rainfed systems.

## 16.8 KIEN GIANG, VIETNAM

Rice-based systems in Kien Giang will face threats from increased temperature, floods, and saline water intrusion (Table 33). Both irrigated and rainfed rice cropping systems will be severely affected.

Dry season rice and early wet season rice will be affected by heat and increased minimum temperature. In this context, heat-tolerant varieties will be necessary over the medium to long term. Shifting the cropping calendar to avoid the April-May period when maximum temperature peaks could improve yields. In irrigated and rainfed systems, SRI techniques can be applied to mitigate declining yields and GHG emissions, since farmers' water management capacities are high in the Mekong Delta.

**Table 33: Main threats, vulnerabilities, and adaptation options for crops in Kien Giang Province, Vietnam**

| Vulnerable Crop | Threat | Impact Summary | Vulnerability | Adaptation Option |
|---|---|---|---|---|
| **Irrigated rice** | Increased temperature | About 50% of days of maximum temperature are expected to exceed the comfort zone in both the wet and dry season. An increase in temperature in the early rainy season can cause heat stress, reducing rice tilling and yields. | High | Heat-tolerant varieties<br><br>Shifting calendar to avoid April–May peak temperature |
| **Rainfed rice**<br>**Irrigated rice** | Sea level rise & saline water intrusion | Sea level rise causes saline intrusion inland through canal systems in dry season, which salinizes irrigation canal water and paddy soils and increases flood amplitude in the rainy season. The saline intrusion shortens favorable cropping period and constrains growth and yields of rice crops. The increase in flood amplitude will lead to water inundation or submergence, particularly in periods of locally high rainfall. | High to Very High | Saline-tolerant and/or short-growth duration varieties, adaptive rice farming practices (washing saline water, rice transplantation, agrochemical application, etc.), rotational rice-shrimp/upland crop farming, fish culture in flooded rice fields, salinity and flood management structures |

Adaptation to SLR will require a combination of technical changes and infrastructure development to protect crops from saline water intrusion and floods. Saline-tolerant and short-growth duration rice varieties with high yields and good-grain quality will be of great importance to farmers. In addition, other adaptive rice farming practices need to be undertaken including appropriate land preparation for washing saline from the soil and the application of potassium, which enhances rice tolerance to saline intrusion. Moreover, landuse plans can be modified and areas currently implementing two or three rice crops can shift to rice-shrimp (or short-growth duration upland crops) rotations in case the saline water intrusion level increases. In these systems, rice is cultivated in the rainy season, following a single or double shrimp crop in dry season. It requires modification of the rice plot, with a ditch around the plot required for shrimp culture. In the rainy season, saline deposits and sediments are flushed away with the first rains before rice is transplanted or broadcast.

In freshwater areas with the increase in flood amplitude, early maturation rice can be used to reduce the risk of losing the crops to floods. Additional fish culture in individual flooded rice fields between the second rice harvest and the dry season crop in December could be an option that will add value to flooded rice fields. In the dry season, drip irrigation for vegetable production can be tested in areas where freshwater is limited. This technique can be combined with water storage and/or rainwater harvesting to allow for a vegetable crop.

Rice-shrimp culture systems will enhance the synergy between agriculture and aquaculture systems, as will fish culture in flooded rice fields. While rice-shrimp systems are well developed and were found to be a sustainable production system for farmers in the Mekong Delta, fish culture in flooded rice fields is not as well practiced and faces economic profitability issues (Joffre and Sheriff 2011). The development of inundation and flood management structures such as dikes and sluices will be necessary to minimize risks induced by SLR for rice-based farming systems. Lastly, the rehabilitation and reforestation of the mangrove belt can help to reduce erosion caused by wave action on sea dikes and can minimize the maintenance cost of such infrastructure.

Specific timeframes for adaptation responses in Kien Giang Province are presented in Table 34.

**Table 34: Adaptation planning for Kien Giang Province, Mekong Delta, Vietnam**

| Level of Response | Short Period (next five years) | Medium Period (5 to 10 years) | Long Period (more than 10 years) |
|---|---|---|---|
| **Adaptation deficit** | Heat-tolerant and saline-tolerant rice varieties and adaptive rice farming practices | Salinity and flood management infrastructure at the farm and community level (small-scale) | Salinity and flood management and irrigation/drainage infrastructure at provincial and inter-provincial scale<br>Establishment of community-based natural resource management |
| **Additional adaptation** | Improved saline and submergence-tolerant varieties and SRI techniques | Salinity and flood management infrastructure at the community level (small-scale)<br>Catching and reserving rainwater for irrigation in the dry season<br>Rehabilitation and development of mangroves | |
| **Adaptation to induce system shift** | Shift to alternate rice-shrimp/upland crops<br>Shift to dry season vegetable production with drip irrigation | | |

These changes in the production systems will be progressive and dependent on the presence of flood and saline protection infrastructure. The duration of both saline intrusions and floods will determine the spatial arrangement of the landuses and cropping patterns. These adaption options can be up-scaled in similar ecozones that are influenced by both floods and saline water intrusion.

# 17 CONCLUSION

The main adaptation options presented in this report are summarized in Table 35.

**Table 35: Main adaptation options for uplands, lowland rainfed and irrigated zones**

| | Uplands | Lowland Rainfed | Lowland Irrigated |
|---|---|---|---|
| **Increased temperature** | Altitude shift<br>Heat-tolerant varieties | Heat-tolerant varieties<br>Shift in cropping calendar to avoid peak temperature<br>Early maturation varieties<br>Shading | Heat-tolerant varieties<br>Shift in cropping calendar to avoid peak temperature<br>Early maturation varieties |
| **Drought** | Mulch/Permanent cover | Mulch/Permanent cover<br>SRI technique<br>Small-scale water storage<br>Intercropping<br>Conservation agriculture<br>Drought-tolerant varieties<br>Drip irrigation | SRI technique<br>Drip irrigation |
| **Increased rainfall, storms and extreme events** | Mulch/Permanent cover<br>Shift cropping calendar | SRI technique<br>Improve drainage<br>Shift to water logging-tolerant varieties<br>Rainwater collection | SRI technique<br>Improve drainage<br>Shift to water logging-tolerant varieties |
| **Floods** | Shift cropping calendar | Shift cropping calendar<br>Early maturation varieties<br>Submergence-tolerant varieties | Shift cropping calendar<br>Early maturation varieties<br>Submergence-tolerant varieties<br>Shift to dry season crop only<br>Fish culture in flooded rice fields<br>Flood protection infrastructure |
| **Saline intrusion** | | Shift to rice-shrimp system<br>Early maturation and saline-tolerant varieties | Shift to rice-shrimp system<br>Early maturation and saline-tolerant varieties |

Adaptation options presented in this report are based on previous experience in the region. Each of the technical options identified is oriented towards developing more resilient production systems. Interactions with other sectors have not been explored in depth; particularly interactions with the economic sector. Extrapolation to a larger scale of crops or a production system shift is not an easy task since new varieties tolerant to climate stress, market drivers, and national policies concerning landuse or agriculture can have a larger impact on the local agriculture sector compared to changes in rainfall patterns or temperatures.

Production systems are extremely diverse when explored at the farm level, with variations existing in the diversity of soils, water management capacity, access to markets, knowledge, inputs, and equipment. It is difficult to draw definitive conclusions and adaptation strategies for an entire province and even more so for an entire ecozone. Our approach was to highlight the key threats and to propose adaptation solutions and directions that can be investigated for consideration as applied adaptation strategies suited to a particular risk profile. The findings and recommendations proposed in this report need to be validated at the community level and discussed with local experts before the design of tailored adaptation measures.

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# ANNEXES CAM

- CHIANG RAI CROP VULNERABILITY ASSESSMENT – CAM
- SAKON NAKHON CROP VULNERABILITY ASSESSMENT – CAM
- KHAMMOUAN CROP VULNERABILITY ASSESSMENT – CAM
- CHAMPASAK, CROP VULNERABILITY ASSESSMENT – CAM
- KAMPONG THOM, CROP VULNERABILITY ASSESSMENT – CAM
- MONDULKIRI, CROP VULNERABILITY ASSESSMENT – CAM
- KIEN GIANG, CROP VULNERABILITY ASSESSMENT – CAM
- GIA LAI, CROP VULNERABILITY ASSESSMENT – CAM

# 18 CHIANG RAI CROP VULNERABILITY ASSESSMENT – CAM

## 18.1 UPLAND RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | The critical temperature will not be reached during the entire crop, with less than about 10% to 12% of the days above 35°C.<br>High temperature in October, during ripening stage might have an impact. | **Medium** | Medium[22] | Medium | Increase in temperature in the rainy season might affect rice growth during the different stages of the culture resulting in a lower yield. | High[23] | Medium | |
| Increase in precipitation | Maximum precipitation up to 317 mm. | **Low** | Low[24] | Low | Water logging or flooding will not affect upland rice. Drought period will not be increased. The impact will be positive. | High[25] | Medium | |

[22] Increase in Temperature in the rainy season can affect rice growth and yield. Temperature exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperature will reduce the number of grain (Sheehy et al. 2006). However, rice can grow in warm conditions up to 36°C and sustain a mean temperature of the warmest month up to 42°C. The highest vulnerability is during the ripening stage with a lower tolerance to high temperature (above 30°C).

[23] Internal adaptive capacity is high, with capacity to grow in warm temperature. Critical temperature is 36°C at some growth stages and can sustain a mean temperature of the warmest month up to 42°C.

[24] Can affect rice growth and yield if severe rain happens during the cultivation period, e.g., abnormal climatic event (usually related to storm event). Rice can grow with up to 650 mm per month (here maximum is up to 317 mm).

[25] Range of suitable rainfall per month is wide from 100 to 650 mm per month.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Decrease in water availability | Reduced water availability in August to September at the end of the rainy season of 1% only.<br>Can generate water stress during ripening stage. | **Low** | High[26] | Medium | Can affect yield if water stress happens during flowering.<br>Can generate water stress during ripening stage. | Low[27] | Medium | |
| Drought (in rainy season, different from baseline) | Late season, in November before harvesting with precipitation potentially below 50 mm.<br>Reduced water availability in August to September at the end of the rainy season of 1% only. | **Low** | High[28] | Medium | Depending on the length of the dry spell, impact can be severe with yield reduction | Low[29] | Medium | Will affect negatively HH food security |
| Storms | Daily precipitation above 160 mm can happen and increase erosion and affect crops on steep slopes. Storm frequency low (0–2). | **Very Low** | Low[30] | Low | Chiang Rai Province is located far from the typhoon route. | High[31] | Low | Will affect negatively HH food security |
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Low[32] | Medium | Low due to other limiting factors | High[33] | Medium | Improve HH food security |

26 Reduced water availability can generate water stress during ripening stage.

27 Low internal capacity; medium external capacity with the use of drought resistant varieties and using mulch of vegetal cover. But rainfall over 50 mm per month can still be enough to achieve a yield.

28 Dry spell in the rainy season can affect rice yield and abnormal rainfall pattern can generate water stress in rainfed system. Rainfall needs to be over 50 mm per month.

29 Low internal capacity; medium external capacity with the use of drought resistant varieties and using mulch of vegetal cover. But rainfall over 50 mm per month can still be enough to achieve a yield.

30 Strong wind might damage the rice, as well as erosion. Storms during harvest might be an issue and excessive rainfall might affect the crop.

31 Range of suitable rainfall per month is wide from 100 to 650 mm per month.

32 Increased $CO_2$ level will increased rice yield (Krishnan 2007), however it will depends on other limiting actors such as nitrogen fertilization. We considered the sensitive as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

33 Internal and external capacity are high and farmers can benefit from the increase of $CO_2$ concentration by using adequate fertilization and rice field management and increase their rice yield.

## 18.2 LOWLAND RAINFED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | 10% to 12% of the days above 35°C. High temperature in October, during ripening stage might have an impact in the case of long term rice varieties. | **Medium** | High[34] | High | Increase in temperature in the rainy season might affect rice growth during the different stages of the culture resulting in a lower yield. | Low[35] | High | |
| Increase in precipitation | More water available from May to August. No false start of the monsoon observed in May or June, reducing the vulnerability of losing the crop. | **Low** | Low[36] | Low | Exposure is low and more rainfall might reduce water stress | Medium[37] | Medium | |
| Decrease in water availability | Increased water stress due to higher temperature in August to September.<br>In October, water availability is reduced. But intensity is very low with a decrease of 1%. | **Low** | High | Medium | Can generate water stress during ripening stage | Low[38] | Medium | |

34 Temperature exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperature will reduce the number of grain (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

35 External adaptive capacity is low, with lack of access to new varieties and extension services. Internal adaptive capacity is high, with capacity to grow in warm temperatures, critical temperature is 45°C at some growth stages, but with negative impact on yield.

36 Submergence of lowland rainfed rice due to extreme rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield of 21% (Yoshida 1981).

37 External adaptive capacity is low, with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high, traditional lowland rainfed rice is more adapted to submergence compared to HYV rice.

38 Difficult access to drought-resistant varieties

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in water availability | No significant change. | **Low** | Very Low[39] | Low | Low potential impact. An increase in soil water availability will not be a threat and will benefit the plant growth and limit water stress. See increase of precipitation or storm for water related threats. | High[40] | Medium | |
| Drought (in rainy season, different from baseline) | Reduced water availability in August to September at the end of the rainy season of only 1%. | **Low** | High[41] | Medium | Depending on the frequency of the dry spell, impact level is medium. | Low[42] | Medium | Will affect negatively HH food security |
| Flash floods | More intensive events with high rainfall (more than 160 mm per day). Will increase the intensity of flash floods. | **Medium** | Medium | Medium | In Chiang Rai Province the topographic profile is prone to flash floods. | Low[43] | Medium | Will affect negatively HH food security |
| Storms | Daily precipitation above 160 mm can happen and increase erosion and affect crops in steep slopes. Storm frequency low (0–2) | **Medium** | Medium[44] | Low | Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield, but with less impact than in dry season rice. However, Chiang Rai Province is located far from the typhoon route. | Medium[45] | Medium | Will affect negatively HH food security |

39 Rice is tolerant to anoxia.

40 Internal capacity, with lowland rice adapted to submergence and high soil water content.

41 Dry spell in the rainy season can affect rice yield and abnormal rainfall pattern which can generate water stress in rainfed systems.

42 Difficult access to drought-resistant varieties

43 Rice crop will be damaged by the submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

44 Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield, with traditional varieties more resistant and resilient to this climatic event.

45 It depends on the rice varieties planted, tolerant to submersion or not.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Low[46] | Medium | Low due to other limiting factors | High[47] | Medium | Improve HH food security |

## 18.3 MAIZE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Stress for maize in the case of early wet season crop, in April or May, with temperatures above 35°C. Maximum temperature can be higher than 35°C in the worst case during the rainy season, but less than 10% to 12% of the days above 35°C. | **Medium** | Low[48] | Medium | The exposure and sensitivity were ranked as medium since the critical temperature will not be reached during the entire crop | Low[49] | Medium | |

[46] Increased $CO_2$ level will increased rice yield (Krishnan 2007), however it depends on other limiting actors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

[47] Internal and external capacity are high and farmers can benefit from the increase of $CO_2$ concentration by using adequate fertilization and rice field management and increase their rice yield.

[48] Temperature higher than 35°C on a prolonged period inhibit maize growth. Above 40°C (average mean temperature) the conditions are not suitable for maize cultivation.

[49] Internal capacity is low. Shift in cropping calendar to avoid high temperature is possible.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Increase of precipitation below 30% during growing season. | **Medium** | Medium[50] | Medium | Some areas of Chiang Rai have low precipitation and an increase in precipitation will increase suitability for rainfed culture | Low[51] | Medium | |
| Increase in water availability | The increase of water availability will not reach water logging effect and anoxia, with an increase of 1% compare to baseline. | **Low** | Very Low | Low | Does not influence maize production, and can ultimately reduce water stress and have beneficial effect, increasing the water storage in the root zone. | Low | Medium | |
| Drought (in rainy season, different from baseline) | Rainfall above 50 mm from April to November and no false start of the rainy season compared to baseline. More exposure when crops grow on sandy, gravelly soil or shallow soils, especially from August to September when the water availability is reduced (1%) | **Low** | High[52] | Medium | Medium impact, with limited drought but high sensitivity of the crop | Low[53] | Medium | |
| Flooding | Increased rainfall in the wet season (5% to 10%) will increase flood intensity. More intense extreme events in terms of rainfall (>160 mm/day) | **Medium** | High[54] | Medium | The threat will depend on the location of the crop, along rivers and in flood prone areas. | Low[55] | Medium | |

50 Rainfall should be between 500 and 1200 mm during the crop cycle. Increase of precipitation will not be suitable for maize growth if the precipitation is over 1600 mm during the growth cycle.

