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

Summary Report

February 2014



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“School girl in Khoum Donekeo, Khammouan Province, Lao PDR” by Pakprim O./DAI

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 project (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 agriculture, 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

3S River Basins	Sekong, Sesan and Srepok River Basins
AusAID	Australian Agency for International Development
CAM	Climate Change Adaptation and Mitigation Methodology
CC	Climate Change
CWRs	Crop Wild Relatives
FAO	Food and Agriculture Organization of the United Nations
g/L	Grams per liter
GMS	Greater Mekong Subregion
ha	Hectare
ICEM	International Centre for Environmental Management
IPCC	Intergovernmental Panel on Climate Change
km	Kilometer
Lao PDR	Lao People's Democratic Republic
LMB	Lower Mekong Basin
LUSET	Land Use Suitability Evaluation Tool
m ³ /s	Cubic Meter per Second
Mekong ARCC	USAID Mekong Adaptation and Resilience to Climate Change Project
mm	Millimeter
MRC	Mekong River Commission
MT/yr	Million Tonnes per year
NTFPs	Non-Timber Forest Products
PAs	Protected Areas
SLR	Sea Level Rise
sq km / km ²	Square Kilometer
UN REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation
USAID	United States Agency for International Development
VA	Vulnerability Assessment
WFP	United Nations World Food Programme

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“Xeo Quan villagers identified community vulnerabilities and negative impacts of climate change.” by Pakprim O./DAI

I A STUDY OF CLIMATE CHANGE IN THE MEKONG RIVER BASIN

This is a study of climate change and water resources, food security, livelihoods, and biodiversity in the Mekong River Basin. It lays the foundation for the whole USAID Mekong ARCC project by providing the scientific evidence base for identifying highly vulnerable and valuable agricultural and natural systems assets in the Lower Mekong Basin (LMB).¹ In response to the projected impacts, it defines broad adaptation options and priorities, and guides the selection of pilot sites for enhancing existing adaptation effort and for demonstrating and testing new adaptation strategies. The study focuses on five critical livelihood sectors: agriculture, capture fisheries and aquaculture, livestock, natural systems, and rural infrastructure and health.

The study recognizes that most families in the region are small-scale farmers² who depend on wild plants and animals as much as they do domesticated breeds. Their farming activities are interwoven with surrounding natural systems and are shaped by the seasons and by variable and changing climate.

Throughout this summary report, the reviewer will notice bracketed numbers that are embedded in the text. These numbers reference specific sections of *the USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Main Report* where more detail on a given topic is provided.

¹ The LMB covers territory within Cambodia, Lao PDR, Thailand and Vietnam.

² For example, in Lao PDR, 36.4% of farm holdings are between 1.0 and 2.0 ha, 23.8% are between 0.5 and 1.0 ha, and 12.5% are less than 0.5 ha. The remaining 27.4% of farm holdings are over 2.0 ha. Throughout the LMB, average farm size is 2.8 ha with about 70% ranging in area from 1.5 to 3.0 ha.

2 THE LIVELIHOOD SECTORS

2.1 OVERVIEW

The LMB is a region of rich diversity—of landscapes, biodiversity, and ethnic and cultural diversity. It lies in the Indo-Burma Biodiversity Hotspot, and includes 12 of the World Wildlife Fund for Nature's (WWF) Global 200 Ecoregions: critical landscapes of international biological importance. The region is one of the eight main Vavilov Centers where the wild relatives of most of the world's domesticated plants originated.

The diversity and productivity of the Mekong region is driven by a unique combination of hydroclimatic features that define the timing and variability of water runoff, transport, and discharge through the watershed. The Mekong River is central to the hydrology of the LMB. It is associated with the largest wetland complex in the region. At one time, wetland ecosystems covered much of the basin. Now, about 42% of the LMB is wetland (seasonal and permanent) but only 55,498 km² or 22% of that area constitutes natural wetlands. The rest is man-made or converted wetlands mostly associated with agriculture, especially for rainfed and irrigated rice, which is the staple food of the region (ICEM 2012).³

The LMB is dominated by agricultural land uses. More than 100,000 km² of the basin's total cultivated land is used to produce rice. Already, Vietnam and Thailand use their arable land within the basin to its full extent for producing paddy rice and other crops. Commercialization of agriculture has led to the expansion of cash crops, including several tree crops such as rubber, coffee, cashew, fruits, and fast-growing species for pulp and paper. In many areas, commercial plantations have replaced subsistence food crops often involving forest clearing. Other cash crops including cassava, soybean, and sugarcane have expanded rapidly through improved yields and increased area under production.

The Mekong region's forested landscape has been transformed for agriculture and other developments. In the last 35 years, close to one-third of forests have been lost and at current rates little more than 10% to 20% of original cover will remain by 2030. Large connected areas of “core” forest—defined as areas of at least 3.2 km² of uninterrupted forest—have declined from over 70% in 1973 to about 20% in 2009 with negative implications for the species they sustain (WWF 2013).⁴ Deforestation and linked agricultural expansion are the main causes of land degradation in the region affecting between 10% and 40% of land in each country (UNEP and TEI 2007).⁵

During the past two decades, change in farming and natural systems has accelerated due to a wide range of infrastructure developments in particular relating to roads, power facilities and irrigation.

³ ICEM. 2012. Basin-Wide Climate Change Impact and Vulnerability Assessment for Wetlands of the Lower Mekong Basin for Adaptation Planning: Synthesis paper on adaptation of Mekong wetlands to climate change, prepared for the Mekong River Commission.

⁴ WWF. 2013. Ecosystems in the Greater Mekong: past trends, current status, possible futures.

⁵ UNEP (United Nations Environment Programme) and TEI (Thailand Environment Institute). 2007. Greater Mekong environment outlook 2007. Bangkok.

For example, GIS analysis by the Mekong River Commission suggests that there are 15,000 to 30,000 dams or full stream impediments to natural flow throughout the basin. Hydropower dams exist or are planned for all of the region's main rivers. As of 2008, some US\$10 billion was invested in Greater Mekong Subregion (GMS)⁶ transport projects, of which 90% was devoted to roads (ADB 2008).⁷ Transport developments have contributed significantly to poverty reduction in the region, providing access to markets and opening more land for habitation and use.

Economic expansion and demographic shifts are transforming the economies and environment of the region at a pace and scale never before experienced. This trend brings expanding employment opportunities but also carries risks, for example, in terms of increased exposure to price shocks, natural resources degradation, and growing inequities. [2.3]

The basin supports around 65 million people, some 80% dependent on agriculture and natural resources for their subsistence and livelihoods. All countries of the region have groups and families that remain chronically poor, or are vulnerable to falling into poverty and food insecurity. They are acutely sensitive to adverse weather events such as floods and droughts, as well as to degradation of the natural environment. [2.4]

An important crosscutting issue is the differentiated impacts of climate change on women, children, and vulnerable groups. Rural communities and households in the basin are not homogenous entities. Disparities exist in terms of assets, access to services and resources, and income opportunities. These considerations are a central focus of rural poverty assessments, yet they require even greater prominence in climate change assessments because existing social disparities are exacerbated as a result of climate shocks. Vulnerable and disempowered groups in the LMB are more affected by negative climate change impacts and have less capacity to adapt to those impacts. [5.8.2]

2.2 AGRICULTURE

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 reflects an intensification of production with higher yields. New areas for cultivation are opening in Lao PDR, the Vietnamese Central Highlands, and Cambodia while the arable land in Northeast Thailand is now decreasing.