51 Internal capacity is low. Shift in cropping calendar to avoid high precipitation period.

52 Maize is not drought tolerant. Dry spell, like 5 days without rain and rainfall less than 50 mm per month can be an issue. Limited rainfall after sowing and during the crop can generate water stress and reduce yield.

53 Use management techniques such as mulching to reduce water stress.

54 No tolerance to water logging.

55 Cannot stand water logging and no flood protection system.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flash floods | More intensive events with high rainfall (more than 160 mm per day) will increase the intensity of flash floods | **Medium** | High | Medium | In Chiang Rai Province the topographic profile is prone to flash floods. | Low[56] | Medium | Will affect negatively HH food security |
| Storms | Daily precipitation above 160 mm can happen and will increase erosion and affect crops in steep slopes Storm frequency low (0–2) | **Medium** | Medium | Medium | Impact depends on the topography and the soil type of the area. Flat area with heavy soil will generate waterlogging after a storm that can affect the maize crop. In other configuration, storm will have a lower impact. | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth of maize. | **High** | Low[57] | Medium | Increase of yield should be significant but water use efficiency should be increased | Low | Medium | |

56 Maize will be damaged by submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems

57 As a C4 plant, the impact should be lower than for C3 plants.

## 18.4 LITCHI

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Might create a shift or a constraint. Minimum temperature median will be below 15°C from December to February. More than 20% of the days with minimum temperature below 15°C. Relative minimum temperature will increase by 20% in December. | **Medium** | Medium[58] | Medium | Increased minimum temperature might create a constraint. | Low[59] | Medium | |
| Increase in precipitation | Precipitation below 1,700 mm (median precipitation). Increased precipitation in the rainy season, 50% chance to be above the comfort zone of litchi. | **Medium** | Low[60] | Medium | Increase in precipitation does not go above the optimum range but it can influence disease outbreaks | High[61] | Medium | |
| Storms | Increased storm events will happen, with daily rainfall above 160 mm Storm frequency low (0–2) | **Low** | Medium[62] | Medium | Strong winds and rainfall might damage the plantation, especially at young stage | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth during early stages | **Medium** | Medium | Medium | Impact of CO2 fertilization might have an impact but no scientific evidence | Low | Medium | |

58 Optimal temperature between 20°C to 30°C, but tolerate range between 15°C to 40°C. Maximum altitude is 2,000 masl. Litchi needs a chilling period for flowering with temperatures about 7°C to 12°C or below 20°C to 22°C depending on the cultivar. Litchi crops are sensitive to low temperature changes, requiring temperature below 15°C for at least 100 hours to flower during the winter months from November to December in the blooming period. In 2009, the average low temperature was over 20°C affecting more than 50% of the litchi fruit productivity in Chiang Rai

59 Need new cultivar or cultivate at higher elevations where temperature is lower.

60 Tolerate range between 700–2,800 mm per year but optimum between 1,000–1,700 mm.

61 Wide range of rainfall (700–2,800 mm)

62 The tree is sensitive to high winds especially in combination with low relative humidity.

## 18.5 RUBBER

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Dry season high temperature might be over the optimum (29°C).<br>70% of the days above 29°C.<br>Increase in maximum temperature will be between 5% and 10% higher with highest increase during the wet season, out of the comfort zone.<br>Minimum temperature will increase by 10% to 28% and less days closer to the absolute minimum temperature (10°C).<br>Less than 10% of the days below 10°C in 2050. | **High** | Medium[63] | Medium | Production growth might be affected in the dry season with high temperature;<br>Cultivation will be possible in higher altitude, with increase of temperature in winter | Low | Medium | Require labor force for tapping Rubber |
| Increase in precipitation | Suitable range of rainfall, with less than 4,000 mm. It will reduce the drought period at the end and beginning of rainy season | **Low** | Very Low[64] | Low | Increase of precipitation will not change the suitability for rubber plantation in this area;<br>Heavy rainfall can create water logging if rubber is planted in lowland and on heavy soil. | High[65] | Low | |
| Decrease in water availability | Reduce water availability of less than 1% in dry season (March-April) and August–September. | **Very Low** | High[66] | Low | Very limited impact | Low | Medium | |

63 Optimum temperature: 29°C.
64 Rainfall should be between 1,200 and 4,000 mm.
65 Wide range of rainfall is suitable.
66 Rubber is not drought resistant.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in water availability | No significant change in water availability in the province (less than 1%). | **Very Low** | Medium | Low | Will not impact rubber production significantly, but increase of water availability can reduce water stress. | Low internal and external capacity | Low | |
| Drought (in rainy season, different from baseline) | Decrease in water availability in August-September not significant. Precipitation in the dry season will increase from March to November (5% to 40%) | **Very Low** | Medium[67] | Low | Dry spell in the rainy season will not impact rubber growth and culture. | Low | Medium | |
| Flooding | Increased rainfall in the wet season (5% to 10%) will increase flood intensity.<br>More intense extreme events in terms of rainfall (>160 mm/day). | **Very Low** | High[68] | Low | Along the river, and floodplain, flood and water logging occurring during the grow season can affect rubber yield, however the area is relatively small and rubber is usually planted on higher ground. | Low[69] | Medium | |
| Flash floods | Increased rainfall in the wet season (5% to 10%) will increase flood intensity.<br>More intense extreme events in terms of rainfall (>160 mm/day). | **Low** | High[70] | Medium | In Chiang Rai Province the topographic profile prone to flash floods. | Low | Medium | |

67 Rubber is not drought resistant and a dry spell during the rainy season might affect the crop during short periods. The length of drought needs to be longer than 3-4 months to cause loss in the crop.
68 Sensitivity is high, with little tolerance to anoxia.
69 Cannot stand water logging and no flood protection system
70 Sensitivity is higher on young trees.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | Can be affected by strong wind if soil is shallow and tree is destroyed. Significant rainfall can lead to submergence of the rubber. (Flash floods generated by storms are mentioned in the "Flash Flood" threat).<br>Impact depends on the soil type of the area: if shallow soil, strong wind can affect young rubber tree. In other configuration, storm will have a lower impact. | **Low** | Low | Low | Extreme rainfall event above 160 mm per day | Low external and internal adaptive capacity (no specific varieties and no specific manage-ment to limit the impact of wind and heavy rainfall). | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth during early stages | **Medium** | Medium | Medium | Impact of $CO_2$ fertilization might have an impact, but no clear scientific evidence (only for young stages) | Low adaptive capacity to this change. | Medium | |

# 19 SAKON NAKHON CROP VULNERABILITY ASSESSMENT – CAM

## 19.1 LOWLAND RAINFED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum temperature will be below 35°C during the growing season.<br>Maximum temperature will be above 35°C during the growing period. The increase of temperature will be 5% to 9% during the wet season, equivalent to an increase of 10% of days above 35°C.<br>More than 75% of the daily maximum temperature will be below 35°C and maximum temperature stays in the comfort zone. | **Medium** | High[71] | High | Increase in temperature in the rainy season might affect rice growth during the different stage of the culture resulting in a lower yield. | Low[72] | High | |

[71] Temperature exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperature will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).
[72] External adaptive capacity is low with lack of access to new varieties and extension services. Internal adaptive capacity is high with capacity to grow in warm temperature, but with negative impact on yield.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Increase of rainfall in August can reach levels of tolerance with more than 650 mm in a month, which corresponds to a maximum of rainfall per month for rice.<br>Increased rainfall can affect young seedlings, with an increase in rainfall higher than 20% in this month.<br>25% of the rainfall in August will be above 750 mm.<br>Increase of rainfall is also important in September (>20%) possibly during flowering stage (depending on calendar and variety used).<br>During the entire wet season, 50% of total rainfall will be above comfort zone. | **High** | Low[73] | Medium | Significant rainfall during the growing season, with extreme events of precipitation can affect the yield of rice and damage crops during different stages of growth. | Medium[74] | Medium | |
| Increase in water availability | No significant change | **Very Low** | Very Low[75] | Low | Low potential impact | Low[76] | Low | |
| Drought (in rainy season, different from baseline) | Rainfall (+5 to 20%) and water availability (+6%) projected increase in wet season.<br>No change in drought month compared to baseline. | **Very Low** | High[77] | Medium | Increased rainfall and water availability will be positive regarding water stress for rice culture | Low[78] | Medium | Will affect negatively HH food security |

73 Submergence of lowland rainfed rice due to significant rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21% (Yoshida 1981).

74 External adaptive capacity is low with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high, with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

75 Rice is tolerant to anoxia.

76 Internal capacity, with lowland rice adapted to submergence and high soil water content.

77 Dry spell in the rainy season can affect rice yield and abnormal rainfall patterns can generate water stress in rainfed system

78 Difficult access to drought-resistant varieties

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flooding | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day. Storm frequency is medium (6–8). | **Medium** | Medium | Medium | Lowlands and fields close to wetlands and river might be more exposed to flooding in 2050. The damage depends also on the height and the duration of the flood. | Medium | Medium | |
| Flash floods | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day. Storm frequency is medium (6–8). | **Medium** | Medium | Medium | Depends on the geography and the topography. Flash floods are related to storms and heavy rainfall in the rainy season. | Low[79] | Medium | Will affect negatively HH food security |
| Storms | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day. Storm frequency is medium (6–8) | **Medium** | Medium[80] | Medium | Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield | Medium[81] | Medium | Will affect negatively HH food security |
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield | **High** | Low[82] | Medium | Low due to other limiting factors | High[83] | Medium | Improve HH food security |

[79] Rice crop will be damaged by the submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

[80] Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield, with traditional varieties more resistant and resilient to this climatic event

[81] It depends on the rice varieties planted, and whether they are tolerant to submersion or not.

[82] Increased $CO_2$ level will increase rice yield (Krishnan 2007) however it depends on other limiting actors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

[83] Internal and external capacity are high and farmers can benefit from the increase in $CO_2$ concentration by using adequate fertilization and rice field management to increase their rice yield.

## 19.2 SUGARCANE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum temperature will be above 34°C from March to July and maximum extreme will be above 38°C during the same period. Increased temperature will be between 4.5% and 9% during the growth period. 50% of daily maximum temperature will be outside of the comfort zone during the wet season. | **High** | Medium[84] | High | High temperature in the dry season. It might also be beneficial before harvesting period, with high sugar production in dry season. | High[85] | Medium | |
| Increase in precipitation | From May to September rainfall will be above the lower limit. Drought will be similar to baseline condition in the dry season, before harvesting. Decrease of precipitation in January and February will be 10% to 12% but the amount of rainfall is low (less than 30 mm/month) | **Low** | Medium[86] | Medium | Increase of precipitation will be beneficial. Some areas with dry spell in the dry season might become more suitable for sugarcane growth but can induce more disease. | Low | Medium | |
| Increase in water availability | Increase in water availability will happen during the wet season (6%) with slight decrease in the dry season (<1%). | **Low** | Medium[87] | Medium | Does not influence sugarcane production unless it is water logging (see flood). But increase of water availability can reduce water stress | Low[88] | Medium | |

84 Temperature higher than 34°C for a prolonged period is not suitable for sugarcane cultivation and temperature above 38°C stops growth.
85 Internal capacity is high; sugarcane is a robust plant and can grow under high temperature.
86 Rainfall should be above 1,300 mm during the crop cycle for optimum growth. During ripening (dry season) heavy rainfall is not desirable.
87 Water availability favors growth of sugarcane, the plant can also tolerate water logging.
88 Internal capacity low (not drought tolerant). External capacity: access to irrigation in this region.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Drought (in rainy season, different from baseline) | Drought will happen in the dry season, but not significantly different than baseline. | **Low** | Medium[89] | Medium | Low impact in the rainy and dry season | Low[90] | Medium | |
| Flooding | Increased rainfall from May to November can increase flood intensity and frequency. | **Medium** | Medium[91] | Medium | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. | Medium | Medium | |
| Flash floods | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day. Storm frequency is medium (6–8). | **Medium** | High | Medium | Depends on the geography and the topography. | Low[92] | Medium | |
| Storms | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day Storm frequency is medium (6–8). | **Medium** | Medium[93] | Medium | Impact depends on the topography and the soil type of the area. Flat area with heavy soil will generate waterlogging after a storm that can affect the sugarcane crop. In other configuration, storm will have a lower impact. | Medium[94] | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth. | **Medium** | Medium | Medium | Impact of $CO_2$ fertilization might have an impact, but no clear scientific evidence. | Medium adaptive capacity to this change through improved farming practices. | Medium | Positive impact |

89 Sugarcane is not drought tolerant and requires a minimum of 100-180 mm of rainfall per month during the growing cycle. If there is water stress, with dry spell and less than 30 mm within a 10 day period, the yield will be reduced. Dry climate is preferred before harvest in the dry season. Water stress will be reduced if there is access to irrigation (common in the region).

90 Low internal capacity of the crop to tolerate drought

91 Sensitivity is medium; the plant can tolerate 1 week water logging.

92 Sugarcane crop will be damaged by physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

93 Storms can affect sugarcane with strong wind and significant rainfall that can lead to submergence of the sugarcane crop.

94 Certain internal adaptive capacity to water logging.

## 19.3 CASSAVA

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum temperature will be above 35°C from March–June, while growth period starts in April/May.<br>Increase in temperature will be between 5% and 9% during the year.<br>More than 50% of the daily maximum temperature will be above 35°C from March–May. | **Medium** | Low[95] | Medium | Impact of increase temperature in the early stage of the cycle and before harvest in longer cycle.<br>It might affect the growth but will not be above the suitability limit. | High[96] | Medium | Reduce potential animal feed for livestock sector |

95 Temperature higher than 35°C on a prolonged period is not suitable for cassava cultivation.

96 Cassava is a robust plant. External capacity to develop resistant varieties can be high with important involvement of the private sector. Shifting planting calendar might be an option to avoid the hottest period.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | From May to September rainfall will be above the lower limit.<br>Extreme rainfall in the rainy season might affect plant growth with waterlogging and humid conditions, with increase of disease and fungal infection.<br>Total precipitation during the growth cycle will be above upper limit (>2,300 mm), with total precipitation 50% in dry and rainy season higher than the baseline.<br>Decrease of precipitation in January and February will be 10% to 12% but the amount of rainfall is low (less than 30 mm/month) and will not affect the plant growth. | **High** | High[97] | High | Precipitation will be above optimum range, leading to waterlogging and causing more disease and lower yield | Low | High | Reduce potential animal feed for livestock sector |
| Increase in water availability | Increase in water availability will happen during the wet season (6%) with slight decrease in the dry season (<1%).<br>Will not affect cassava production, a drought-resistant crop, unless it is related to waterlogging | **Low** | Very Low | Low | Does not influence cassava production unless it is waterlogging (see flood) | Low | Medium | |

[97] Rainfall should be between 1,000 and 1,500 mm during the crop cycle for optimum growth but can support up to 2,300 mm.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Drought (in rainy season, different from baseline) | Increase in water availability will happen during the wet season (6%) and slight decrease in the dry season (<1%). Increased rainfall up to 27% per month. | **Very low** | Very Low[98] | Very low | Dry spell in the rainy season will not impact cassava grow. | High | Low | |
| Flooding | Increased rainfall from May to November can increase flood intensity and frequency | **Medium** | Very High[99] | High | The threat will depend on the location of the crop, along rivers and in flood prone areas. | Low[100] | High | Reduce potential animal feed for livestock sector |
| Flash floods | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day. Storm frequency is medium (6–8). | **Medium** | High | Medium | Depends on the geography and the topography. | Low | Medium | Reduce potential animal feed for livestock sector |
| Storms | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day. | **Medium** | Medium | Medium | Impact depends on the topography and the soil type of the area. Flat area with heavy soil will generate waterlogging after a storm. In other configuration, storm will have a lower impact | Low | Medium | Reduce potential animal feed for livestock sector |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth | **Medium** | Low | Medium | $CO_2$ increase might have an impact but it depends upon other limiting factors - soil nutrients and sunlight | Medium[101] | Medium | Increasing production and beneficial to livestock |

98 Cassava is drought tolerant and requires a minimum of 500 mm of rainfall during the growing cycle. The length of the dry season needs to be longer than 6 months to cause loss in the crop.

99 No tolerance to waterlogging

100 Cannot stand waterlogging and no flood protection system

101 Adaptive capacity from advanced farming practices and varietal improvement

## 19.4 RUBBER

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Dry season high with the average maximum of 35°C and 43°C as a maximum absolute.<br>Average maximum temperature will be above the optimum for more than 10 months (90% of the days). Maximum absolute will not be reached (45°C).<br>Increase in temperature will be between 5% and 9% during the year. More than 50% of the daily maximum temperature will be above 35°C from March to May. | **High** | Medium[102] | High | High temperature during the late dry season and early dry season. It might affect growth and production. | Low | High | Require labor force for tapping rubber |
| Increase in precipitation | Precipitation is increased by 5% to 25% from March to December. It will reduce water stress, with higher precipitation in October and April shortening the dry season and drought when rainfall is below 100 mm per month.<br>Total rainfall is still below the maximum range (4,000 mm). Total rainfall in the wet season might be above the optimum range, leading to waterlogging and reducing growth with a median rainfall above 2,200 mm. | **Medium** | Very Low[103] | Low | Possible threat due to excessive rainfall in the wet season. But general positive effect on drought, shortening the dry season for rubber. | High | Low | |

[102] Optimum temperature: 29°C

[103] Rainfall should be between 1,200 and 4,000 mm during the year.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in water availability | No significant change in water availability in the province | **Very Low** | Medium | Low | Will not impact rubber production significantly | Low | Medium | |
| Drought (in rainy season, different from baseline) | Increase in rainfall (7% to 27%) at the end of the rainy and dry season might reduce water stress (October, November, December, March, and April).<br>Reduction in drought frequency in March and April. | **Very Low** | Medium[104] | Low | No dry spell in rainy season and dry season drought will be similar to baseline with similar water availability | Low | Medium | |

104 Rubber is not drought resistant and a dry spell during the rainy season might affect the crop during short periods. The length of the drought needs to be longer than 3-4 months to cause loss in the crop.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flooding | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day. Storm frequency is medium (6–8). | **Low** | High[105] | Medium | Along the river and floodplains, flood and water logging occurring during the growing season can affect rubber yield, however the area is relatively small and rubber is usually planted on higher ground. | Low[106] | Medium | |
| Flash floods | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day. Storm frequency is medium (6–8). | **Low** | High[107] | Medium | Depends on the geography and the topography. Flash floods are related to storms and heavy rainfall in the rainy season. | Low[108] | Medium | |
| Storms | One rainfall event with almost 200 mm in a day. And more than 11 with more than 100 mm in a day. Storm frequency is medium (6–8). | **Medium** | Low[109] | Medium | Impact depends on the soil type of the area: if shallow soil, strong wind can affect young rubber tree. In other configuration, storm will have a lower impact. | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth during early stages. | **Medium** | Medium[110] | Medium | Impact of $CO_2$ fertilization might have an impact. | Low adaptive capacity to this change. | Medium | |

105 Sensitivity is high, with little tolerance to anoxia.

106 Cannot stand waterlogging and no flood protection system.

107 Debris can damage the rubber tree. Impact also depends on the age of the plantation, young trees being more sensitive.

108 Rubber yield will suffer from submergence and the physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems. Rubber plantation will reduce the erosion.

109 Trees can be destroyed by strong wind if soil is shallow and significant rainfall can lead to submergence of the rubber.

110 No clear scientific evidence (only for young stages).

# 20 KHAMMOUAN CROP VULNERABILITY ASSESSMENT – CAM

## 20.1 LOWLAND RAINFED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | The predicted maximum temperature is above 35°C in July and early August.<br>Increase of temperature is up to 16% compared to the baseline in July-August.<br>Less than 10% of days are below 35°C.<br>Less than 30% of the daily max temperature is within the comfort zone. | **Medium** | High[111] | High | Increase in temperature in the rainy season might affect rice growth during the different stages of the culture resulting in a lower yield. | Low[112] | High | |
| Increase in precipitation | Increase of rainfall is significant in May and September (+20% compared to baseline), with precipitation above 700 mm per month in August and above 1,000 mm in the extreme years. Total precipitation during the rainy season will be outside the comfort zone. | **High** | Low[113] | Medium | Increase of rainfall might damage rice. | Medium[114] | Medium | |

[111] Temperature exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperature will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

[112] External adaptive capacity is low, with lack of access to new varieties and extension services. Internal adaptive capacity is high, with capacity to grow in warm temperatures. Critical temperature is 45°C at some growth stages, but with negative impact on yield.

[113] Submergence of lowland rainfed rice due to extreme rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21%. (Yoshida 1981)

[114] External adaptive capacity is low with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in water availability | Increase in water availability will be 7% in June and lower during the rest of the rainy season. No significant changes. | **Very Low** | Very Low | Low | Low potential impact | High[115] | Low | |
| Drought (in rainy season, different from baseline) | Unlikely to happen with more than 2,000 mm precipitation in the rainy season.<br>Reduction of drought (4%) in October with other months similar to baseline. | **Very Low** | High[116] | Low | Not a significant impact with increasing rainfall. | Low[117] | Medium | Will affect negatively HH food security |
| Flooding | Higher rainfall during the wet season. 15 days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of the flood will be higher. | **High** | Medium | High | Flooding within the Xe Ban Fai floodplain can happen in the rainy season with negative impact to rice culture. The damage depends also on the height and the duration of the flood. | Medium | High | |
| Flash floods | 15 days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of the flood will be higher. | **High** | Medium | High | In the case of Khammouan, narrow valleys are present in the eastern and northern part of the province and can be subject to flash flood. | Low[118] | High | Will affect negatively HH food security |

[115] High internal capacity to tolerate anoxia and flood conditions.

[116] Dry spell in the rainy season can affect rice yield and abnormal rainfall patterns can generate water stress in rainfed system.

[117] Difficult access to drought-resistant varieties.

[118] Rice crop will be damaged by the submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment to flash flood protection systems.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of the flood will be higher.<br>High storm frequency (13–20). | **High** | Medium[119] | High | Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield. | Medium[120] | High | Will affect negatively HH food security |
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield | **High** | Low[121] | Medium | Low due to other limiting factors. | High[122] | Medium | Improve HH food security |

[119] Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield, with traditional varieties more resistant and resilient to this climatic event.

[120] It depends on the rice varieties planted and whether they are tolerant to submersion or not.

[121] Increased $CO_2$ level will increase rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

[122] Internal and external capacity are high and farmers can benefit from the increase in $CO_2$ concentration by using adequate fertilization and rice field management, which can result in an increase to their rice yield.

## 20.2 IRRIGATED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Increase in temperature in the dry season does not reach critical temperature. 35°C is reached in less than 5% of the days during the year. Maximum temperature is above 35°C only February to May, with higher temperatures in March and April, but no significant difference compared to baseline, with an increase lower than 10% during the growth period.<br>75% of the daily maximum temperature is below 30°C. | **Low** | High[123] | Medium | Increase of temperature will not have a significant impact on dry season rice.<br>Temperature is still in the acceptable range. | Low[124] | Medium | |
| Increase in precipitation | Increased rainfall limits drought vulnerability and water use from irrigation. Rainfall will increase only in April (+30%) when dry season rice is usually harvested.<br>Reduced precipitation in January and February (10%) is not significant (less than 10 mm difference compared to baseline). | **Low** | Low[125] | Low | Low impact will not affect rice culture. | Medium[126] | Medium | |

[123] Temperatures exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperatures will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

[124] External adaptive capacity is low with lack of access to new varieties and extension services. Internal adaptive capacity is high with capacity to grow in warm temperatures; critical temperature is 45°C at some growth stages, but with negative impact on yield.

[125] Submergence of lowland rainfed rice due to important rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21%. (Yoshida 1981)

[126] External adaptive capacity is low, with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Decrease in water availability | Decrease in water availability will not be significant (less than 2%). | **Very Low** | Very High | Medium | It depends on the irrigation schemes and water storage capacity (micro-reservoir, etc.) or river intake. The exposure is considered very low since the change in water availability will not be significant in this region (less than 2%) | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Medium/ Low[127] | Medium | Low due to other limiting factors | High[128] | Medium | Improve HH food security |

127 Increased $CO_2$ level will increase rice yield (Krishnan 2007), however it depends on other limiting actors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

128 Internal and external capacity are high and farmers can benefit from the increase in $CO_2$ concentration by using adequate fertilization and rice field management, which results in an increase to their rice yield.

## 20.3 CASSAVA

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | The predicted maximum temperatures are above 35°C from March to August, but average maximum is below 35°C during the year.<br>Increase of temperature is up 16% compared to the baseline in July-August. Less than 10% of days are below 35°C.<br>Less than 30% of the daily max temperature is within the comfort zone in the wet season. In the dry season more than 60% of the daily max temperature is within the comfort zone. | **Low** | Low[129] | Low | Increased temperature will reduce the yield but not significantly. Threat is medium. | High[130] | Medium | Reduce potential animal feed for livestock sector |
| Increase in precipitation | Peak precipitation in August of more than 700 mm.<br>Increased precipitation of 5% to 27% between April and November. Maximum precipitation above 800 mm in June, July, August.<br>Almost 50% of total precipitation during wet season above comfort zone. | **High** | High[131] | High | Some areas of Khammouan have high precipitation and are not suitable for cassava, especially for crops cultivated in lowland areas with heavy soil prone to waterlogging. | Low | High | Reduce potential animal feed for livestock sector |
| Decrease in water availability | Changes in water availability between -0.5% in April to 7% in June. | **Low** | Low | Low | No significant impact | High | Very Low | |

[129] Temperatures higher than 35°C for a prolonged period are not suitable for cassava cultivation.
[130] Cassava is a robust plant. External capacity to develop resistant varieties could be high with important involvement by the private sector. Shifting planting calendar might be an option to avoid the hottest period.
[131] Rainfall should be between 1,000 and 1,500 mm during the crop cycle for optimum growth but can support up to 2,300 mm.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Drought (in rainy season, different from baseline) | Dry spell in the rainy season will not affect growth.<br>Frequency of drought will not change compared to baseline. | **Very Low** | Very Low[132] | Very Low | Dry spell in the rainy season will not impact cassava growth. | High | Very Low | |
| Flooding | 15 Days with 100 mm of rainfall or more with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August. | **High** | High[133] | High | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. But due to higher rainfall, especially during the rainy season, flooding will more likely occur. | Low[134] | High | Reduce potential animal feed for livestock sector |
| Flash floods | 15 Days with 100 mm of rainfall or more with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August.<br>High storm frequency (13–20). | **High** | High | High | Depends on the geography and topography of the landscape. In addition to waterlogging in the fields, debris can damage the crops. | Low | High | Reduce potential animal feed for livestock sector |
| Storms | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August. High storm frequency (13–20) | **High** | Medium | High | Impact depends on the topography and the soil type of the area. Flat areas with heavy soil will generate waterlogging after a storm that can affect the cassava crop. In other configurations, storm will have a lower impact. | Low | High | Reduce potential animal feed for livestock sector |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth. | **High** | Medium | Medium | $CO_2$ increase might have an impact but it depends upon other limiting factors such as soil nutrients and sunlight | Medium[135] | Medium | Increasing production and beneficial to livestock |

132 Cassava is drought tolerant and requires a minimum of 500 mm of rainfall during the growing cycle. The length of the dry season needs to be longer than 6 months to cause a loss in the crop.

133 No tolerance to waterlogging.

134 Cannot stand waterlogging and no flood protection system.

135 Adaptive capacity from advanced farming practices and varietal improvements.

## 20.4 RUBBER

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Increase in temperature can allow for increased cultivation area, particularly due to higher temperatures in winter (minimum temperature will increase by 5% to 11%).<br>Increased temperatures will still be within the acceptable range, even more suitable in some cases—closer to 29°C.<br>More days with maximum temperature of 29°C (32% in 2050 and 12% in baseline). | **Medium** | Medium[136] | Medium | Production might be affected in the dry season with high temperatures, especially in the lower altitude floodplain along the Mekong, but cultivation will be possible in higher altitudes. | Low | Medium | Require labor force for tapping rubber |

136 Optimum temperature: 29°C

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Increase in rainfall between 3% and 25% from March to December. More rainfall in March and April will reduce drought period. Rainfall will be above 100 mm from April to October. Increase of precipitation will not change the suitability for rubber plantations in this area, being still in the suitable range for rainfall, with less than 4,000 mm. It will reduce the drought period at the end and beginning of the rainy season. Heavy rainfall can create waterlogging if rubber is planted in lowland and on heavy soil, especially from June to August. | **Low** | Very low[137] | Low | Increase of precipitation will not change the suitability for rubber plantations in this area being still in the suitable range for rainfall. | High | Low | |
| Increase in water availability | No significant change in water availability in the province, between -1% to +7%. | **Very Low** | Medium | Low | Will not significantly impact rubber production. | Low | Medium | |
| Drought (in rainy season, different from baseline) | The length of the drought needs to be longer than 3-4 months to cause loss in the crop, and precipitation in the dry season will increase in April (+25%) and October–November (+11%) and December (+10%). | **Very Low** | Medium[138] | Low | Dry spell in the rainy season will not impact rubber growth and culture. | Low | Medium | |

137 Rainfall should be between 1,200 and 4,000 mm during the year.

138 Rubber is not drought resistant and a dry spell during the rainy season might affect the crop during short periods. The length of the drought needs to be longer than 3-4 month to cause loss in the crop.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flooding | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August.<br>High storm frequency (13–20). | **Low** | High[139] | Medium | Along the river, and floodplains, flood and water logging occurring during the growing season can affect rubber yield, however the area is relatively small and rubber is usually planted on higher ground. | Low[140] | Medium | |
| Flash floods | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August.<br>High storm frequency (13–20). | **Medium** | Low[141] | Medium | Depends on the geography and the topography of the landscape. Flash floods are related to storms and heavy rainfall in the rainy season. | Low[142] | Medium | |
| Storms | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August.<br>High storm frequency (13–20). | **High** | Low[143] | Medium | Impact depends on the soil type of the area: if soils are shallow, strong wind can affect young rubber tree. In other configurations, storm will have a lower impact. | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth during early stages. | **Medium** | Medium[144] | Medium | Impact of $CO_2$ fertilization might have an impact) | Low adaptive capacity to this change. | Medium | |

139 Sensitivity is high with little tolerance to anoxia

140 Cannot stand waterlogging and no flood protection system

141 Debris can damage the rubber tree. Impact also depends on the age of the plantation, young trees being more sensitive.

142 Rubber yield will suffer from submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems. Rubber plantation will reduce the erosion.

143 Rubber trees can be affected by strong wind if soil is shallow, and significant rainfall can lead to submergence of the rubber trees.

144 No clear scientific evidence (only for young stages).

## 20.5 MAIZE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | More than 50% of maximum temperature is above comfort zone in wet season.<br>16% increase of maximum temperature in July.<br>The predicted maximum temperature is above 35°C in July and early August and will affect maize growth.<br>In July, the maximum temperature is above 40°C limiting growth of maize. | **High** | Low[145] | Medium | The critical temperature will not be reached during the entire crop.<br>It might be a stress for maize in the case of an early wet season crop in April or May. | Low[146] | Medium | |

145 Temperatures higher than 35°C on a prolonged period inhibit maize growth. Above 40°C (average mean temperature), the conditions are not suitable for maize cultivation.

146 Internal capacity is low. Shift in cropping calendar to avoid high temperature is possible.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Some areas of Khammouan have high precipitation and are not suitable for maize. Increase of precipitation will affect the suitability of certain regions. Only regions close to the Mekong with lower rainfall patterns will be suitable. Early crop starting in May will be preferable to avoid peak rainfall in August.<br>Peak precipitation in August of more than 700 mm.<br>Increased precipitation of 5% to 27% between April and November.<br>Maximum precipitation above 800 mm in June, July, and August.<br>Almost 50% of total precipitation during wet season is above comfort zone.<br>Precipitation will increase in early rainy season (May) allows for an early start. | **High** | Medium[147] | High | Suitability for maize production will be reduced by high rainfall.<br>Potential drought will be reduced. | Low[148] | High | |
| Increase in water availability | Increase in water availability between -0.5% in April to 7% in June. | **Very Low** | Very Low | Medium | No effect on maize crop. | Low | Low | |
| Drought (in rainy season, different from baseline) | Only possible drought if planting early crop in April | **Very Low** | High[149] | Low | Low incidence, with increased rainfall and similar water availability compared to the baseline | Low[150] | Medium | |

147 Rainfall should be between 500 and 1,200 mm during the crop cycle. Increase of precipitation will not be suitable for maize growth if the precipitation is over 1,600 mm during the growing cycle.

148 Internal capacity is low. Shift in cropping calendar to avoid high precipitation period.

149 Maize is not drought tolerant. A dry spell, e.g., 5 days without rain and rainfall under 50 mm per month, can be an issue. Limited rainfall after sowing and during the crop can generate water stress and reduce yield.