Growing conditions are diverse, from the mountainous areas of Lao PDR and the Central Highlands in Vietnam to the lowland plain in the Mekong Delta. Farming systems range from traditional shifting agriculture dominated by upland rice through industrial plantation, including smallholder intensive rice farmers. Rainfed agriculture dominates with rainfed rice the main crop, representing 75% of agricultural area. Around 50% of the rice is produced in the Vietnamese Mekong Delta, followed by Northeast Thailand (around 30% in 2003). Vietnam and Thailand are among the five main rice exporters in the world. Other commercial crops such as maize, soya, or cassava are of growing importance and mostly rainfed.

⁶ The GMS countries are Cambodia, the People's Republic of China (specifically Yunnan Province and Guangxi Zhuang Autonomous Region), Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam.

⁷ ADB (Asian Development Bank). 2008. Transport and Trade Facilitation in the Greater Mekong Subregion—Time to Shift Gears. Reference Number: SAP: REG 2008-86, Sector Assistance Program Evaluation, December 2008.

Similar patterns can be highlighted across countries with the spread of commercial crops and the emergence of commercial agriculture. Maize is found across all countries, while cassava is already farmed in Thailand and the Vietnamese Central Highlands and is now starting in Lao PDR and Cambodia. Sugarcane is mostly found in Northeast Thailand, with this region accounting for more than 70% of the LMB planted area. The expansions of commercial crops and industrial plantations of rubber, coffee, and eucalyptus are driven by market demand and foreign investment. In the future, demand for bio-fuel (soya, maize, and sugarcane), animal feed (cassava), and starch (cassava) is likely to rise and the demand for rubber and sugar will continue to be strong, also driven by local conditions. In the Vietnamese Central Highlands, for example, the degradation of soil and ground water resources and the lack of rural labor have contributed to a shift from coffee to rubber plantations.

This study focuses on commercial crops and rice culture—i.e., the main crops and forestry species in terms of total area of production and greatest increase in production and cultivated area in the past 12 years. Rice was selected as a target species (specifically the main staple crops including lowland rainfed, irrigated, and upland rice), as were cassava, soybean, sugarcane, rubber, and Robusta coffee. Most commercial crops can be found in industrial and smallholder farming systems. For example, most of the cassava production in the LMB is based on smallholder production but is considered as an industrial crop.

Over the long term, the LMB's agricultural transition from subsistence to commercial and industrial systems can have positive implications for the alleviation of poverty and the provision of food security. However, in the short to medium term, the commercialization of agriculture poses significant threats to the security of the rural poor due to linked natural system degradation, the lack of alternative livelihoods, low labor mobility, loss of land tenure, and higher market prices for food.

Subsistence-based systems are inherently integrated with natural systems. These systems tend to be more diverse and complex and a failure in one component can be substituted by another. Consider, for example, the different circumstances of two production systems: one intensively farmed pigs and the other subsistence use of wild pigs. The risks of major productivity losses or cost increases are great in the intensive pig farm if, for example, (i) the price of commercial pig fodder changes, (ii) there is a rapid outbreak of disease, or (iii) there is a heat wave that farm facilities are not designed to accommodate. The subsistence-based system is more resilient because: (i) it is not dependent on fodder, (ii) wild pigs are more resistant to disease outbreaks, and (iii) wild pigs are able to move to cooler habitat in heat wave conditions. Similar comparisons can be made for subsistence capture fisheries and aquaculture or harvesting of non-timber forest products (NTFPs) compared to industrial crops.

Losses in agricultural production due to climate change and other factors will have varied effects depending on the roles that men and women take in production. For example, if women hold primary responsibility for livestock production, losses in that area may affect their income generation. Women are often involved in labor-intensive tasks such as planting and tending crops, so their workload is likely to increase. Also, there is discrepancy along gender lines concerning access to the information required in a changing climate: it is often only men who participate in agricultural extension programs, for example.

A critical issue is ecological sustainability. The shift to commercial agriculture has meant more intensive cultivation of land, clearance of forestlands, increased application of fertilizers and pesticides, and large irrigation diversions. Natural resources are the foundation of rural welfare. The degradation of water supplies, soil erosion, and loss of access to NTFPs all has negative welfare impacts. [2.4.3]

2.3 LIVESTOCK

Livestock production systems in the basin range from traditional smallholder practices to large, highly productive commercial enterprises. [5.2] Traditional systems are small scale, using low-intensity, low-input, and low-output approaches. They typically raise stock of local genetics and have limited market orientation. They contribute well over 90% of total numbers of producers in the LMB and over 50% of total production. These systems dominate the higher-elevation forested and more sloping ecozones and typically are associated with low-income, vulnerable households. Women, the elderly, and children are often responsible for household livestock, providing them with an important source of cash income and increased social standing. [5.2.1]

In Gia Lai, for example, women take the lead role in raising pigs because this activity normally occurs around the home. Climate changes that result in lower pig productivity and higher mortality may reduce the income earning potential of women. Pigs are also an important form of savings and an asset in times of emergency. Loss of these assets may reduce the capacity of women to provide food for their family in times of scarcity. [5.8.2] Small- and medium-scale commercial operations are most vulnerable and have limited capacity to adapt.

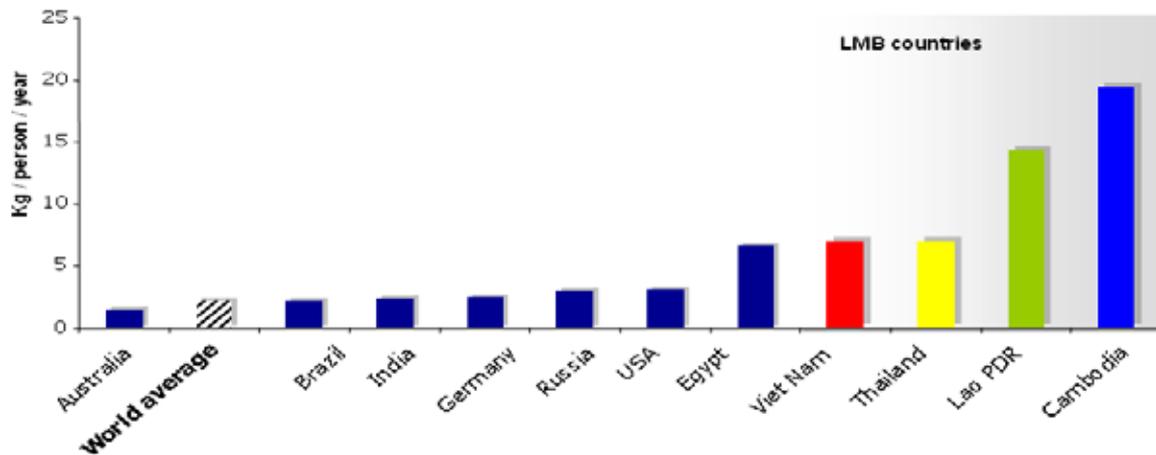
2.4 FISHERIES

Capture fisheries and aquaculture are vitally important for food and for the livelihoods. Mekong communities have the highest per capita consumption of fish in the world—up to 50 kg/head/year in some parts of the basin.