150 Use management techniques such as mulching to reduce water stress.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flooding | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August.<br>High storm frequency (13-20). | **High** | High[151] | High | The threat will depend on the location of the crop, e.g., along rivers and in flood prone areas. | Low[152] | High | |
| Flash floods | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August.<br>High storm frequency (13–20). | **High** | High | High | Depends on the geography and the topography of the area. | Low[153] | High | Will affect negatively HH food security |
| Storms | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August.<br>High storm frequency (13–20). | **High** | Medium | High | Impact depends on topography and the soil type of the area. Flat areas with heavy soil will generate waterlogging after a storm that can affect the maize crop. In other configurations, storms will have a lower impact. | Low | High | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth of maize. | **High** | Low[154] | Medium | Increase of yield could be significant but water use efficiency would need to be increased. | Low | Medium | |

151 No tolerance to waterlogging.

152 Cannot stand waterlogging and no flood protection system.

153 Rice crop will be damaged by submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

154 As a C4 plant, the impact should be lower than for C3 plants.

## 20.6 SUGARCANE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Cultivation in the lower altitude areas might be affected with some days of maximum temperature above 40°C.<br>Highest increase in temperature in July (16%).<br>Less than 10% of the days with temperatures above 35°C.<br>Temperature above 34°C during the dry season, before harvest. | **Medium** | Medium[155] | Medium | Maximum temperature will still be within the optimum, with less than 5% of the days above 40°C. | High[156] | Medium | |
| Increase in precipitation | Impact on drought in the dry season might be significant in October and in April, with more than 110 mm of rainfall.<br>High precipitation in wet season (more than 700 mm in August) can lead to waterlogging. | **Medium** | Medium[157] | Medium | Significant precipitation might increase the pest and fungi outbreak. Some areas with dry spells in the dry season might become more suitable for sugarcane growth. | Low | Medium | |
| Increase in water availability | Increase in water availability between -0.5% in April to 7% in June. | **Very Low** | Medium[158] | Low | Does not influence sugarcane production unless it is waterlogging (see flood). But an increase in water availability can reduce water stress. | Low[159] | Medium | |

155 Temperature higher than 34°C on a prolonged period is not suitable for sugarcane cultivation and temperature above 38°C stops growth.

156 Internal capacity is high; sugarcane is a robust plant and can grow under high temperature.

157 Rainfall should be above 1,300 mm during the crop cycle for optimum growth, with monthly distribution over the year of 110–180 mm. During ripening (dry season), heavy rainfall is not desirable.

158 Water availability favors growth of sugarcane. The plant can also tolerate waterlogging.

159 Internal capacity (not drought tolerant). External capacity: access to irrigation in this region.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Drought (in rainy season, different from baseline) | Drought will happen in the dry season, but is not significantly different than baseline. | **Very Low** | Medium[160] | Low | Low impact in the rainy and dry season. | Low[161] | Medium | |
| Flooding | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of floods will be higher.<br>Monthly rainfall above 500 mm per month in June, July, and August. | **High** | Medium[162] | High | Exposure will be higher in floodplains. But due to higher rainfall particularly during the rainy season, flooding will more likely occur. | Medium | High | |
| Flash floods | More than 3 days will receive above 150 mm of rainfall. 15 Days with 100 mm of rainfall or more, with a maximum of 200mm.<br>High storm frequency (13–20). | **High** | High | High | Depends on the geography and the topography of the area. | Low[163] | High | |
| Storms | 15 Days with 100 mm of rainfall or more, with a maximum of 200 mm. Incidence and amplitude of the flood will be higher.<br>High storm frequency (13–20). | **High** | Medium[164] | High | Impact depends on the topography and the soil type of the area. | Medium[165] (internal) | High | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth | **Medium** | Medium | Medium | Impact of $CO_2$ fertilization might have an impact, but no clear scientific evidence. | Medium | Medium | Positive impact |

160 Sugarcane is not drought tolerant and requires a minimum of 100–180 mm of rainfall per month during the growth cycle. If there is water stress, with dry spell and less than 30 mm within a 10 day period, the yield will be reduced. Dry climate is preferred before harvest in the dry season. Water stress will be reduced if there is access to irrigation (common in the region).

161 Low internal capacity of the crop to tolerate drought.

162 Sensitivity is medium, the plant can tolerate 1 week of waterlogging.

163 Sugarcane crop will be damaged by physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

164 Storm can affect sugarcane with strong wind and significant rainfall that can lead to submergence of the sugarcane crop.

165 Certain adaptive capacity to waterlogging.

# 21 CHAMPASAK, CROP VULNERABILITY ASSESSMENT – CAM

## 21.1 LOWLAND RAINFED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum temperature will be above 35°C only in May. Maximum temperature will not reach 45°C.<br>Increase of temperature will be between 6% and 12% during the growing period<br>Early crop in May will face high temperatures with 50% of the daily maximum temperatures above 35°C. During the rest of the growth period the exposure is lower (less than 25% of the daily maximum temperature).<br>Daily maximum temperature is above the comfort zone during the wet season, but 75% of days are below 35°C. | **Medium** | High[166] | High | Increase in temperature during the rainy season might affect rice growth during the different stages of the culture resulting in a lower yield. | Low[167] | High | |

[166] Temperature exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperature will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).
[167] External adaptive capacity is low, with lack of access to new varieties and extension services. Internal adaptive capacity is high, with capacity to grow in warm temperatures; critical temperature is 45°C at some growth stages, but with negative impact on yield.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Increased rainfall of 5% to 18% during the crop period. Maximum monthly rainfall of 425 mm in August will still be within the acceptable range for rainfall. Extreme months in July or August can reach more than 600 mm of rainfall and might damage the rice crop. | **Medium** | Low[168] | Medium | Increase of rainfall will benefit the rice crop with fewer droughts. Only extreme events with high monthly rainfall will damage the rice. | Medium[169] | Medium | |
| Decrease in water availability | Decrease in water availability will not be significant, with a decrease between 2.5% to 0% | **Very Low** | High | Low | Low potential impact | Low | Low | |
| Drought (in rainy season, different from baseline) | Drought will be more frequent in April (before the rice crop) and in November (end of the crop) but the increase of frequency is not significant (4%). | **Very Low** | High[170] | Low | Not a significant impact with projected increase in rainfall. | Low[171] | Medium | Will affect negatively HH food security |
| Flooding | Higher rainfall during the wet season. Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **Low** | Medium | Low | Lowlands and fields close to wetlands and river might be more exposed to flooding in 2050. The damage depends also on the height and the duration of the flood. | Medium | Medium | |

168 Submergence of lowland rainfed rice due to important rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21%. (Yoshida 1981)

169 External adaptive capacity is low with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high, with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

170 Dry spells in the rainy season can affect rice yield and abnormal rainfall patterns can generate water stress in rainfed systems.

171 Difficult access to drought-resistant varieties.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flash floods | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **Medium** | Medium | Medium | However this threat is extremely variable, depending on local topography, soil type, and land cover. In Champasak Province, the topographic profile is not prone to flash floods. | Low[172] | Medium | Will affect negatively HH food security |
| Storms | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **High** | Medium[173] | High | Rainy season rice can be submerged following increase of rainfall; and a prolonged submergence will reduce yield. | Medium[174] | High | Will affect negatively HH food security |
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Low[175] | Medium | Low due to other limiting factors. | High[176] | Medium | Improve HH food security |

172 Rice crop will be damaged by submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

173 Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield, with traditional varieties more resistant and resilient to this climatic event.

174 It depends on the rice varieties planted, and whether they are tolerant to submersion or not.

175 Increased $CO_2$ level will increase rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

176 Internal and external capacity are high and farmers can benefit from the increase of $CO_2$ concentration by using adequatefertilization and rice field management and increase their rice yield.

## 21.2 IRRIGATED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum daily temperature (35°C) is reached from March to May, at the end of the growing cycle.<br>More than 30% of days are above 35°C.<br>45°C maximum temperature not reached.<br>Increased temperature of 5% to 9% during the growth period.<br>Critical period in March, April, and May with more than 50% of daily temperatures above 35°C and above comfort zone. | **High** | High[177] | High | Increased temperature will reduce yield, especially at the end of the dry season during flowering. | Low[178] | High | |
| Increase in precipitation | Monthly rainfall will decrease and the absolute value of the change remains low; 4 to 107 mm. | **Medium** | Low[179] | Medium | Medium impact depends on the rice variety used. But absolute value of change compared to baseline not high. | Medium[180] | Medium | |

177 Temperatures exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperature will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

178 External adaptive capacity is low, with lack of access to new varieties and extension services. Internal adaptive capacity is high, with capacity to grow in warm temperatures; critical temperature is 45°C at some growth stages, but with negative impact on yield.

179 Submergence of lowland rainfed rice due to significant rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21%. (Yoshida 1981)

180 External adaptive capacity is low, with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high, with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Decrease in water availability | Decease in water availability will be 2% to 3% and not significant during the growth period. | **Very Low** | Very High | Medium | Only in case of water shortage to irrigate rice due to increased competition for water between sectors, lack of rainfall and/ or storage capacity, or issues concerning management of the irrigation scheme. | Low[181] | Medium | |
| Flash floods | Unlikely to happen in dry season. | **Very Low** | High | Medium | However this threat is extremely variable, depending on the local topography, soil type, and land cover. In Champasak Province, the topographic profile is not prone to flash floods. | Low[182] | Medium | Will affect negatively HH food security |
| Storms | Unlikely to happen in the dry season. | **Very Low** | Medium[183] | Low | Dry season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield, especially in the case of HYV short rice varieties. In addition, strong winds might damage the rice, but the frequency of these events in dry season is very low. | Low[184] | Medium | Will affect negatively HH food security |

181 Internal capacity, with lowland rice adapted to submergence and high soil water content.

182 Rice crop will be damaged by submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

183 Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield, with traditional varieties more resistant and resilient to this climatic event.

184 It depends on the rice varieties planted, and whether they are tolerant to submersion or not.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Medium/ Low[185] | Medium | Low due to other limiting factors. | High[186] | Medium | Improve HH food security |

## 21.3 CASSAVA

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum daily temperature is above 35°C from February to May (growing period starts in April/May).<br>Increase in temperature will be between 5% and 12% during the year.<br>More than 30% of the daily maximum temperature will be above 35°C from March to May. | **Low** | Low[187] | Low | Impact of increased temperature in the early stage of the cycle and before harvest in the case of longer cycle. | High[188] | Medium | Reduce potential animal feed for livestock sector |

185 Increased $CO_2$ level will increased rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

186 Internal and external capacity are high and farmers can benefit from the increase in $CO_2$ concentration by using adequate fertilization and rice field management, which will increase their rice yield.

187 Temperature higher than 35°C for a prolonged period is not suitable for cassava cultivation.

188 Cassava is a robust plant. External capacity to develop resistant varieties could be high with important involvement by the private sector. Shifting planting calendar might be an option to avoid the hottest period.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | From May to September rainfall will be above the lower limit.<br>Total precipitation during the growth cycle will be below upper limit (>2,300 mm), with total precipitation 50% in rainy season higher than the baseline.<br>Decrease of precipitation in January to April will be 10% to 12% but the amount of rainfall is low (less than 30mm/month) and will not affect the plant growth. | **Medium** | High[189] | High | Precipitation will be above optimum range, leading to waterlogging, more disease, and lower yield.<br>Increase in precipitation from May to December can create waterlogging conditions and affect cassava yield. | Low | High | Reduce potential animal feed for livestock sector |
| Decrease in water availability | Very low, less than 3% during the crop cycle. | **Very Low** | Very Low | Very Low | No significant impact | High | Very Low | |
| Drought (in rainy season, different from baseline) | Decrease in water availability will happen during the wet season but will be limited (<5%).<br>Increased overall rainfall up to 15% per month.<br>Increased drought frequency in February (8%). | **Low** | Very Low[190] | Low | Dry spell in the rainy season will not impact cassava growth. | High | Low | |
| Flooding | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **Low** | Very High[191] | Medium | The threat will depend on the location of the crop, e.g., along rivers and in flood prone areas. | Low[192] | Medium | Reduce potential animal feed for livestock sector |

189 Rainfall should be between 1,000 and 1,500 mm during the crop cycle for optimum growth but can support up to 2,300 mm.
190 Cassava is drought tolerant and requires a minimum of 500 mm of rainfall during the growing cycle. The length of the dry season needs to be longer than 6 months to cause loss in the crop.
191 No tolerance to waterlogging.
192 Cannot stand waterlogging and no flood protection systems.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flash floods | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **Medium** | High | Medium | Depends on the geography and the topography of the landscape. In addition to waterlogging in the fields, debris can damage the crops. | Low | Medium | Reduce potential animal feed for livestock sector |
| Storms | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **High** | Medium | Medium | Impact will depends on the topography and the soil type of the area. Flat areas with heavy soil will generate waterlogging after a storm that can affect the cassava crop. In other configurations, storms will have a lower impact. | Low | High | Reduce potential animal feed for livestock sector |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth | **High** | Medium | Medium | $CO_2$ increase might have an impact but it depends upon other limiting factors such as soil nutrients and sunlight | Medium[193] | Medium | Increasing production and beneficial to livestock |

[193] Adaptive capacity from advanced farming practices and varietal improvements

## 21.4 RUBBER

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum temperature will be above the optimum for more than 11 months (>90% of the days). Maximum absolute will not be reached (45°C).<br>Increase in temperature will be between 5% and 12% during the year.<br>More than 30% of the daily maximum temperature will be above 35°C from February to May. | **Medium** | Medium[194] | High | Production might be affected in the dry season with high temperatures, especially in the floodplains along the Mekong (low altitude).<br>Higher altitude with minimum temperature will be accessible to rubber. | Low | Medium | Require labor force for tapping rubber |
| Increase in precipitation | Precipitation is increased by 5% to 32% from May to December. It will reduce water stress, with higher precipitation in December.<br>Reduced precipitation in April will increase the drought period and dry season.<br>Total rainfall is below the maximum range (4,000 mm). Total rainfall in the wet season might be above the optimum range, leading to waterlogging and reduced yield. | **Medium** | Very low[195] | Low | Increase of precipitation will not change the suitability for rubber plantation in this area, being still in the suitable range for rainfall. | High | Low | |
| Decrease in water availability | Decrease in water availability will not be significant, with a decrease between 5% and 0%. | **Low** | Medium | Low | Will not significantly impact rubber production. | Low | Medium | |

[194] Optimum temperature: 29°C.
[195] Rainfall should be between 1,200 and 4,000 mm during the year.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Drought (in rainy season , different from baseline) | No dry spell in the rainy season. Increased drought frequency in the dry season, from March to April. However water availability is reduced by only 5%. | **Medium** | Medium[196] | Medium | Dry spell in the rainy season will not impact rubber grow and culture. Water stress can happen at the end of the dry season in April with delayed rainfall) | Low | Medium | |
| Flooding | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **Low** | High[197] | Medium | Along the river, and floodplains, flooding and water logging occurring during the growing season can affect rubber yield, however the area is relatively small and rubber is usually planted on higher ground. | Low[198] | Medium | |
| Flash floods | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **Medium** | Low[199] | Medium | Depends on the geography and the topography of the area. Flash floods are related to storms and heavy rainfall in the rainy season. | Low[200] | Medium | |

196 Rubber is not drought resistant and a dry spell during the rainy season might affect the crop during short periods. The length of the drought needs to be longer than 3-4 month to cause loss in the crop.

197 Sensitivity is high, with little tolerance to anoxia.

198 Cannot stand waterlogging and no flood protection system.

199 Debris can damage the rubber tree. Impact also depends on the age of the plantation, young trees being more sensitive.