Capture Fisheries

The basin's capture fisheries are crucial for food security. The LMB's freshwater fishery is the world's largest, producing some 2.1 million tonnes per year (close to 22% of the world's freshwater fish yield). The region also has a substantial coastal fishery producing 0.5 million tonnes per year (Figure 1). This catch of fish is supplemented by about 0.5 million tonnes per year of other aquatic animals (for example, freshwater shrimps, snails, crabs, and frogs).

Figure 1: Current estimates of fish production for selected countries including those within the Lower Mekong Basin



Source: ICEM, 2010⁸

With 781 known species, it is home to the second highest fish biodiversity in the world after the Amazon River. Virtually all fish species have a commercial value. The small-scale Mud Carp, for example, is of huge importance for fish paste production in several Mekong countries. The biodiversity and productivity of the fishery is linked inextricably to the annual flood pulse and the diverse range of natural habitats it maintains—as well as some artificial habitats such as rice fields and reservoirs. Although the fishery is very productive, there are serious declines in the stocks of certain species, including some of the giant fish species. In addition, the average size of some species is reducing, suggesting stocks are being over-fished and changes to habitats are affecting life cycles.

Despite the seasonal abundance of fish, many households remain desperately poor—and with few other livelihood opportunities, a decline in the Mekong capture fishery would be catastrophic for them. [5.5]

The fishes of the Mekong can be grouped broadly according to their ecology and migration behavior.

Upland fishes: The fishes of the small streams in upland areas of the Mekong basin are often overlooked by fisheries scientists, as their contribution to total fisheries productivity is modest. However, as other hunting options decrease, an increasing number of upland households now rely on fish products from small water bodies and streams in the uplands. These fish, which inhabit the cool clear waters of upland forests, look particularly vulnerable to a wide range of pressures, including climate change.

The 'Black fish' group covers species which do not leave the floodplains and wetlands, spending the dry season in remaining deep pools. Most Black fish species are able to survive poor water quality conditions and harsh dry season environments, and their limited migratory habits may make them less vulnerable to wetlands and riverine fragmentation. This group, including snakeheads, catfishes, and the climbing perch, may be more 'climate proof' and less affected by climate change.

⁸ ICEM. 2010. MRC Strategic Environmental Assessment (SEA) of hydropower on the Mekong mainstream. Hanoi, Viet Nam.

The **'White fish'** group accounts for around 87% of Mekong fish species and 50% of the total catch. Many undertake long distance migrations, in particular between lower floodplains and the Mekong mainstream and tributaries. This group includes the carp family (cyprinids) and most catfishes (*Pangasiidae*). White fish species generally require higher water quality conditions in terms of dissolved oxygen and alkalinity, and are more vulnerable to increased temperatures, especially at maturation and fry stages. The effects of climate change on some of these species may be severe. Any decline of migratory white fish would have a great effect on local communities who have relied on these seasonal resources for generations. Landless fishing families would be particularly at risk to the losses in fisheries productivity.

Estuarine fish such as Sea Bass are found in the lower reaches of the river system. They include many species tolerant of a wide range of salinities due to the great variation in annual freshwater flows. These species will be vulnerable to certain aspects of climate change, such as temperature increases in shallow coastal areas, but less vulnerable to others, such as sea level rise. Estuarine fisheries support many coastal communities in the Mekong Delta and their decline would affect the livelihoods of many people who have few alternative livelihoods options.

Aquaculture

Over the past 30 years, the Mekong's aquaculture sector has boomed, providing livelihoods to hundreds of thousands of households. The latest production estimates of around 1.9 million tonnes are now similar to the production levels from the capture fisheries and looks set to surpass capture fisheries over the next few years. Much of this production (1.6 million tonnes) is from intensive catfish culture (particularly *Pangasius* spp) and shrimp farms and is destined for export. Traditionally, many aquaculture systems have been dependent on the capture fisheries for wild-caught juveniles for culture and low-value fish for feed. However the development of hatcheries and the increased availability of commercial fish feeds throughout the LMB have reduced this dependence on wild resources.

Semi-intensive and extensive aquaculture systems often include a significant proportion of wild fish in the harvests. A wide range of indigenous species are cultured in the LMB. A number of exotic species are also cultured, often in polycultures with indigenous fish. In the Thailand part of the LMB, tilapia is the most commonly cultured fish (41%) followed by Clarias Catfish, (26%), barb (11%), Snakeskin Gourami (7%), and giant freshwater prawns (6%). In the Delta, aquaculture production is dominated by Pangasids (1.6 million tonnes/year) followed by Tiger shrimp (*Penaeus monodon*), although production there is now facing environmental and economic constraints.

Current trends in aquaculture include a reduction in use of low value fish for fish feed, an increase in the use of hatchery-reared juveniles, and the culture of 'new' fish species/strains such as 'Tub Tim' Fish (*Oreochromis* spp). As LMB countries become wealthier, the demand for diverse and inexpensive fresh fish is increasing. It is unlikely that the capture fisheries, no matter how well-managed, would be able to keep pace with this demand. The disappearance of some fish species from the capture fishery (e.g., *Oxyeleotris marmorata*) and the growing market acceptance of exotic fish such as tilapia are creating opportunities for aquaculture. The sector therefore looks set to continue to grow, generating wealth and creating new livelihood opportunities for rural people.

Much of this aquaculture expansion has resulted in new areas being utilized for aquaculture. This is certainly true of the coastal region where large areas of mangrove and/or rice fields have been converted to shrimp farms. Large freshwater wetland areas considered suitable for the expansion of inland aquaculture also exist. However, environmental constraints are starting to affect aquaculture production and diseases and water quality issues are increasingly affecting production in intensive culture systems.

Any increased costs of farmed fish resulting from climate change adaptation measures could have a serious indirect effect on poorer people's diet where no other obvious animal protein alternatives exist.

2.5 NATURAL SYSTEMS

Natural ecosystems within and outside protected areas are under pressure throughout the Lower Mekong region. Healthy natural systems are a foundation for the development and well-being of livelihood systems and are essential in building resilience in communities and across economic sectors. They are critical to food security. Even households that have moved beyond a marginal existence and possess productive assets, such as irrigation infrastructure and farm machinery, have much to lose from reduced access to healthy natural systems and resources. [2.3]

NTFPs make a significant contribution to national and local economies in the region and can make up over 30% of the income of individual farming families. Crop wild relatives (CWRs), often forgotten by all except crop researchers, are important as a source of genetic material for the improvement of existing crops, including the development of resistance to disease and extremes of temperature and drought. Protected areas now represent the last vestiges of the original plant and animal assemblages of the region and, for many NTFPs and CWRs, the only areas where they grow in the wild.

Protected Areas

The four countries of the LMB—Cambodia, Lao PDR, Thailand, and Vietnam—have established one of the largest protected area systems in the world. Those systems include more than 116 protected areas in the LMB covering 16% of the basin's land area. In Cambodia, Lao PDR, and Thailand, the protected area systems cover well over 20% of national land area.

Most of the significant remaining forest areas and upper watershed areas of the LMB are contained within these protected areas. All the protected areas and linked natural areas of forest and wetlands are of increasing importance as an essential part of healthy productive farming ecosystems—increasing as populations grow and as access to arable land diminishes.