200 Rubber yield will suffer from submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems. Rubber plantation will reduce the erosion.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **High** | Low[201] | Medium | Impact depends on the soil type of the area: if shallow soil, strong wind can affect young rubber trees. In other configurations, storms will have a lower impact. | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth during early stages. | **Medium** | Medium[202] | Medium | Impact of $CO_2$ fertilization might have an impact. | Low adaptive capacity to this change. | Medium | |

[201] Rubber trees can be affected by strong wind if soil is shallow, and significant rainfall can lead to submergence of the rubber.
[202] No clear scientific evidence (only for young stages)

## 21.5 MAIZE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Maximum daily temperatures are higher than 35°C during the growth period and will affect the plant's growth.<br>Increase of temperature will be between 6% and 12% during the growing period.<br>Early crop in May will face high temperatures, with 50% of the daily maximum temperature above 35°C. During the rest of the growth period the exposure is lower (less than 25% of the daily max temperature).<br>Daily maximum temperature is above comfort zone during the wet season, but 75% of days below 35°C threshold. | **High** | Low[203] | Medium | The exposure and sensitivity were ranked as medium since the critical temperature will not be reached during the entire crop period.<br>It might be a stress for maize in the case of an early wet season crop, in April or May. | Low[204] | Medium | |
| Increase in precipitation | Precipitation will be within acceptable range (below 1,600 mm) from May to August but lower suitability than baseline.<br>Increase of rainfall of 5% to 18% from May to October. Precipitation in July and August will be above the best suitable range, with more than 50% of the monthly precipitation above 400 mm. | **High** | Medium[205] | High | Suitability for maize production will be reduced by high rainfall.<br>Potential drought will be reduced. | Low[206] | High | |

203 Temperatures higher than 35°C for a prolonged period inhibit maize growth. Above 40°C (average mean temperature) the conditions are not suitable for maize cultivation.
204 Internal capacity is low. Shift in cropping calendar to avoid high temperature is possible.
205 Rainfall should be between 500 and 1,200 mm during the crop cycle. Increase of precipitation will not be suitable for maize growth if the precipitation is over 1,600 mm during the growing cycle.
206 Internal capacity is low. Shift in cropping calendar to avoid high precipitation period.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Decrease in water availability | Limited decrease in water availability (less than 3% during the cropping season) | **Very Low** | High | Medium | No significant impact on maize crop | Low | Medium | |
| Drought (in rainy season, different from baseline) | Dry spell, e.g., 5 days without rain and rainfall under 50 mm per month, can be an issue especially for an early wet season crop (April) with more than 16% of drought frequency in April | **Very Low** | High[207] | Low | Low incidence, with increase in projected rainfall and similar water availability compared to baseline | Low[208] | Medium | |
| Flooding | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **Medium** | High[209] | Medium | The threat will depend on the location of the crop, e.g., along rivers and in flood prone areas. | Low[210] | Medium | |
| Flash floods | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **Medium** | High | Medium | Depends on the geography and the topography of the area. | Low[211] | Medium | Will affect negatively HH food security |

207 Maize is not drought tolerant. A dry spell, e.g., 5 days without rain and rainfall under 50 mm per month, can be an issue. Limited rainfall after sowing and during the crop can generate water stress and reduce yield.

208 Use management techniques such as mulching to reduce water stress.

209 No tolerance to waterlogging.

210 Cannot stand waterlogging and no flood protection system.

211 Rice crop will be damaged by submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | Extreme events with more than 140 mm/day of rainfall will occur and more than 3 events with more than 100 mm/day. | **High** | Medium | Medium | Impact depends on the topography and the soil type of the area. Flat areas with heavy soil will generate waterlogging after a storm that can affect the maize crop. In other configurations, storm will have a lower impact. | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth of maize. | **High** | Low[212] | Medium | Increase of yield could be significant but water use efficiency would need to be increased | Low | Medium | |

212 As a C4 plant, the impact should be lower than for C3 plants.

## 21.6 ROBUSTA COFFEE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum temperature is above 32°C from January to November (80% of the days). Extreme max temperature is above 36°C from January to October (20% of the days). Increase in temperature of 5% to 12% across the year. | **Very high** | Medium[213] | Very High | In the coffee production area the production will be affected by higher temperature. | Medium[214] | Very High | |
| Increase in precipitation | Wet years will be above suitable range, with increased rainfall in wet season (above comfort zone). Increased rainfall from May to December (5% to 38%). | **High** | Medium[215] | High | Increased rainfall can reach upper threshold. | Low[216] | High | |
| Decrease in precipitation | Reduction of 12% to 2% from January to April. | **Low** | Medium | Medium | Increased water stress. Without irrigation, this might reduce the yield. | Medium | Medium | |
| Drought (in rainy season, different from baseline) | Long dry spells can affect production (longer than 20–30 days). Increased frequency of dry spells from March to April (4% to 16%). | **Medium** | Medium[217] | Medium | Dry spells will be increased in the dry season, with reduced rainfall, increasing water stress | Medium[218] | Medium | |

213 Dry season high temperature is above optimum range that might affect coffee growth and production, if mean annual max temperature is above 32°C.
214 Suitable range is up to 32°C. External capacity is high, with shade management technique.
215 Rainfall should be between 1,000 and 2,500 mm during the year.
216 Depending on the drainage capacity of the soil
217 The length of drought needs to be longer than 20–30 days with rainfall, which has a low probability of occurring.
218 Internal capacity of the crop to tolerate drought and possibility of external capacity to develop ground water irrigation

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flash floods | Extreme events with more than 250 mm/day of rainfall will occur and more than 7 events with more than 100 mm/day. | **Medium** | Medium[219] | Medium | On the Bolaven Plateau the exposure to flash flood is very low and the impact on coffee is not likely to occur | Medium | Medium | |
| Storms | Extreme events with more than 250 mm/day of rainfall will occur and more than 7 events with more than 100 mm/day.<br>Storms happen outside of the harvest period (dry season) and will not affect production. | **High** | Low | Medium | Impact depends on the soil type of the area: if shallow soil. In other configurations, storm will have a lower impact. | Low[220] | High | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on growth and water use efficiency. | **Low** | Low | Low | Impact of $CO_2$ fertilization might have an impact, but no clear scientific evidence | Medium | Medium | |

219 Internal, coffee can sustain short period of waterlogging.

220 Adaptive capacity low—no specific varieties and no specific management to limit the impact of wind and heavy rainfall.

# 22 KAMPONG THOM, CROP VULNERABILITY ASSESSMENT – CAM

## 22.1 LOWLAND RAINFED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum temperature below 35°C during the growth period.<br>Absolute maximum can be above 35°C (less than 15% of the days), but below 45°C.<br>Increase of maximum temperature ranges from 8% to 11% compared to baseline during the growth period, with more than 75% of the maximum daily temperatures above the comfort zone. | **Medium** | High[221] | High | Increase in temperature in the rainy season might affect rice growth during different stages of the culture resulting in a lower yield. | Low[222] | High | |

221 Temperatures exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperatures will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

222 External adaptive capacity is low, with lack of access to new varieties and extension services. Internal adaptive capacity is high, with capacity to grow in warm temperature; critical temperature is 45°C at some growth stages, but with negative impact on yield.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Increased rainfall from May to November (2% to 12% compared to baseline) will reduce water stress.<br>Shift of onset of rainy season, higher frequency of rainfall event above 200mm in May (28%) compared to baseline (16%) and June (40% compare to 28% in the baseline). Planting date might be delayed.<br>No excessive rainfall (maximum below 500 mm per month in September).<br>More rainfall in East Kampong Thom, with increased rainfall from 5% to 17% (May to November).<br>Shift of onset of wet season in May only (20% baseline, 32% prediction).<br>More extreme rainfall in September and July (>450 mm) compared to southwest. | **Medium** | Low[223] | Medium | Reduced water stress with more rainfall.<br>Delay of rainy season, can be problematic with photoperiodic rice (traditional rice). | Medium[224] | Medium | |
| Decrease in water availability | Decrease in water availability will be between -8% and -4% during the crop in eastern Kampong Thom (less in southwest).<br>However, rainfall at the same time is above 100 mm per month. | **Low** | High | Medium | Limited impact, more pronounced in eastern part of Kampong Thom. | Low | Medium | |

223 Submergence of lowland rainfed rice due to significant rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield of 21%. (Yoshida 1981)

224 External adaptive capacity is low, with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Drought (in rainy season, different from baseline) | More drought in November (+8%) in southwest.<br>More drought frequency in eastern part of province (+4% in July and August). | **Low/Very Low** | High[225] | Medium | Not a significant impact with increase in projected rainfall. Impact more important or more frequent in the eastern part of the province. Limited impact in southwest part. | Low[226] | Medium | Will affect negatively HH food security |
| Flooding | 3 days with more than 100 mm, including 1 day above 160 mm in eastern part of the province.<br>Flood-prone areas around the Mekong and Tonle Sap lake in the southwestern part of the province where threat is more significant. | **Very High** | High | Very High | Annual flooding from the Tonle Sap and Mekong River. Threat is significant. | Medium[227] | Very High | |

225 Dry spell in the rainy season can affect rice yield and abnormal rainfall patterns can generate water stress in rainfed system.
226 Difficult access to drought resistant varieties.
227 The internal adaptive capacity is medium because it depends on the rice varieties planted (deep-water rice, rainfed rice, etc.), and there is limited access to varieties adapted to flooding.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | 3 days with more than 100 mm, including 1 day above 160 mm in eastern part of the province. Flood-prone areas around the Mekong and Tonle Sap lake in the southwestern part of the province. Low Storm frequency (0–2). | **Low** | Medium[228] | Medium | Low storm frequency | Medium[229] | Medium | Will affect negatively HH food security |
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Low[230] | Medium | Low due to other limiting factors | High[231] | Medium | Improve HH food security |

228 Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield, with traditional varieties more resistant and resilient to this climatic event.

229 It depends on the rice varieties planted, and whether they are tolerant to submersion or not.

230 Increased $CO_2$ level will increase rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

231 Internal and external capacity are high and farmers can benefit from the increase of $CO_2$ concentration by using adequate fertilization and rice field management, which could increase their rice yield.

## 22.2 IRRIGATED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Increase in temperature in the dry season does not reach critical temperature. 35°C is reached in less than 15% of the days during the year.<br>Maximum temperatures are above 35°C February to May, with higher temperatures in March and April by 7% to 11%.<br>More than 50% of maximum daily temperatures above 35°C in March and April. | **High** | High[232] | High | Increase of temperature will have significant effect on rice yield | Low[233] | High | |
| Increase in precipitation | Heavy rainfall is unlikely to happen in the dry season, with decreased rainfall from January to April. | **Low** | Low[234] | Low | Low impact will not affect rice culture. | Medium[235] | Medium | |

232 Temperatures exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperatures will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

233 External adaptive capacity is low, with lack of access to new varieties and extension services. Internal adaptive capacity is high, with capacity to grow in warm temperatures; critical temperature is 45°C at some growth stages, but with negative impact on yield.

234 Submergence of lowland rainfed rice due to significant rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21%. (Yoshida 1981)

235 External adaptive capacity is low, with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high with traditional lowland rainfed rice more adapted to submergence compare to HYV rice.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in atmospheric $CO_2$ | Increase in $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Medium/ Low[236] | Medium | Low due to other limiting factors. | High[237] | Medium | Improve HH food security |

## 22.3 CASSAVA

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Frequency of days above 35°C is higher by 12% during the year. Maximum temperatures do not reach the upper limit (45°C). Increase in temperatures during the growth cycle between 8% and 14%. If harvested in late dry season or if grown as semi-perennial crops, dry season high temperature might be a constraint. Optimal growth conditions (between 20°C and 29°C) are less frequent with higher temperatures, especially in wet season (growing season). 50% of days below 29°C in baseline, only 10% in CC. Daily max temperature above comfort zone in wet season. Increase in minimum temperature will not affect the suitability significantly. | **Medium** | Low[238] | Medium | Production might be affected in the dry season with high temperatures, especially in the dry season with average temperatures above 35°C from March to April. | High[239] | Medium | Reduce potential animal feed for livestock sector |

236 Increased $CO_2$ level will increased rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

237 Internal and external capacity are high and farmers can benefit from the increase of $CO_2$ concentration by using adequate fertilization and rice field management, which will increase their rice yield.

238 Temperature higher than 35°C for a prolonged period is not suitable for cassava cultivation.

239 Cassava is a robust plant. External capacity to develop resistant varieties could be high with important involvement by the private sector. Shifting planting calendar might be an option to avoid the hottest period.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Increased precipitation from May to November (5% to 16%).<br>Total rainfall below 2,300 mm during the growth cycle.<br>Total rainfall still within the suitable range with 50% of the total precipitation during the wet season, around 1,100 mm.<br>Increase of precipitation will affect the suitability of certain areas, especially in lowlands where it can create water logging.<br>Risk is higher from July to September, with extreme events above 450 mm. | **Medium** | High[240] | Medium | Increase of precipitation will affect the suitability of certain areas, especially in lowlands where it can create water logging. Otherwise the impact level will be low. | Low | Medium | Reduce potential animal feed for livestock sector |
| Decrease in water availability | More water stress from January to November with decrease in water availability (-4% to -10%) across the year. Potential water stress at the beginning of the crop with reduced water availability. | **Low** | Low | Low | No significant impact. | High[241] | Very Low | |
| Drought (in rainy season, different from baseline) | Dry spells in the rainy season will not affect growth.<br>Increased drought frequency in April (+28%), might delay the planting season. | **Very Low** | Very Low[242] | Very Low | Dry spell in the rainy season will not impact cassava grow. | High | Very Low | |

240 Rainfall should be between 1,000 and 1,500 mm during the crop cycle for optimum growth but can support up to 2,300 mm.

241 Internal capacity is high, cassava is a robust plant. External capacity to develop resistant varieties could be high with important involvement by the private sector. Development of shorter-term varieties in case the drought period is extended.

242 Cassava is drought tolerant and requires a minimum of 500 mm of rainfall during the growing cycle. The length of the dry season needs to be longer than 6 month to cause a loss in the crop.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flooding | Precipitation above 500 mm per month in October.<br>Total precipitation in the wet season above 1,700 mm.<br>Extreme rainfall events: 1 day above 160 mm and 3 days above 100 mm.<br>Kampong Thom is a flood-prone area but eastern part of the province is less. | **High** | High[243] | High | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. But due to high rainfall and increased rainfall in the rainy season, flooding will likely occur. | Low[244] | High | Reduce potential animal feed for livestock sector |
| Storms | 3 days with more than 100 mm, including 1 day above 160 mm in eastern part of the province.<br>Flood-prone areas around the Mekong and Tonle Sap lake in the southwest part of the province.<br>Low storm frequency (0–2). | **Low** | Medium | Medium | Impact depends on the topography and the soil type of the area. Flat areas with heavy soil will generate waterlogging after a storm that can affect the cassava crop. In other configurations, storm will have a lower impact | Low | Medium | Reduce potential animal feed for livestock sector |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth. | **High** | Medium | Medium | $CO_2$ increase might have an impact but it depends upon other limiting factors such as soil nutrients and sunlight. | Medium[245] | Medium | Increasing production and beneficial to livestock |

243 No tolerance to waterlogging.

244 Cannot stand waterlogging and no flood protection system.

245 Adaptive capacity from advanced farming practices and varietal improvement.

## 22.4 RUBBER

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Dry season high temperatures might be over the optimum (29°C), with daily maximum temperatures above 35°C from February to May but no extreme values above 44°C. Exposure is higher in the dry season. However the occurrence of days above 35°C is below 20%. Dry season (March to May) will have more days above 35°C as daily maximum temperature. Increase of temperature by 14% in August. March and April will have more than 50% of the daily max temperatures above 35°C. | **Medium** | Medium[246] | Medium | Medium impact due to higher temperature. | Low | Medium | Require labor force for tapping rubber |
| Increase in precipitation | Increased rainfall in May and November (5% to18%). Annual rainfall will increase and limit water stress. Annual rainfall still within the range of optimum rainfall. | **Low** | Very low[247] | Low | Increase of precipitation will not change the suitability for rubber plantations in this area, being still in the suitable range of rainfall. | High | Low | |
| Decrease in precipitation | Reduced rainfall in January and February (-15%) will increase water stress during those months with rainfall below 100 mm. No specific change in dry season regarding the comfort zone. | **Low** | High | Medium | Lower rainfall can generate drought and water stress for the trees. However, the precipitation in the dry season will still fall within the actual comfort zone. | Low | Medium | |

246 Optimum temperature: 29°C.

247 Rainfall should be between 1,200 and 4,000 mm during the year.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Decrease in water availability | More water stress from January to November with decreased water availability (-4% to -10%).<br>Increased water stress in the dry season. | **Medium** | High | Medium | Will not significantly impact rubber production. The precipitation in the dry season will still fall within the actual comfort zone. | Low | Medium | |
| Drought (in rainy season, different from baseline) | Increased frequency of drought at the end of the dry season (April, +20%) might affect production, with reduced precipitation in the dry season too affecting water availability (-5% to -1%).<br>Increased drought in the rainy season will be limited with higher frequency in July and August (+4%). | **Medium** | Medium[248] | Medium | Increased frequency of drought at the end of the dry season (April) might affect production with reduced precipitation in the dry season too. | Low | Medium | |
| Flooding | Extreme rainfall events: 1 day above 160 mm and 3 days above 100 mm. Kampong Thom has flood-prone areas but eastern part of the province is less. | **Low** | High[249] | Medium | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. Sensitivity is high, with little tolerance to anoxia. However the planted area in flood prone area is relatively small and rubber is usually planted on higher ground. | Low[250] | Medium | |

[248] Rubber is not drought resistant and a dry spell during the rainy season might affect the crop during short periods. The length of the drought needs to be longer than 3-4 months to cause loss in the crop.

[249] Sensitivity is high, with little tolerance to anoxia.