Around 90% of the basin's protected areas have communities living within them—and most are experiencing growing populations. More than 25% of the region's protected areas are used for agriculture, 30% for grazing, 30% for fisheries, and 90% for hunting, gathering, and extraction. In addition, protected areas in all countries except Thailand are open for major infrastructure development such as hydropower schemes, roads, mining, plantations, and tourism facilities. [5.4]

2.6 HEALTH AND RURAL INFRASTRUCTURE

Health and rural infrastructure conditions are closely related. Provision of potable water supply and toilets, for example, is closely related to reduce incidence of enteric diseases, protein malnutrition in infants, and infant mortality. The development of roads and bridges and establishment of health centers are closely related to access to adequate pre-natal and post-natal care—and as a consequence to reducing the maternal death rate. [5.7.2]

Health

The general trend of declining poverty levels in the LMB has been driven by, and contributed to, improving health conditions. Since the 1960s, all four countries have seen dramatic improvements in life expectancy. Cambodia and Lao PDR continue to lag well behind Thailand and Vietnam, and this is reflected in other health indicators. For example, in 2008, in Cambodia and Lao PDR the proportion of deaths attributable to communicable diseases and maternal, prenatal, and nutritional conditions remains at 47% and 41% of deaths respectively. These largely preventable diseases affecting mothers and infants are associated with poor environmental sanitation and limited access to basic healthcare. [5.7.3]

Health coverage is not uniform across the region, with access to health services much better in urban and lowland areas. There are over 70 different ethnic groups in the region. Ethnic minority groups in remote upland areas in particular tend to have much poorer access to health services. Groups with already marginal livelihoods have reduced capacity to respond to adverse climate shifts and are more likely to be adversely affected by climate change.

Typically women are the primary caregivers for the sick. Greater incidence of illness in household members places a greater burden on women which limits their capacity for other tasks and income-generating activities. Regarding women's direct health concerns, water scarcity is related to higher rates of gynecological disease. Women spend much of their time in and around the family dwelling where stagnant water is common, a major breeding ground for the disease vectors which are expected to increase in abundance and extent due to climate change in many areas of the basin. Also, pregnant women are generally more vulnerable to climate-related disease epidemics for physiological reasons. [5.8.2]

Rural Infrastructure

The level and quality of infrastructure across the region varies greatly between and within countries. Thailand has a significantly higher level of infrastructure development, while Vietnam has been going through a rapid transition since the mid-1990s. Cambodia and Lao PDR lag behind. The relatively advanced transport infrastructure of the Isan region in Thailand is in stark contrast to the unpaved, sparse road network in upland areas of Lao PDR and Cambodia, for example.

Lao PDR has a relatively high rate of electrification for its income level; as of 2012, 80.3% of Lao households had electricity. In comparison, Cambodia has a low electrification rate, partly due to low government investment. In contrast, electrification in Thailand and Vietnam is almost universal, largely as a result of dedicated government programs.

The overall level of poverty in a particular location in the LMB is indicative of the level and quality of rural infrastructure such as road networks, bridges, irrigation, water supply, household dwellings, and municipal buildings. Remote rural locations with poor communities are generally the areas with the lowest levels of infrastructure. [5.7.4]

3 DRIVERS OF CHANGE IN LIVELIHOOD SECTORS

The study found that development trends are transforming the LMB ecology and economies at a pace and scale so significant that it becomes difficult to discern the impacts of climate change on livelihoods against the background noise of other change. Key development influences were identified and assessed for each target livelihood sector.

3.1 AGRICULTURE

Understanding the complexity of the agriculture sector and its many drivers helps to design integrated adaptation strategies. Population growth, change in food diet, hydropower development, agrarian changes, and trends in labor are considered local drivers. The sector is also influenced by direct foreign investment and international market demand for some commodities such as bio-fuel, rubber, and animal feed.

Food demand in the region will continue to rise as populations grow and diets change—higher consumption of fruits, sugar, and oils, for example, will induce changes in the agricultural sector.

National agriculture policies can have far-reaching impacts on the sector, such as those supporting and promoting a specific commodity. In the past decade, Northeast Thailand has been fundamentally modified by support for rubber plantations and development of the rubber industry. Thailand is now the number one rubber producer in the world.

The urbanization process has a major effect on rural development bringing centralization of markets, services, and seasonal and permanent migration of agriculture labor to cities. Urbanization also leads to conflict for land use as agricultural areas are swallowed up by expanding settlements, industrial zones, and infrastructure.

The LMB is one of the most active regions in the world for hydropower development. The development of extensive networks and cascades of hydropower reservoirs will have far reaching impacts on agriculture in the region. Already, competition for water in the dry season between farmers and electricity producers is a significant concern.

3.2 LIVESTOCK

Alongside expected climate changes, the basin is undergoing significant socio-economic and physical changes affecting livestock production, consumption, and livelihoods. Increasing household incomes have led to greater domestic demand for livestock-derived products. Globalization, and corresponding growing links to global markets, is promoting competition and subsequent pressure for domestic production.

The high human and livestock populations, number of livestock-raising households, and the nature of production in the basin contribute to emerging infectious disease risks, notably zoonoses. Outbreaks and endemic diseases are major production and public health concerns.

Mechanization and the introduction of higher-productivity genotypes has had varied levels of success impacting yields, costs of production, and disease risks. Increasing concern over and investment in food safety and quality assurance is driving regulatory changes. Agricultural policy and policymaking processes vary widely at sub-national, national, and regional levels but environmental concerns are gaining more weight. At the same time, transparency and associated issues of good governance remain a challenge. [6.2]

3.3 CAPTURE FISHERIES

Development trends threatening the future of Mekong capture fisheries may completely overshadow the effects of climate change. The productivity of the fishery is inextricably bound up with the seasonal pulse of dry and wet seasons and the connectivity of the rivers, streams, and floodplains. Developments that affect these characteristics will reduce productivity and biodiversity of the fishery, with indirect yet significant effects to the millions of people who depend on the fishery for their livelihoods.

The greatest threats to capture fisheries is the alteration of river morphology and hydrology caused by hydropower projects, the excavation of channels to aid navigation, and the extraction of ground and surface waters for irrigation. Physical barriers constraining the migration of fish species will result in sudden failures of components of the fishery. Plans for cascades of dams, as proposed for the Nam Ngum tributary to the Mekong River, for example, could be catastrophic for this tributary's fishery diversity and productivity. Similarly, the plans for 12 hydropower dams on the mainstream Mekong River would "fundamentally undermine the abundance, productivity, and diversity of the Mekong fish resources" (ICEM 2010).⁹

Other threats include fragmentation of the river and floodplain fisheries (with resultant loss of connectivity); habitat destruction or change; overfishing and aggressive, unsustainable fishing methods, such as explosives; exotic fish populations; water pollution; changes in water flows and levels through dam releases; and climate change mitigation for other sectors (such as large-scale irrigation projects).

There is a tendency to blame unplanned and unwanted events in the region's capture fisheries on climate change, even when other causes seem more likely. Climate change is becoming a scapegoat for shortcomings in more conventional fisheries management. Consequently, climate change presents an opportunity to use vulnerability assessments and adaptation planning as a force for concerted and integrated management of LMB fisheries in ways which address all threats in an integrated way. [6.4]

⁹ICEM. 2010. MRC Strategic Environmental Assessment (SEA) of hydropower on the Mekong mainstream: summary of the final report. Hanoi, Viet Nam.

3.4 AQUACULTURE

Although aquaculture is seen as a way to offset declining capture fisheries, a number of development trends are adding pressure on the region's aquaculture systems.

Pollution and increasing demand for water during the dry season, for example, has the potential to constrain aquaculture development, particularly in the Mekong Delta. At the same time, it is expected that the increase in dams will result in increased dry season water flows, which would be advantageous for aquaculture.

The use of pesticides and drugs in the more intensive systems are of concern to the region's aquaculture. Their use may be affected by certain diseases becoming more virulent as a result of changed conditions, such as increased temperatures. [6.5]

3.5 NATURAL SYSTEMS

In the shorter term, existing threats to the basin's natural systems are more important than the threats from climate change—although addressing existing threats will increase long-term resilience. Habitat loss due to poor protection measures, deforestation, and changes in land use (e.g., more extensive and more intensive agriculture, plantations, and aquaculture) is very significant. Where the habitats are still more or less intact, over-harvesting and destructive, non-sustainable, and illegal collection are the most important stressors reducing the populations of many NTFPs and overall ecosystem health.

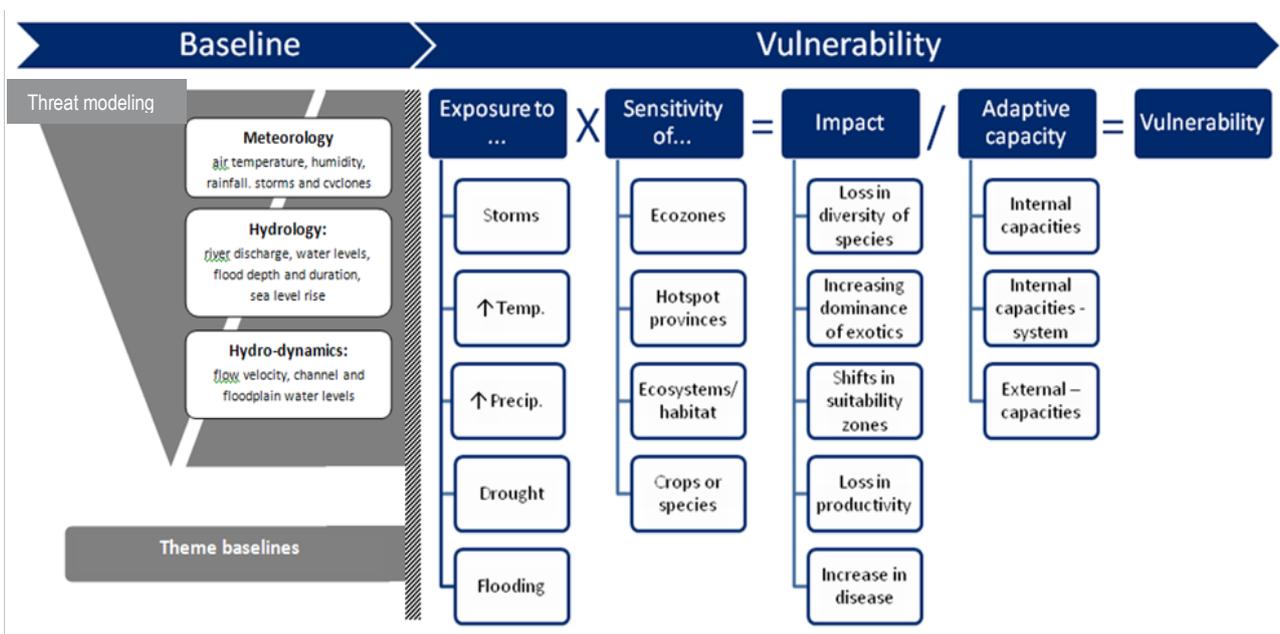
4 STUDY METHOD

The study overlaid projected climate and hydrological change on the current status and trends in key livelihood sectors of the LMB: agriculture, livestock, natural systems, capture fisheries and aquaculture, and health and rural infrastructure.

ICEM’s ‘Climate change vulnerability assessment and adaptation methodology’ (CAM) was applied to the important ecosystems, species, and assets identified for each of the livelihood sectors. CAM has three main phases: vulnerability assessment, adaptation planning, and adaptation implementation. This study focuses on the first phase: impact and vulnerability assessment for large areas, key crops and wild species, but also identifies in broad terms adaptation responses to the most important projected impacts in vulnerable areas.

The CAM method uses four important factors to assess the vulnerability of target species and systems to the defined climate change threats: exposure, sensitivity, impact, and adaptive capacity. Figure 2 provides a summary of the impact and vulnerability assessment process. [3.13]

Figure 2: Climate change impact and vulnerability assessment process



Addressing Other Drivers of Change in Climate Change Adaptation

The difficulties of discerning climate change influences against the background of development noise were addressed in two ways. The first was to project climate change far enough into the future (i.e., 2050) so its effects stand out against the backdrop of other influences—and then to work back to less distant time slices (e.g., 2030). The second was to identify the main development trends and drivers of change during the baseline assessment and then to ‘park’ that information—to be picked

up again and considered during adaptation planning so that integrated responses to a variety of threats can be defined. By following this approach, the impacts and vulnerabilities due to climate change can be defined in isolation without distraction from development forces. [6]