[250] Cannot stand waterlogging and no flood protection system.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | Extreme rainfall events: 1 day above 160 mm and 3 days above 100 mm. Low storm frequency. | **Low** | Low[251] | Low | Impact depends on the soil type of the area: if shallow soil, strong wind can affect young rubber trees. In other configurations, storm will have a lower impact. | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth during early stages. | **Medium** | Medium[252] | Medium | Impact of $CO_2$ fertilization might have a positive impact on growth. | Low adaptive capacity to this change | Medium | |

## 22.5 SOYBEAN

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Higher maximum temperatures in the rainy season will create stress and limit yield. Temperatures will increase by more than 8% compare to the baseline.<br>More than 50% of days with maximum temperatures higher than 35°C in April, and extreme max temperatures (<25% of frequency) higher than 35°C during the crop season. | **High** | High[253] | High | Impact of increased temperature on soybean growth will be great. It might be a stress for soybean in the case of an early wet season crop, in April or May. | Low[254] | High | |

[251] Rubber trees can be affected by strong wind if soil is shallow, and significant rainfall can lead to submergence of the rubber.
[252] No clear scientific evidence (only for young stages).
[253] Temperatures higher than 35°C for a prolonged period inhibit soybean growth.
[254] Internal capacity is low but shift in cropping calendar to avoid high temperature is possible.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Increased rainfall from May to November (5% to 17% compared to baseline) will reduce water stress.<br>Shift of onset of rainy season, higher frequency in May (32%) compared to baseline (20%).<br>Harvest in September might be a problem with increased rainfall and extreme events with more than 450 mm per month.<br>Early planting in April is still risky with greater than 50% chance to have less than 100 mm. | **Low** | Medium[255] | Medium | Possibility to shift calendar in early wet season (April) or later in June to avoid peak rainfall in August | Low[256] | Medium | |
| Decrease in water availability | Decrease in water availability between -10% and -4% during the crop.<br>However, rainfall at the same time is above 100 mm per month. | **Medium** | High | High | High impact due to decrease in water availability. | Low | High | |

255 Rainfall should be between above 500 and 1,000 mm during the crop cycle.
256 Shift in cropping calendar to avoid high precipitation period during harvest.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Drought (in rainy season, different from baseline) | A dry spell, e.g., 5 days without rain and rainfall under 50 mm per month, can be an issue especially for an early wet season crop (April, +20%). | **Low** | High[257] | Medium | Limited rainfall after sowing and during the crop can generate water stress and reduce yield. More exposure when crops grow on sandy, gravelly soil or shallow soils. Vulnerability is higher in case of early wet season crop (April). | Low[258] | Medium | |
| Flooding | Precipitation above 500 mm per month in October.<br>Total precipitation in the wet season above 1,700 mm.<br>Extreme rainfall events: 1 day above 160 mm and 3 days above 100 mm.<br>Kampong Thom has flood-prone areas but eastern part of the province is less prone to flooding. | **High** | High[259] | High | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. | Low[260] | High | |
| Storms | Precipitation above 500 mm per month in October.<br>Extreme rainfall events: 1 day above 160 mm and 3 days above 100 mm.<br>Kampong Thom has flood-prone areas but eastern part of the province is less prone.<br>Low storm frequency (0–2). | **Low** | Medium | Medium | Storms can affect soybean crop with strong winds and significant rainfall that can lead to submergence of the soybean crop. | Low[261] | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth of soybean. | **High** | Medium | Medium | Increase in yield will be significant if other parameters for plant growth are not constraining. | Low | Medium | Increased production |

257 Soybean is not drought tolerant. A dry spell, e.g., 5 days without rain and rainfall under 50 mm per month, can be an issue especially for an early wet season crop (April).
258 Management techniques such as mulching can reduce water stress.
259 Sensitivity is high, with no tolerance to waterlogging during early stage of growth (1st month).
260 Cannot tolerate high water depth and no flood protection system.
261 No specific varieties and no specific management to limit waterlogging.

# 23 MONDULKIRI, CROP VULNERABILITY ASSESSMENT – CAM

## 23.1 LOWLAND RAINFED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Average maximum temperatures below 35°C during the growing period.<br>Absolute maximums can be above 35°C (less than 25% of time), but below 45°C.<br>Increase of maximum temperature is between 12% and 17% compared to baseline during growing period, with more than 50% of the maximum daily temperatures above the comfort zone. | **Medium** | High[262] | High | Increase in temperature in the rainy season might affect rice growth during the different stages of the culture resulting in a lower yield. | Low[263] | High | |

262 Temperatures exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperatures will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

263 External adaptive capacity is low, with lack of access to new varieties and extension services. Internal adaptive capacity is high, with capacity to grow in warm temperatures; critical temperature is 45°C at some growth stages, but with negative impact on yield.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Upper limit for monthly precipitation is about 650 mm per month for rice in the first month, and 500 mm to 600 mm at flowering and ripening stages.<br>Increased precipitation can be an issue in October with 549 mm per month in an average year, and maximum above 1,000 mm and upper 3rd percentile above 600 mm.<br>Increased rainfall from May to November (5% to 14% compared to baseline) will reduce water stress.<br>Shift of onset of rainy season, higher frequency in May (36%) compared to baseline (24%). | **Low** | Low[264] | Low | Increase of rainfall will benefit the rice crop with fewer droughts. Only extreme events with high monthly rainfall will damage the rice. | High[265] | Medium | |
| Decrease in water availability | Decrease in water availability will be between -18% and 0% during the crop season.<br>However, rainfall at the same time will be above 100 mm per month. | **Low** | High | Medium | Low potential impact | Medium | Medium | |

264 Submergence of lowland rainfed rice due to significant rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21% (Yoshida 1981). Traditional rice is more tolerant to submergence. Farmers can apply adaptive farming practices to take use of higher rainfall at early stages and mitigate impacts of heavy rains at later stages.

265 External adaptive capacity is low, with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Drought (in rainy season, different from baseline) | Change in water availability is between 0% and 15% (negatively) compared to current situation, but monthly rainfall will increase and drought frequency is not significantly different during the crop season (May to November). | **Low** | High[266] | Medium | Not a significant impact with increased rainfall. | Medium[267] | Medium | Will affect negatively HH food security |
| Flooding | Precipitation above 500 mm per month in October.<br>Total precipitation in the wet season above 1,700 mm.<br>21 days during the wet season with more than 100 mm including 1 day above 160 mm.<br>Floodplains are limited in Mondulkiri. | **Low** | Medium | Medium | Lowlands and fields close to wetlands and the river might be more exposed to flooding in 2050. The damage depends also on the height and the duration of the flood. | Medium | Medium | |
| Flash floods | 21 days with more than 100 mm including 1 day above 160 mm. | **Medium** | High | Medium | However this threat is extremely variable, depending on local topography, soil type, and land cover. Lowland rice is more exposed than other crops since its location in the topo-sequence is in lowlands and recent terraces. | Low[268] | Medium | Will affect negatively HH food security |

266 A dry spell in the rainy season can affect rice yield and abnormal rainfall patterns can generate water stress in rainfed systems.
267 Difficult access to drought-resistant varieties.
268 Rice crop will be damaged by submergence and physical debris transported by flash floods. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | 21 days with more than 100 mm including 1 day above 160 mm.<br>Precipitation above 500 mm per month in October.<br>Number of storm 9–12. | **High** | Medium[269] | High | Rainy season rice can be submerged following increased rainfall and a prolonged submergence will reduce yield. | Medium[270] | Medium | Will affect negatively HH food security |
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Low[271] | Medium | Low due to other limiting factors. | High[272] | Medium | Improve HH food security |

269 Rainy season rice can be submerged following an increase of rainfall and a prolonged submergence will reduce yield, with traditional varieties more resistant and resilient to this climatic event.

270 It depends on the rice varieties planted, and whether they are tolerant to submersion or not.

271 Increased $CO_2$ levels will increase rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

272 Internal and external capacity are high and farmers can benefit from the increase of $CO_2$ concentration by using adequate fertilization and rice field management, which will increase their rice yield.

## 23.2 CASSAVA

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Maximum temperature reaching the upper limit (45°C).<br>Increase in temperature during the growth cycle between 10% and 18%.<br>If harvested in the late dry season or if grown as semi-perennial crop, dry season high temperature might be a constraint.<br>Optimal growth conditions (between 20°C and 29°C) are less frequent with higher temperatures, especially in wet season (growing season).<br>Around 15% of the days are above 35°C (compared to less than 5% in the baseline). | **Medium** | Low[273] | Medium | Impact of increased temperature in the early stage of the cycle and before harvest in longer cycle. It might affect the growth but will not be above the suitability limit. | High[274] | Medium | Reduce potential animal feed for livestock sector |
| Increase in precipitation | Increased precipitation from May to November (5% to13%).<br>Increase of precipitation will affect the suitability of certain areas, especially in lowlands where it can create water logging. | **Low** | High[275] | Medium | Precipitation will still be above optimum range, leading to waterlogging, more disease and lower yield.<br>Increase in precipitation from May to November can create waterlogging conditions and affect cassava yield. | Medium | Medium | Reduce potential animal feed for livestock sector |

273 Temperatures higher than 35°C for a prolonged period are not suitable for cassava cultivation.

274 Cassava is a robust plant. External capacity to develop resistant varieties could be high with important involvement by the private sector. Shifting planting calendar might be an option to avoid the hottest period.

275 Rainfall should be between 1,000 and 1,500 mm during the crop cycle for optimum growth but can support up to 2,300 mm.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Decrease in precipitation | Reduced rainfall from December to April (3% to 12%) with increased water stress during those months with rainfall below 100 mm.<br>No specific change in dry season regarding the comfort zone.<br>Annual precipitation will increase but still within optimum range. | **Very Low** | Very Low | Very Low | The precipitation in the dry season will still fall within the actual comfort zone. | High | Low | |
| Decrease in water availability | More water stress from January to November with decreased water availability (-5% to -15%) | **Medium** | Very Low | Low | No significant impact | High | Low | |
| Drought (in rainy season, different from baseline) | Dry spell in the rainy season will not affect plant growth. | **Very Low** | Very Low[276] | Very Low | Dry spell in the rainy season will not impact cassava growth. | High | Very Low | |
| Flooding | Precipitation above 500 mm per month in October. Total precipitation in the wet season above 1,700 mm.<br>21 days with more than 100 mm including 1 day above 160 mm.<br>Floodplains are limited in Mondulkiri. | **Low** | Very High[277] | Medium | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. | Low[278] | Medium | Reduce potential animal feed for livestock sector |

276 Cassava is drought tolerant and requires a minimum of 500 mm of rainfall during the growing cycle. The length of the dry season needs to be longer than 6 months to cause loss in the crop.

277 No tolerance to waterlogging.

278 Cannot stand waterlogging and no flood protection system.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flash floods | 21 days with more than 100 mm including 1 day above 160 mm. | **Low** | High | Medium | Depends on the geography and the topography of the area. In addition to waterlogging in the fields, debris can damage the crops. | Low | Medium | Reduce potential animal feed for livestock sector |
| Storms | 21 days with more than 100 mm including 1 day above 160 mm.<br>Precipitation above 500 mm per month in October.<br>Number of storm 9–12. | **High** | Medium | Medium | Impact depends on the topography and the soil type of the area. Flat areas with heavy soil will generate waterlogging after a storm that can affect the cassava crop. In other configurations, storm will have a lower impact. | Low | Medium | Reduce potential animal feed for livestock sector |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth. | **High** | Medium | Medium | $CO_2$ increase might have an impact but it depends upon other limiting factors such as soil nutrients and sunlight. | Medium[279] | Medium | Increasing production and beneficial to livestock |

[279] Adaptive capacity from advanced farming practices and varietal improvements.

## 23.3 RUBBER

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Dry season high temperature might be over the optimum (29°C), with 35°C maximum temperatures up to 45°C. Exposure is higher in the dry season. However the occurrence of days above 35°C is below 20% per year<br>Dry season (March to May) will have more days above 35°C as daily maximum temperature, with increase of temperature by 17% in May.<br>May has more than 50% of the days with maximum temperatures above 35°C and 25% of the days in the dry season will be above 35°C as maximum daily temperature.<br>There will be more minimum temperatures closer to the optimum and less temperature closer to the absolute minimum. | **Medium** | Medium[280] | High | Production might be affected in the dry season. | Low | Medium | Require labor force for tapping rubber |

280 Optimum temperature: 29°C.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Increased rainfall in May and November (5% to 13%). | **Very Low** | Very Low[281] | Very Low | Increase of precipitation will not change the suitability for rubber plantations in this area; it will still fall within the suitable range of rainfall for rubber. | High | Low | |
| Decrease in precipitation | Reduced rainfall from December to April (by 3% to 12%) will increase water stress during those months with rainfall below 100 mm.<br>No specific change in dry season regarding the comfort zone. | **Very Low** | High | Low | Annual precipitation will increase but still within optimum range. | Low | Medium | |
| Decrease in water availability | More water stress from January to November with decreased water availability (-5% to -15%). | **Medium** | High | Medium | Will not significantly impact rubber production. | Low | Medium | |
| Drought (in rainy season, different from baseline) | Increased frequency of drought at the end of the dry season (April: +24%) might affect production, with reduced precipitation in the dry season too and water availability (-5% to -15%) | **Low** | Medium[282] | Medium | Dry spell in the rainy season will not impact rubber growth and culture. | Low | Medium | |

281 Rainfall should be between 1,200 and 4,000 mm during the year.

282 Rubber is not drought resistant and dry spell during the rainy season might affect the crop during short periods. The length of the drought needs to be longer than 3-4 months to cause loss in the crop.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flooding | Along the river and floodplains, floods and water logging occurring during the growing season can affect rubber yield, however the area is relatively small and rubber is usually planted on higher ground. | **Low** | High[283] | Medium | Along the river and floodplains, floods and water logging occurring during the growing season can affect rubber yield, however the area is relatively small and rubber is usually planted on higher ground. | Low[284] | Medium | |
| Flash floods | 21 days with more than 100 mm, including 1 day above 160 mm. Precipitation above 500 mm per month in October. Number of storm 9–12. | **Low** | Low[285] | Low | Depends on the geography and the topography. Flash floods are related to storms and heavy rainfall in the rainy season. | Low[286] | Medium | |
| Storms | 21 days with more than 100 mm, including 1 day above 160 mm. Precipitation above 500 mm per month in October. Number of storm 9-12. | **High** | Low[287] | Medium | Impact depends on the soil type of the area: if shallow soil, strong wind can affect young rubber trees. In other configurations, storms will have a lower impact. | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth during early stages | **Medium** | Medium[288] | Medium | Impact of $CO_2$ fertilization might have a positive impact. | Low adaptive capacity to this change. | Medium | |

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Higher maximum temperatures above 35°C in the rainy season will create stress and limit yield. Temperature will increase by more than 10% compared to the baseline. During the rainy season the daily maximum temperature is above the comfort zone. | **High** | High[289] | High | Impact of increased temperatures on soybean growth will be great. It might be a stress for soybean in the case of an early wet season crop in April or May. | Low[290] | High | |
| Increase in precipitation | Increased rainfall from May to November (5% to 14% compared to baseline) will reduce water stress. Shift of onset of rainy season, higher frequency in May (36%) compared to baseline (24%) Need to avoid October as increased precipitation can be an issue in October with 549 mm per month in average year, and maximum above 1,000 mm and upper 3rd percentile above 600 mm. | **Low** | Medium[291] | Medium | Possibility to shift calendar in early wet season (April) or later in June to avoid heavy rain in August. | Low[292] | Medium | |

289 Temperatures higher than 35°C for a prolonged period inhibit soybean growth.
290 Internal capacity is low but shift in cropping calendar to avoid high temperature is possible.
291 Rainfall should be between above 500 and 1,000 mm during the crop cycle.
292 Shift in cropping calendar to avoid high precipitation period during harvest.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Decrease in water availability | Decrease in water availability will be between 18% and 0% during the crop season.<br>However, rainfall at the same time will be above 100 mm per month. | **Medium** | High | High | High impact due to decease in water availability | Low | High | |
| Drought (in rainy season, different from baseline) | A dry spell, e.g., 5 days without rain and rainfall under 50 mm per month, can be an issue especially for an early wet season crop (April, +24%). | **Low** | High[293] | Low | Limited rainfall after sowing and during the crop season can generate water stress and reduce yield. More exposure when crops grow on sandy, gravelly soil or shallow soils.<br>Vulnerability is higher in the case of an early wet season crop (April). | Low[294] | Medium | |
| Flooding | Precipitation above 500 mm per month in October.<br>Total precipitation in the wet season above 1,700 mm.<br>21 days with more than 100 mm, including 1 day above 160 mm.<br>Floodplains are limited in Mondulkiri. | **Low** | High[295] | Medium | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. | Low[296] | Medium | |

293 Soybean is not drought tolerant. A dry spell, e.g., 5 days without rain and rainfall under 50 mm per month, can be an issue especially for an early wet season crop (April).
294 Management techniques such as mulching can reduce water stress.
295 Sensitivity is high, with no tolerance to waterlogging in early stage of growth (1st month).
296 Cannot stand high water depth and no flood protection system.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flash floods | Precipitation above 500 mm per month in October.<br>Total precipitation in the wet season above 1,700 mm.<br>21 days with more than 100 mm, including 1 day above 160 mm.<br>Floodplains are limited in Mondulkiri. | **Low** | High | Medium | Depends on the geography and topography of the area. Flash floods are related to storms and heavy rainfall in the rainy season.<br>In addition to waterlogging in the fields, debris can damage the crops. | Low | Medium | |
| Storms | Precipitation above 500 mm per month in October.<br>Total precipitation in the wet season above 1,700 mm.<br>21 days with more than 100 mm, including 1 day above 160 mm.<br>Floodplains are limited in Mondulkiri. | **High** | Medium | Medium | Storms can affect soybean crop with strong winds, and significant rainfall that can lead to submergence of the soybean crop.<br>Impact depends on the topography and the soil type of the area. | Low[297] | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth of soybeans. | **High** | Medium | Medium | Increase of yield will be significant if other parameters for plant growth are not constraining. | Low | Medium | Increased production |

297 No specific varieties and no specific management to limit waterlogging.

# 24 KIEN GIANG, CROP VULNERABILITY ASSESSMENT – CAM

## 24.1 RAINFED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Last percentile (75% to 100%) of maximum temperature ranges from 37°C to 41°C in the period of March and May (in the early wet season), compared to the baseline ranging from 35°C to 38°C. Increased temperature between 9% and 12% from June to November. | **Medium** | High[298] | High | The predicted maximum temperature is not frequent; the likelihood of days when the maximum temperature exceeds 35°C is less than 30% during the year. | High[299] | High | |
| Increase in precipitation | Increased precipitation can be an issue in September–October, when the upper 3rd percentile is above 400 mm. Almost 50% of the total precipitation in the wet season is above the comfort zone. | **Medium** | Low[300] | Medium | The exposure also depends on the rice varieties used, elevation and draining systems. Traditional rice varieties well tolerate submergence. | Medium[301] | Medium | |

298 Temperatures exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperatures will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

299 High internal and external adaptive capacity, with heat-tolerant traditional varieties and good farming practices, good extension systems and strong international and government research capacity to develop temperature-resistant varieties.