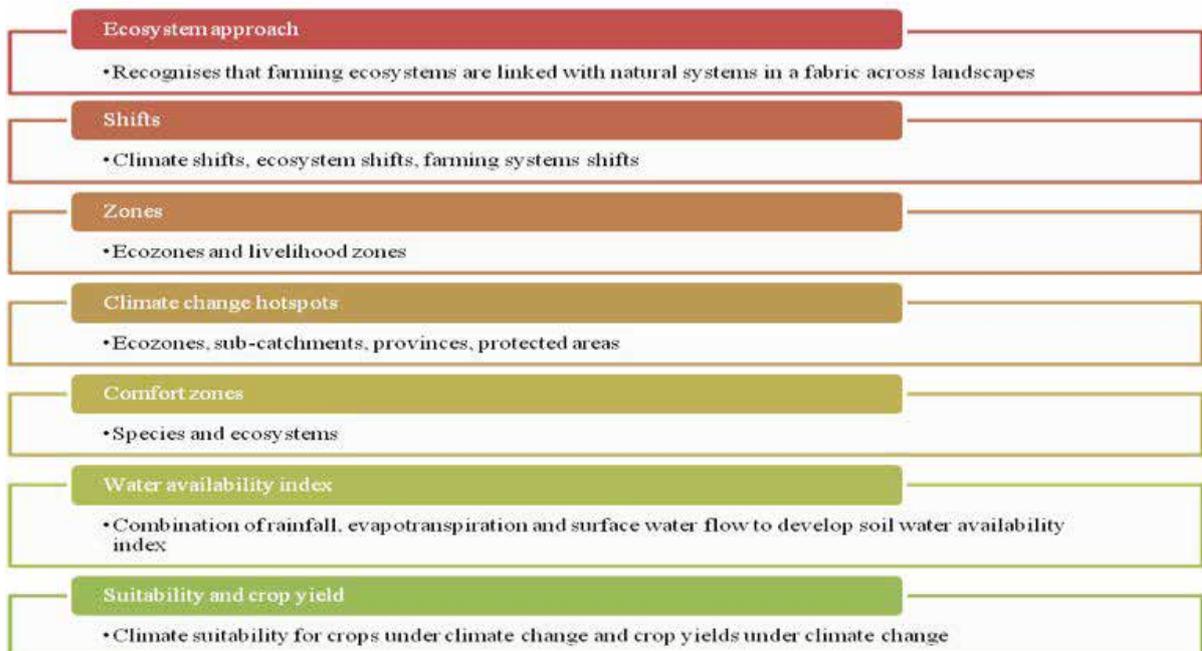
4.1 CLIMATE CHANGE THREAT MODELING

As part of the baseline assessment, the study followed a common process to assessing climate change threats starting from the Intergovernmental Panel on Climate Change (IPCC) emissions scenarios and ending with specific threats at the province level. The process utilized a combination of climate and hydrological modeling together with statistical and GIS data analysis. Modeling and downscaling were used to convert scenarios of future greenhouse gas emissions to broad-scale changes in climate and subsequently to changes in climate and hydrological variables at the regional or local level. The modeling results were then compiled into climate change threat profiles for each priority province. The profiles presented information on threats that the sector groups had identified as important for key species and systems. A detailed description of the modeling methodology is provided in Annex A of the main report.

4.2 KEY STUDY CONCEPTS

The study developed a number of concepts to help understand and assess the impacts of climate change on livelihoods and to define adaptation responses to them. These approaches are demonstrated below in Figure 3 and include concepts such as zoning to better define climate change hotspots, and methods for estimating crop suitability and yield in the context of a shifting climate.

Figure 3: Key methodological concepts developed by the study



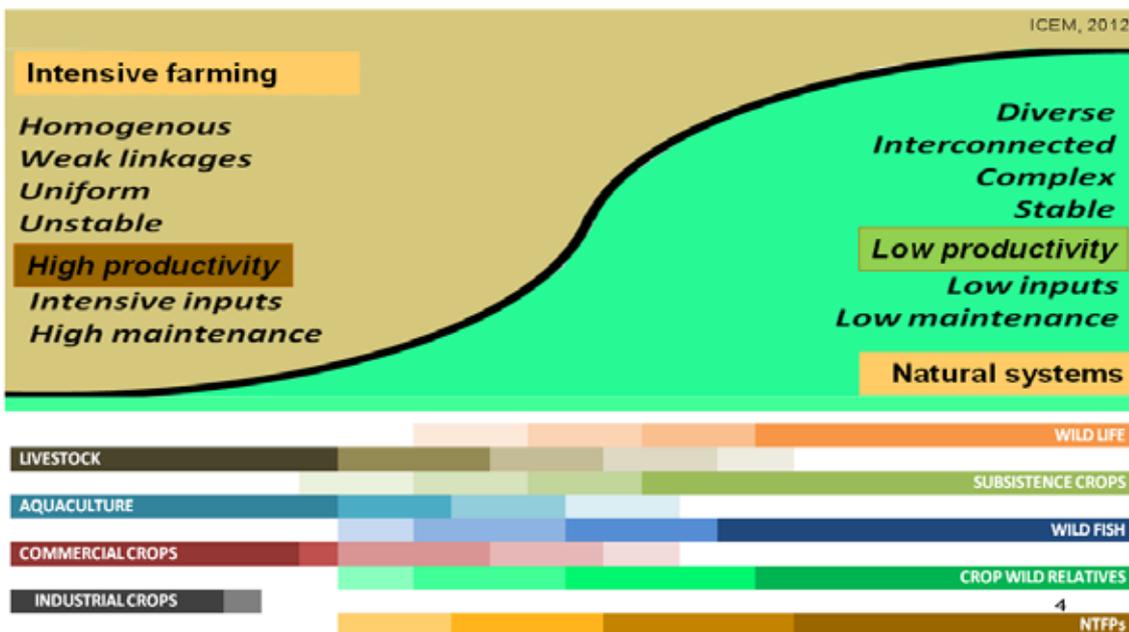
Ecosystem-based Approach

Natural ecosystems usually contain many species and complex interrelationships among them. In contrast, an agricultural system contains fewer species and is simpler in its functioning. The complexity or diversity in natural systems brings with it relative stability and resilience when faced with disturbances from storms, floods, and drought. The diversity provides a cushioning effect allowing the system to adjust and to fill gaps even if certain species and/or habitats are lost.

Agricultural systems have relatively few species of plants and animals, primarily the crops and animals that the farmer grows. In conventional farming systems, that simplicity is managed and maintained for maximum production. Yet, systems with few species are less flexible—they are more easily disrupted by outside forces and require greater investment to keep stable (Figure 4).

This study was directed to take an ecosystem-based approach. The interpretation of that directive was to regard farms in the LMB as part of highly integrated ecosystems across landscapes—the study refers to “farming ecosystems” in which the use of produce and services spills out from the immediate farm holding into more natural waterways and forests. The greater the disturbance to domestic holdings, the tighter will be the dependence on and connection with the natural system components.¹⁰ The trend in the region is for farming ecosystems to shift from right to left along the Figure 4 continuum and from resilient to more vulnerable compositions requiring more intensive management.

Figure 4: Lower Mekong Basin farming systems and climate change vulnerability continuum



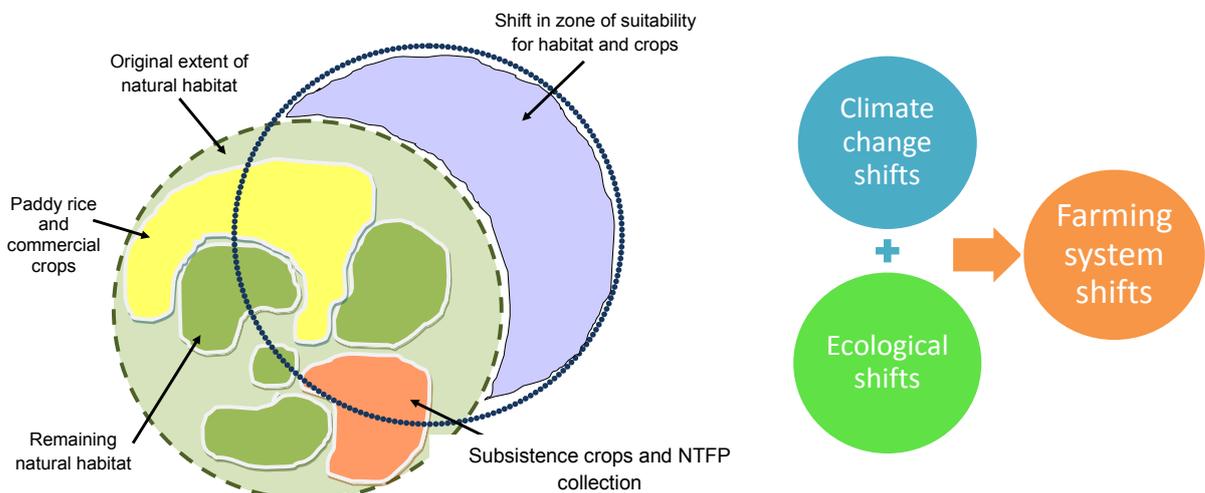
¹⁰ In a natural resource management context an ecosystem-based approach is the integrated management of land, water and living resources to promote conservation and equitable sustainable use.

Shifts

The concept of shifts is important when analyzing climate change threats and potential impacts. A shift is when a system or component of that system changes in state or location to accommodate changes in climate and hydrology. The study team defined three types of shifts in the basin—climate change shifts and ecosystem shifts, which together lead to farming system shifts.

Climate change shifts are spatial or temporal changes in regular or extreme climate. They include geographic shifts—which prompt changes in areas of suitability for specific habitats and/or crops; elevation shifts—affecting highly restricted habitats and species; and seasonal shifts—inducing a change in yields and cropping patterns (Figure 5). The onset of wet season flow in Chiang Saen under climate change, for example, is projected to shift 15 days later. [4.3.3]

Figure 5: Geographic shift in climate leading to farming ecosystem shifts



Extreme climate event shifts include changes in the intensity, frequency, and location of those events. For example, flash flooding and soil loss in upland areas are expected to become more frequent. Macroevents such as saltwater intrusion in the delta are projected to become more intense due to increasing sea levels and storm surge.

Projected shifts in extreme climate events such as drought, flooding, flash floods, and storms will lead to permanent ecosystem changes. The period of agricultural drought per year, for example, may significantly increase in large areas in the south and east of the basin by 2050 leading to a change in species composition in protected areas.

Changes in climate will lead to overall ecological shifts as species and habitats adapt to the new climate regime. Climate and ecological shifts will lead to shifts in farming ecosystems: crops and NTFPs that once flourished in an area will no longer be suited to the new conditions. [3.1.1.2]

Zones

The study used a spatial approach, working from the overall basin level down to ecozones, catchments, provinces, and protected areas. Basin-wide analysis focused on broad-scale themes such as climate threats and shifting crop suitability. The study defined 12 distinct ecozones consisting of areas of similar climate, ecosystems, and agricultural characteristics and potential. These were chosen rather than agricultural zones as the basic spatial unit for the region because of the need to emphasize the fundamental importance of natural systems and biodiversity in local livelihoods and farming systems. [3.1.2.1]

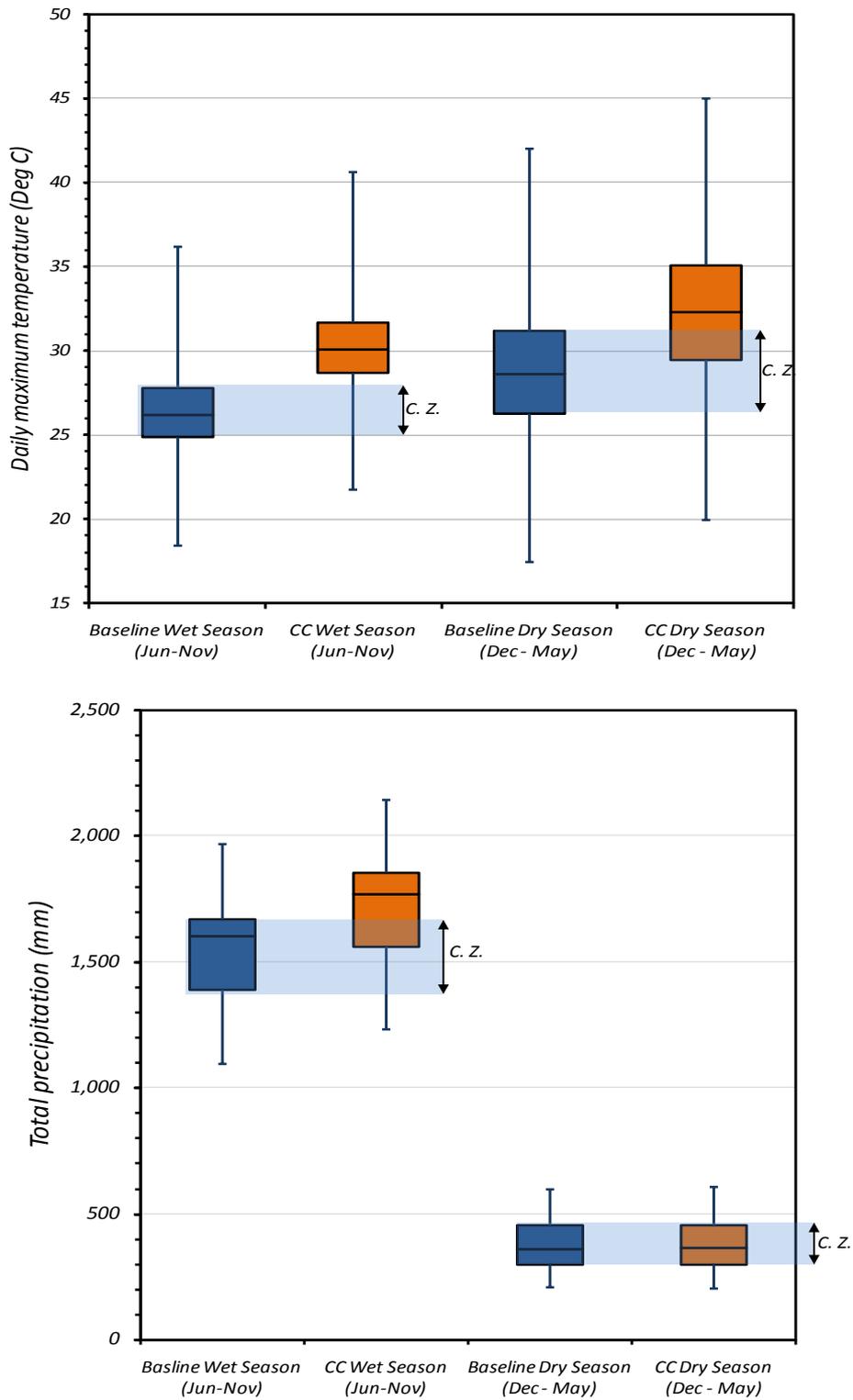
The 12 ecozones were then aggregated into five ‘livelihood zones’—forested uplands, intensively-used uplands, lowland plains and plateaus, floodplain, and delta—in order to assess vulnerability and adaptation responses of socio-economic systems. The study also identified priority or most-threatened provinces through an assessment of the climate change threats. Species and systems vulnerability were then identified at the province and protected area cluster level. [3.1.2]

Comfort Zones

Comfort zones are where species and ecosystems experience the most suitable growing conditions in terms of the range and timing of temperature and rainfall. All species have a range of climate in which they grow and prosper most comfortably. Comfort zones are defined to include 50% of the baseline variability around the mean in temperature and rainfall for typical months, seasons and years for a given species or ecosystem.

For example, Figure 6 shows the wet and dry season comfort zones for mid-elevation dry broadleaf forest in Mondulkiri Province. In this area the ecosystem is most comfortable within a daily maximum temperature of between 25°C and 28°C during the wet season and between 26°C and 31°C during the dry season. By 2050 the daily maximum temperature during the wet season will shift outside the baseline comfort zone. The dry season temperature will not shift as dramatically, but will still fall more than 60% outside the forest ecosystem’s comfort zone, resulting in dry season habitat stress.