300 Submergence of lowland rainfed rice due to significant rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21%. (Yoshida 1981)

301 Medium internal and external adaptive capacity, with farming practices and submergence management systems; and international and local research agencies are developing submergence-resistant varieties.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Decrease in precipitation | The decrease in precipitation might occur in April (-10%), May (early rainy season), and in December (-8%, late rainy season) and causes salinity intrusion and acidification, particularly in rotational shrimp and rice farming areas. | **Medium** | High | Medium | The decrease in precipitation that will occur in April and May (early rainy season) and in December (late rainy season) causes rice damage from salinity intrusion and acidification. | Medium | Medium | |
| Decrease in water availability | Decrease of water availability between -6% to -8%. | **Very Low** | High | Low | Low potential impact | High | Low | |
| Drought (in rainy season, different from baseline) | The likelihood of drought occurrence in early and late rainy season is about 8% higher than the baseline in May. | **Medium** | Medium[302] | Medium | A dry spell can reduce yield, in combined effect of salinity and acidity. Occurrence probability of drought is predicted to be low. | Medium[303] | Medium | Will affect negatively HH food security |
| Flooding | Flooding strongly impacts rice yield. Flood areas are significant in Kien Giang. | **High** | Medium | High | Floods reduce yield although it depends on draining systems. The impact depends also on rice stage and flood duration. | Medium[304] | High | |
| Storms | About 1-2 storms directly hit Kien Giang Province.<br>1 event with more than 200 mm rainfall per day and 6 events with more than 100 mm per day. | **Medium** | Medium[305] | Medium | Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield. | Medium[306] | Medium | Will affect negatively HH food security |

302 A dry spell in the rainy season can affect rice yield and abnormal rainfall patterns, which can generate water stress in rainfed systems.
303 Difficult access to drought-resistant varieties.
304 External adaptive capacity is medium because of poor drainage systems coupled with international research capacity to develop submergence-resistant varieties.
305 Rainy season rice can be submerged following increase of rainfall, and a prolonged submergence will reduce yield with traditional varieties more resistant and resilient to this climatic event.
306 It depends on the rice varieties planted, and whether they are tolerant to submersion or not.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Sea level rise | Sea level rise causes salinization of paddy fields along coastal areas, resulting in longer saline periods in the dry season and shorter freshwater time window for rice, without salinity control systems. Rice can be damaged by saline water intrusion during spring tide and in early and late rainy season. 30 cm in 2050. | **High** | Very High | Very High | Rice crop suffers a significant yield loss with a salinity concentration above 4%. The severity differs with time and duration of stress, and rice varieties. | High[307] | High | |
| Increasing salinity | Increased salinity intrusion due to SLR and lower fresh water flow. Increased affected area in the MKD: 90,000 ha by 2050 | **High** | Very High[308] | Very High | Yield losses depend on time and duration of stress, soil properties, and rainfall distribution. | High[309] | High | |
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Low[310] | Low | Low due to other limiting factors. | High[311] | Medium | Improve HH food security |

307 High internal and external adaptive capacity, with shifting rice to rice-shrimp rotational farming or shrimp mono-culture by farmers, developing salinity control systems by local government and development of new rice varieties tolerant to salinity by international and local research agencies.

308 From salinity of 2%, rice yield reduces about 1 tonne/ha for salinity-sensitive varieties and about 0.4 tonne/ha for salinity-tolerant varieties for each increase in salinity of 1%.The damage becomes more severe if the stress occurs during young, panicle initiation and flowering stages.

309 High internal and external adaptive capacity, with shifting rice to rice-shrimp rotational farming or shrimp mono-culture by farmers, developing salinity control systems by local government and development of new rice varieties tolerant to salinity by international and local research agencies.

310 Increased $CO_2$ level will increase rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization. We considered the sensitivity as low since rainfed rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

311 Internal and external capacity are high and farmers can benefit from the increase of $CO_2$ concentration by using adequate fertilization and rice field management, which will increase their rice yield.

## 24.2 IRRIGATED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Last percentile (75% to 100%) of maximum temperature ranges 37°C to 41°C in the period of March to May (in early wet season), compared to the baseline ranging 35°C to 38°C.<br>March and April have 50% of the maximum temperature above 35°C. | **Medium (dry season-DS crop) - Medium (wet season - WS crop),** | High[312] | High | The predicted maximum temperature is frequent and the will impact on rice growth in both dry and wet season | High[313] | High | |
| Increase in precipitation | Increased precipitation can be an issue in September–October, when the upper 3rd percentile is above 400 mm.<br>Almost 50% of the total precipitation in the wet season is above the comfort zone. | **Low (DS crop) - Medium (WS crop)** | Medium[314] | Medium | Medium impact on rice culture. | Medium[315] | Medium | |

312 Temperatures exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperatures will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

313 High internal and external adaptive capacity, with heat-tolerant traditional varieties and good farming practices, good extension systems and strong international and government research capacity to develop temperature-resistant varieties.

314 Submergence of lowland rainfed rice due to significant rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21%. (Yoshida 1981)

315 External adaptive capacity is low, with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Decrease in precipitation | A decrease in precipitation might occur in April (-10%), May (early rainy season), and in December (-8% late rainy season). | **Medium** | Medium | Medium | The decrease in precipitation might occur in April and May (early rainy season), causing a water deficit during the early stages of the WS crop. The result is reduced tillering (or production of side shoots) of the rice plant. The problem becomes more severe with lower discharge rates from the Mekong in the dry season. | High[316] | Medium | |
| Drought (in rainy season, different from baseline) | The likelihood of drought occurrence in the early and late rainy season is about 8% higher than the baseline in May. | **Low (DS crop) – Medium (WS crop).** | Medium[317] | Medium | A dry spell can reduce yield, in combined effect of salinity and acidity. Occurrence probability of drought is predicted low. | Medium[318] | Medium | Will affect negatively HH food security |
| Flooding | Flooding strongly impacts rice yield. Flood areas are significant in Kien Giang, but exposure is limited on DS crop. | **High** | Medium | High | Flooding reduces yield although impact depends on other factors such as drainage systems, rice stage, and flood duration. | Medium[319] | High | |

316 High internal and external adaptive capacity with farming practices, irrigation systems, and international and local research agencies developing shorter-growth duration varieties.

317 A dry spell in the rainy season can affect rice yield and abnormal rainfall patterns, which can generate water stress in rainfed systems.

318 Difficult access to drought-resistant varieties

319 External adaptive capacity is medium because of poor drainage systems coupled with international research capacity to develop submergence-resistant varieties.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | About 1–2 storms directly hit Kien Giang Province.<br>1 event with more than 200 mm rainfall per day and 6 events with more than 100 mm per day, but exposure is low for DS crops. | **Low** | Low[320] | Low | Wet season rice yield might be reduced from extreme heavy rains and strong winds, particularly during flowering and ripening stages of the WS crop. However, the severity of storms is low in freshwater and irrigated rice areas. | Medium[321] | Medium (WS)<br>Low for (DS) | Will affect negatively HH food security |
| Sea level rise | Sea level rise causes salinization of paddy fields along coastal areas, resulting in longer saline periods in the dry season and shorter freshwater time window for rice, without salinity control systems. Rice can be damaged by saline water intrusion during spring tide and in early and late rainy season. | **Low (DS crop) – High (WS crop)** | High | Medium (DS crop) - High (WS crop) | Rice crop suffers a significant yield loss with a salinity concentration above 4%. The severity differs with time and duration of stress and rice varieties. | High[322] | Medium (DS)<br>High (WS) | |

320 Rainy season rice can be submerged following increased rainfall and a prolonged submergence will reduce yield, with traditional varieties more resistant and resilient to this climatic event.

321 It depends on the rice varieties planted, and whether they are tolerant to submersion or not.

322 High internal and external adaptive capacity, with shifting rice to rice-shrimp rotational farming or shrimp mono-culture by farmers, developing salinity control systems by local government and development of new rice varieties tolerant to salinity by international and local research agencies.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increasing salinity | High (DS crop) – High (WS crop) | **High (DS crop) - Medium (WS crop)** | Very High[323] | High | Yield losses depend on time and duration stress, soil properties, rainfall distribution. | High[324] | High | |
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Low[325] | Low | Low due to other limiting factors | High[326] | Medium | Improve HH food security |

323 From salinity of 2%, rice yield is reduced by about 1 tonne/ha, for salinity-sensitive varieties and about 0.4 tonne/ha for salinity-tolerant varieties, for each increase in salinity of 1‰. The damage becomes more severe if the stress occurs during young, panicle initiation and flowering stages.

324 High internal and external adaptive capacity, with shifting rice to rice-shrimp rotational farming or shrimp mono-culture by farmers, developing salinity control systems by local government and development of new rice varieties tolerant to salinity by international and local research agencies.

325 Increased $CO_2$ level will increase rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization.

326 Internal and external capacity are high and farmers can benefit from the increase of $CO_2$ concentration by using adequate fertilization and rice field management, which will increase their rice yield.

# 25 GIA LAI, CROP VULNERABILITY ASSESSMENT – CAM

## 25.1 LOWLAND RAINFED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Last percentile (75% to 100%) of maximum temperature ranges 35°C to 37°C in the period of June–October (wet season crop). In the baseline, maximum temperatures never exceed 35°C. | **Medium** | High[327] | High | Increase in temperature in the rainy season might affect rice growth during the different stages of the culture resulting in a lower yield. The predicted maximum temperature is not that frequent and the main impact on rice will depend on the growth stage and soil water availability. | Low[328] | High | |

327 Temperatures exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperatures will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

328 External adaptive capacity is low, with lack of access to new varieties and extension services. Internal adaptive capacity is high, with capacity to grow in warm temperatures, critical temperature is 45°C at some growth stages, but with negative impact on yield.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Suitable range is 200–400 mm/ month in the first 3 months and 70–150 mm/month in the last month. Increased precipitation can be an issue in August with the upper 3rd percentile above 750mm. | **Medium (lowland) - Very Low (upland)** | Low[329] | Medium (lowland –Low (upland) | The exposure also depends on the rice varieties used, elevation, and draining systems. Upland rainfed rice would be not affected at all. | Medium (lowland) to High (upland) external adaptive capacity[330] | Medium (lowland) - low (upland) | |
| Increase in water availability | Change in water availability is between 0% and 1.5% compared to baseline | **Very Low** | Very Low | Very Low | Low potential impact | High[331] | Very Low | |
| Drought (in rainy season, different from baseline) | Change in water availability is between 0% and 1.5% compared to the baseline, but monthly rainfall will increase and probability of drought is 8% to 56% in October and November, | **Low** | High[332] | Medium | Not a significant impact | Medium[333] | Medium | Will affect negatively HH food security |
| Flooding | Increase of precipitation from June to November (5% to 15%) compared to baseline. 10 days with more than 100 mm and 2 with more than 140 mm. | **Low** | Low (upland) - Medium (lowland) | Low (upland) - Medium (lowland) | Floods reduce yield although impact depends on drainage systems, rice stage, and flood duration. The impact is not significant for upland rice | Medium | Medium | |

329 Submergence of lowland rainfed rice due to significant rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21% (Yoshida 1981).

330 External adaptive capacity is low, with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

331 High internal capacity to tolerate anoxia and flood conditions.

332 A dry spell in the rainy season can affect rice yield, and abnormal rainfall patterns can generate water stress in rainfed systems.

333 Difficult access to drought resistant varieties

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flash floods | Increase of precipitation from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **Low (upland) -Medium (lowland)** | Low (upland) - Medium (lowland) | Low (upland) - Medium (lowland) | The threat is variable depending on local topography, soil type, and land cover. | Low[334] | Medium | Will affect negatively HH food security |
| Storms | Increase of precipitation from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm.<br>7–10 storms per year. | **Medium** | Medium[335] | Medium | Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield | Medium[336] | Medium | Will affect negatively HH food security |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Low[337] | Low | Low due to other limiting factors | High[338] | Medium | Improve HH food security |

334 Rice crop will be damaged by submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of for flash flood protection system.

335 Rainy season rice can be submerged following increase of rainfall and a prolonged submergence will reduce yield, with traditional varieties more resistant and resilient to this climatic event.

336 It depends on the rice varieties planted, and whether they are tolerant to submersion or not.

337 Increased $CO_2$ level will increase rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.

338 Internal and external capacity are high and farmers can benefit from the increase of $CO_2$ concentration by using adequate fertilization and rice field management, which will increase their rice yield.

## 25.2 IRRIGATED RICE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Last percentile (75% to 100%) of maximum temperature ranges 35°C to 37°C in the period of June-October (wet season crop). In the baseline, the maximum temperature never exceeds 35°C. April-May temperature exceeds 35°C and last percentile reaches 40°C. | **Medium** | High[339] | High | The predicted maximum temperature is frequent and this will impact rice growth in both the dry and wet seasons. | Low[340] | High | |
| Increase in precipitation | Suitable range is 200–400 mm/month in the first 3 months and 70–150 mm/month in the last month.<br>Increased precipitation can be an issue in August, with the upper 3rd percentile above 750 mm. However, the availability of irrigation/drainage systems could mitigate the damage to irrigated rice. | **Low** | Low[341] | Low | Low impact, will not affect rice culture. | Medium[342] | Medium | |

339 Temperatures exceeding 35°C at anthesis stage can induce sterility (Yoshida 1981). Increased temperatures will reduce the number of grains (Sheehy et al. 2006). However, rice can grow in warm conditions up to 45°C (critical temperature at germination).

340 External adaptive capacity is low, with lack of access to new varieties and extension services. Internal adaptive capacity is high, with capacity to growth in warm temperature; critical temperature is 45°C at some growth stage, but with negative impact on yield.

341 Submergence of lowland rainfed rice due to significant rainfall can affect rice yield. For example, 25% of submergence during the flowering stage can reduce yield by 21%. (Yoshida 1981)

342 External adaptive capacity is low, with international and government research capacity to develop submergence-resistant varieties, using intermediate plant height (instead of dwarf varieties), but difficulties in reaching small-scale farmers. However, the internal adaptive capacity is high with traditional lowland rainfed rice more adapted to submergence compared to HYV rice.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in atmospheric $CO_2$ | Increased $CO_2$ atmospheric concentration will modify rice crop growth and ultimately increase yield. | **High** | Medium/ Low[343] | Medium | Low due to other limiting factors | High[344] | Medium | Improve HH food security |

## 25.3 CASSAVA

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Less than 20% of the days are above 35°C. April may be the hottest period with more than 50% of the maximum temperatures above 35°C.<br>Increase in minimum temperatures will not significantly affect the suitability and may be beneficial in upland areas where minimum temperatures are more extreme. | **Medium** | Low[345] | Medium | Production might be affected by high temperature (>35°C) from March to May. | High[346] | Medium | Reduce potential animal feed for livestock sector |

343 Increased $CO_2$ level will increase rice yield (Krishnan 2007), however it depends on other limiting factors such as nitrogen fertilization. We considered the sensitivity as low since upland rice is usually grown with limited inputs and therefore the response to $CO_2$ will be limited.
344 Internal and external capacities are high and farmers can benefit from the increase of $CO_2$ concentration by using adequate fertilization and rice field management, which will increase their rice yield.
345 Temperatures higher than 35°C for a prolonged period are not suitable for cassava cultivation.
346 Cassava is a robust plant. External capacity to develop resistant varieties could be high with important involvement by the private sector. Shifting planting calendar might be an option to avoid the hottest period.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Increased rainfall will be above optimum, with high precipitation in August. | **Medium** | High[347] | Medium | Increase of precipitation might create water logging and soil erosion (if steep slope). | Low | High | Reduce potential animal feed for livestock sector |
| Decrease in precipitation | Predicted precipitation in the dry season would be 4% to 8% lower than the baseline. | **Low** | Low | Low | The impacts might be low because the crop is ready for harvesting. | High | Low | |
| Decrease in water availability | Water availability is reduced by 1.5% in the dry season. | **Low** | Low | Low | No significant impact, cassava is drought resistant and the main crop cycle is in the wet season. | High | Very Low | |
| Drought (in rainy season, different from baseline) | The length of the dry season needs to be longer than 6 months to cause loss in the crop. More frequent drought in April may require a shift in the planting date. | **Very Low** | Very Low[348] | Very Low | A dry spell in the rainy season will not impact cassava growth. | High | Very Low | |
| Flooding | Monthly rainfall will increase and only 8% probability that drought could occur in October.<br>Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **Low** | High[349] | Medium | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. | Low[350] | Medium | Reduce potential animal feed for livestock sector |

347 Rainfall should be between 1,000 and 1,500 mm during the crop cycle for optimum growth but can support up to 2,300 mm.

348 Cassava is drought tolerant and requires a minimum of 500 mm of rainfall during the growing cycle. The length of the dry season needs to be longer than 6 months to cause loss in the crop.

349 No tolerance to waterlogging.

350 Cannot stand waterlogging and no flood protection system.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flash floods | Monthly rainfall will increase and only 8% probability that drought could occur in October.<br>Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **High** | High | High | Depends on the geography and the topography of the area. In addition to waterlogging in the fields, debris can damage the crops. | Low | High | Reduce potential animal feed for livestock sector |
| Storms | Monthly rainfall will increase and only 8% probability that drought could occur in October.<br>Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **High** | Medium | High | Impact depends on the topography and the soil type of the area. Flat areas with heavy soil will generate waterlogging after a storm that can affect the cassava crop. In other configurations, storms will have a lower impact. | Low | High | Reduce potential animal feed for livestock sector |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth. | **High** | Medium | Medium | $CO_2$ increase might have an impact but it depends upon other limiting factors such as soil nutrients and sunlight. | Medium[351] | Medium | Increasing production and beneficial to livestock |

351 Adaptive capacity from advanced farming practices and varietal improvements.

## 25.4 RUBBER

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Dry season high temperature might be over the optimum (29°C), 35°C maximum temperature up to 45°C. Exposure is higher in the dry season. However the occurrence of days above 35°C is below 20%. | **Medium** | Medium[352] | Medium | Production might be affected in the dry season with high temperatures, especially in the dry season with average temperature above 35°C from March to May. Optimal growth conditions (between 27°C and 29°C) are less frequent with higher temperatures, especially in wet season. | Low | Medium | Require labor force for tapping rubber |
| Increase in precipitation | 429 mm in August and last percentile up to 900 mm. | **Very Low** | Very Low[353] | Very Low | Increase of precipitation as predicted might not change the suitability for rubber plantations in this area, being still in the suitable range of rainfall. On the annual basis it will increase the suitability. Only excessive rains that might occur in August can reduce production, but the change in frequency is low. | High | Low | |
| Decrease in water availability | The decrease in water availability in the dry season is small (1% to 2%) compared to the baseline. | **Medium** | High | Medium | Lower rainfall can generate drought and water stress for the tree. However the decrease in water availability in the dry season is small. | Low | Medium | |

352 Optimum temperature: 29°C

353 Rainfall should be between 1,200 and 4,000 mm during the year.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increases in water availability | The increase in water availability is small (1% in August) | **Low** | Low | Low | Will not significantly impact rubber production. | Low | Medium | |
| Drought (in rainy season, different from baseline) | No significant difference in rainfall and drought during the dry season. More rain in April. | **Low** | Medium[354] | Medium | A dry spell in the rainy season will not impact rubber growth and culture. | Low | Medium | |
| Flooding | Monthly rainfall increase and only 8% probability that drought could occur in October.<br>Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **Low** | High[355] | Medium | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. Sensitivity is high, with little tolerance to anoxia. Rubber is usually planted on higher ground. | Low[356] | Medium | |
| Flash floods | Monthly rainfall increase and only 8% probability that drought could occur in October.<br>Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **Low** | Low[357] | Low | Depends on the geography and the topography of the area. Flash floods are related to storms and heavy rainfall in the rainy season. | Low[358] | Medium | |

354 Rubber is not drought resistant and a dry spell during the rainy season might affect the crop during short periods. The length of the drought needs to be longer than 3-4 month to cause loss in the crop.

355 Sensitivity is high, with little tolerance to anoxia.

356 Cannot stand waterlogging and no flood protection system.

357 Debris can damage the rubber tree. Impact also depends on the age of the plantation, young trees being more sensitive.

358 Rubber yield will suffer from submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems. Rubber plantation will reduce the erosion.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | Monthly rainfall increase and only 8% probability that drought could occur in October.<br>Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **High** | Low[359] | Medium | Impact depends on the soil type of the area: if shallow soil, strong wind can affect young rubber tree. In other configurations, storm will have a lower impact. | Low | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth during early stages | **Medium** | Medium[360] | Medium | Impact of $CO_2$ fertilization might have an impact | Low adaptive capacity to this change | Medium | |

359 Rubber trees can be affected by strong wind if soil is shallow and significant rainfall that can lead to submergence of the rubber.

360 No clear scientific evidence (only for young stages).

## 25.5 MAIZE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Growth might be affected by high temperatures (>32°C) from May to October. 50% of the days are above 32°C during the year.<br>50% of the maximum temperatures are above 32°C in May and June and last percentile during the rest of the growing season. | **Medium** | Low[361] | Medium | The critical temperature will not be reached during the entire crop season.<br>It might be a stress for maize in the case of an early wet season crop, in April or May. | Low[362] | Medium | |
| Increase in precipitation | Rainfall during the growing cycle is within the optimum range (1,000 to 1,500 mm). Increase of precipitation by 5% to 10% will reduce water stress. | **Low** | Medium[363] | Medium | Increase of precipitation might create water logging and soil erosion (if steep slope). However, excessive rains might occur only in July and/or August. | Low[364] | Medium | |
| Increase in water availability | Water availability increases about 1.5% only in August. | **Low** | Low | Low | No likely impacts on maize crop. | High | Low | |
| Drought (in rainy season, different from baseline) | More frequent drought in April will require shifting the planting data. | **Very Low** | High[365] | Low | Low incidence, with increased rainfall and similar water availability compared to the baseline. | Low[366] | Medium | |

361 Temperatures higher than 35°C for a prolonged period inhibit maize growth. Above 40°C (average mean temperature), the conditions are not suitable for maize cultivation.

362 Internal capacity is low. Shift in cropping calendar to avoid high temperatures is possible.

363 Rainfall should be between 500 and 1,200 mm during the crop cycle. Increase of precipitation will not be suitable for maize growth if precipitation is over 1,600 mm during the growing cycle.

364 Internal capacity is low. Shift in cropping calendar to avoid high precipitation period.

365 Maize is not drought tolerant. A dry spell, e.g., 5 days without rain and rainfall under 50 mm per month, can be an issue. Limited rainfall after sowing and during the crop can generate water stress and reduce yield.

366 Use management techniques such as mulching to reduce water stress.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Flooding | Monthly rainfall increase and only 8% probability that drought could occur in October.<br>Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **Low** | High[367] | Medium | The threat will depend on the location of the crop, e.g., along rivers and in flood-prone areas. | Low[368] | Medium | |
| Flash floods | Monthly rainfall increase and only 8% probability that drought could occur in October.<br>Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **High** | High | High | Depends on the geography and the topography of the area. | Low[369] | High | Will affect negatively HH food security |
| Storms | Monthly rainfall increase and only 8% probability that drought could occur in October.<br>Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 with more than 140 mm. | **High** | Medium | High | Impact depends on the topography and the soil type of the area. Flat areas with heavy soil will generate waterlogging after a storm that can affect the maize crop. In other configurations, storms will have a lower impact. | Low | High | |

367 No tolerance to waterlogging

368 Cannot stand waterlogging and no flood protection system

369 Rice crop will be damaged by submergence and physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth of maize. | **High** | Low[370] | Medium | Increase of yield could be significant but water use efficiency would need to be increased. | Low | Medium | |

## 25.6 SUGARCANE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Changes in temperature are within the favorable range, even in ripening stages, usually in December–February. | **Low** | Medium[371] | Medium | Maximum temperature will still be within the optimum. | High[372] | Medium | |
| Increase in precipitation | Excessive rainfall in July–September might cause water logging. However, sugarcane can tolerate a short spell of water logging (1–2 weeks). | **Low** | Medium[373] | Medium | Significant precipitation might result in increased pest and fungi outbreak. Some areas with dry spells in the dry season might become more suitable for sugarcane growth. | High | Medium | |

370 As a C4 plant, the impact should be lower than for C3 plants.

371 Temperatures higher than 34°C for a prolonged period are not suitable for sugarcane cultivation and temperatures above 38°C stop growth.

372 Internal capacity is high, sugarcane is a robust plant and can grow under high temperatures.

373 Rainfall should be above 1,300 mm during the crop cycle for optimum growth, with repartition during the years of 110-180 mm. During ripening (dry season) heavy rainfall is not desirable.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in water availability | The increase in water availability is small (1% in August). | **Very Low** | Medium[374] | Low | Does not influence sugarcane production unless it is waterlogging (see flooding). But increase of water availability can reduce water stress. | Low[375] | Medium | |
| Drought (in rainy season, different from baseline) | Drought frequency does not change compared to baseline | **Very Low** | Medium[376] | Low | Low impact in the rainy and dry season | Low[377] | Medium | |
| Flooding | Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 days with more than 140 mm. | **Low** | Medium[378] | Medium | Exposure will be higher in floodplains. But due to high rainfall and increased rainfall in the rainy season, flooding will be more likely to occur. | Medium | Medium | |
| Flash floods | Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 days with more than 140 mm. | **Low** | High | Medium | Depends on the geography and the topography of the area. | Low[379] | Medium | |

374 Water availability favors growth of sugarcane, and the plant can also tolerate waterlogging.
375 Internal capacity is low (not drought tolerant).
376 Sugarcane is not drought tolerant and requires a minimum of 100–180 mm of rainfall per month during the growing cycles. If water stress, with dry spell and less than 30 mm within a 10 day period, the yield will be reduced. Dry climate is preferred before harvest in the dry season. Water stress will be reduced if access to irrigation (common in the region).
377 Low internal capacity of the crop to tolerate drought.
378 Sensitivity is medium; the plant can tolerate 1 week waterlogging.
379 Sugarcane crop will be damaged by physical debris transported by the flash flood. External capacity is low. It will require local improvement or adjustment of flash flood protection systems.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Storms | Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 days with more than 140 mm. | **Low** | Medium[380] | Medium | Impact depends on the topography and the soil type of the area. | Medium[381] internal | Medium | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on vegetative growth | **Medium** | Medium | Medium | Impact of $CO_2$ fertilization might have positive effect on crop, but no clear scientific evidence. | Medium | Medium | Positive impact |

## 25.7 ROBUSTA COFFEE

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in temperature | Dry season high temperature might be over the optimum level (26°C), with the favorable upper level 32°C. Exposure is higher in the dry season. The occurrence of days above 35°C is below 50%.<br>Dry season will have average temperature above 32°C from March to July. | **High** | Medium[382] | High | Production might be affected by high temperatures, especially in the dry season with average temperatures above 32°C from March to May.<br>The impact is more significant with Arabica than Robusta, but the cultivation area of Arabica is relatively small in Central Highlands. | Medium[383] | High | |

380 Storms can affect sugarcane with strong winds and significant rainfall that can lead to submergence of the sugarcane crop.

381 Certain adaptive capacity to waterlogging.

382 Dry season high temperature above optimum range, which might affect coffee growth and production if mean annual max temperature is above 32°C.

383 Suitable range is up to 32°C. External capacity is high, with incorporation of shade management techniques.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Increase in precipitation | Annual rainfall around 2,000 mm, still within optimum range. Extreme events in August with last percentile up to 900 mm per month. | **Low** | Low[384] | Low | Increase of precipitation as predicted might not change the suitability for Robusta coffee in this area, being still in the suitable range of rainfall. Excessive rains might occur in June - September but impact may be small due to effective drainage systems as well as the change frequency is low. | High[385] | Low | |
| Decrease in precipitation | Predicted precipitation in the dry season would be 4% to 8% lower than the baseline. | **Low** | Medium | Medium | Increased water stress. Without irrigation, it might reduce the yield. | Medium[386] | Medium | |
| Decrease in water availability | decrease in water availability in the dry season is small 1% to 2%, compared to the baseline | **Low** | High | Medium | Lower rainfall can generate drought and water stress for the tree. However the decrease in water availability in the dry season is small 1% to 2%, compared to the baseline | Low | Medium | |
| Increase in water availability | The increase in water availability is small (1% in August). | **Low** | Low | Low | The increase in water availability is small (1% in August). Robusta can tolerate temporary water logging. | High[387] | Low | |

384 Rainfall should be between 1,000 and 2,500 mm during the year.

385 Depends on the drainage capacity of the soil.

386 Low internal capacity is due to the severe depletion of groundwater source. Medium external capacity from good agricultural extension services. Improving land covers and soil fertility through mulching and organic fertilization will be important.

387 High internal capacity, low water table level and favorable drainage systems can help mitigate the problem.

| Threat/Opportunity | Interpretation of threat/Opportunity | Exposure | Sensitivity | Impact Level | Impact Summary | Adaptive capacity | Vulnerability | Change in production and link with other sector |
|---|---|---|---|---|---|---|---|---|
| Drought (in rainy season, different from baseline) | No change in drought frequency. | **Low** | Low[388] | Low | No significant change. | Medium[389] | Medium | |
| Flash floods | Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 days with more than 140 mm. | **Low** | Medium[390] | Medium | Depends on the geography and the topography of the area. Impact will be significant with young trees. Exposure is low because coffee is usually grown on higher grounds where the likelihood of flash floods is low. | Low | Medium | |
| Storms | Increase of precipitation, from June to November (5% to 15%) compared to baseline.<br>10 days with more than 100 mm and 2 days with more than 140 mm. | **High** | Low | Medium | Impact depends on the soil type of the area: if shallow soil, impact will be greater. In other configurations, storms will have a lower impact. | Low[391] | High | |
| Increase in atmospheric $CO_2$ | Increase of $CO_2$ might have an impact on growth and water use efficiency. | **Low** | Low | Low | Impact of $CO_2$ fertilization might have an impact, but no clear scientific evidence. | Medium | Medium | |

388 The length of the drought needs to be longer than 20–30 days without rainfall, which has a low probability of occurring.
389 Internal capacity of the crop to tolerate drought and possibility to develop ground water irrigation.
390 Internal, coffee can sustain short period of waterlogging.
391 Adaptive capacity is low: no specific varieties and no specific management to limit the impact of winds and heavy rainfall.

"Due to the topography of Khammouoan Province, Central Lao PDR, with both mountainous areas and floodplains, extreme climate events that involve storms and heavy rainfall will increase the threat for lowland rainfed rice, maize, cassava, and sugarcane." *by Ienkate Saengkaew/DAI*

"Maximum daily temperatures exceeding 35°C will inhibit flowering and grain production of rainfed and irrigated rice in many areas of the LMB, including the Mekong Delta. Industrial crops like rubber, robusta coffee, and cassava will be less viable in the heat of the central part of the basin, including the eastern plains of Cambodia,with optimal growth suitability shifting to higher altitudes, including in northern Thailand, and northen Lao PDR."

*– Headlines: USAID Mekong ARCC Climate Study for the Lower Mekong Basin.*

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