Figure 6: Maximum temperature and total precipitation comfort zones for mid-elevation dry broadleaf forest in Mondulkiri (comfort zones shown in blue)



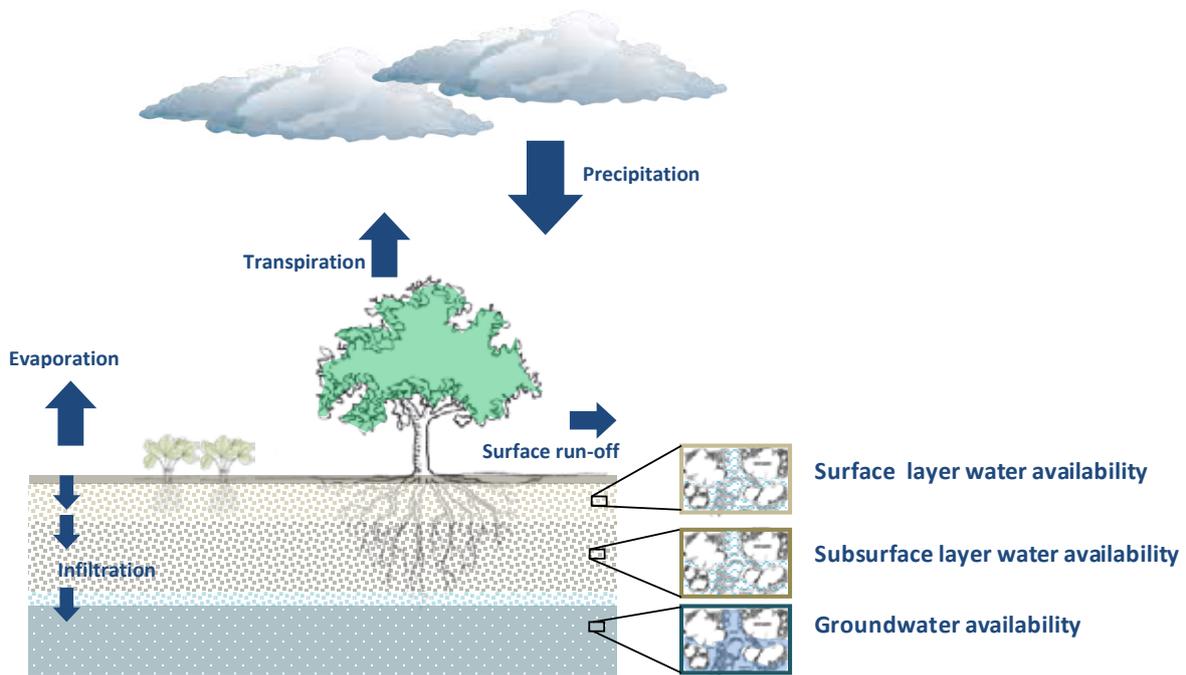
The comfort zone analysis contributed to rapid assessments of climate change impacts on species and habitats. [3.1.1.4]

Water Availability Index

Soil water availability is an important factor for agricultural production and ecosystem health. The water availability index is an innovative modeling approach that the study developed to assess likely impacts of changes in temperature and precipitation on the levels of water available in the soil for vegetation growth.

The index measures the changes in water availability for plants based on the main mechanisms used by plants for water uptake—surface, sub-surface, and ground water (Figure 7). [3.1.1.5]

Figure 7: The water availability index based on mechanisms for water uptake



Suitability and Crop Yield Analysis

The study applied two crop modeling tools to assess the impact of climate change on crops grown in the region: climate suitability modeling and crop yield modeling. Knowing in advance which crops are suitable for the likely future climate conditions in an area will allow farmers to plan crop selection for optimal production. [3.1.1.6]

Hotspots

Climate threat modeling results were used to identify hotspots: those areas affected by the greatest change in temperature or rainfall during the wet and dry season—or the greatest change in flooding during the year. Being ranked as the highest for any one of these five parameters of change would identify an area as a hotspot. The hotspot approach helped to integrate and orient study analysis and findings spatially and provides a scientific basis for the selection of focal areas for the community adaptation initiatives that will be undertaken in subsequent phases of the USAID Mekong ARCC project [3.3]

The majority of hotspots are located in northern Thailand; the northern Annamites (Lao PDR and Vietnam); the Srepok, Sesan, and Sekong (3S) basins in the Southeast of the LMB; and in the Delta. The five highest ranked provinces were Chiang Rai, Gia Lai, Kien Giang, Khammouan, and Mondulkiri. [3.4.4.1]

Table 1: Climate projections for priority provinces

	Chiang Rai	Gia Lai	Kien Giang	Khammouan	Mondulkiri Uplands
Daily maximum temperatures	Increase of between 1°C to 2°C throughout the year	Increase of between 1°C to 5°C throughout the year	Increase of between 2°C to 3°C throughout the year	Increase of between 2°C to 4°C throughout the year	Increase of between 2.5°C to 5°C throughout the year
Daily minimum temperatures	Increase of between 0°C to 2°C throughout the year	Increase of between 3°C to 5°C throughout the year	Increase of between 1°C to 1.5°C throughout the year	Increase of between 1°C to 2°C throughout the year	Increase of between 1°C to 2°C throughout the year
Precipitation					
<i>Wet season</i>	Increase in monthly precipitation up to 40 mm	Increase in monthly precipitation up to 40 mm	Increase in monthly precipitation up to 25 mm	Increase in monthly precipitation up to 75 mm (21%)	Increase in monthly precipitation up to 70 mm (14%)
<i>Dry season</i>	Minor increase in March–May and December. Minor decrease Jan–Feb	Minor decrease in dry season precipitation	Minor decrease in dry season precipitation	Increase in monthly precipitation up to 70 mm (27%)	Decrease in monthly rainfall up to 3 mm/month (12%)
Storms	Large rainfall events will increase in size	Large rainfall events will increase in size	Large daily rainfall events will increase in size up to 50 mm	Large daily rainfall events will increase in size up to 40 mm	Large daily rainfall events will increase in size up to 20 mm
Droughts¹¹	The pattern of agricultural drought will be unchanged	No significant changes in drought trends	Significant increase in the occurrence of agricultural drought conditions in Apr–May	Very little change in drought occurrence	Increase in the occurrence of agricultural drought conditions in April.
Soil water availability	Minor impacts on soil water availability	Minor impacts on soil water availability	N/A	Decrease during Dec–April. Increase up to 7% in May–July	Year-round reduction peaking at a 20% reduction in May
SLR and flooding	NA	NA	Major increases in flood depth and duration.	NA	NA

¹¹ The study used an agricultural definition of drought where a drought month occurs when the precipitation in that month is less than 50% of the potential evapotranspiration.

There is considerable variability in the nature of climate change projected for the hotspot provinces (Table I). Cambodian and Vietnamese provinces are projected to experience large increases in temperature. Lao PDR and Thai provinces will experience large increases in precipitation and Kien Giang in Southern Vietnam will experience the greatest change in flood duration >0.5 m in the Delta from both seaward and upstream influences—especially in southwestern parts of the Province.¹² [4.5]

4.3 CROSS-SECTOR ANALYSIS

The basin-wide nature of the USAID Mekong ARCC study precludes systematic and detailed analysis from a cross-sector perspective in each of the hotspot provinces. Cross-sector links have been highlighted when identified in broad vulnerability assessments and adaptation planning.

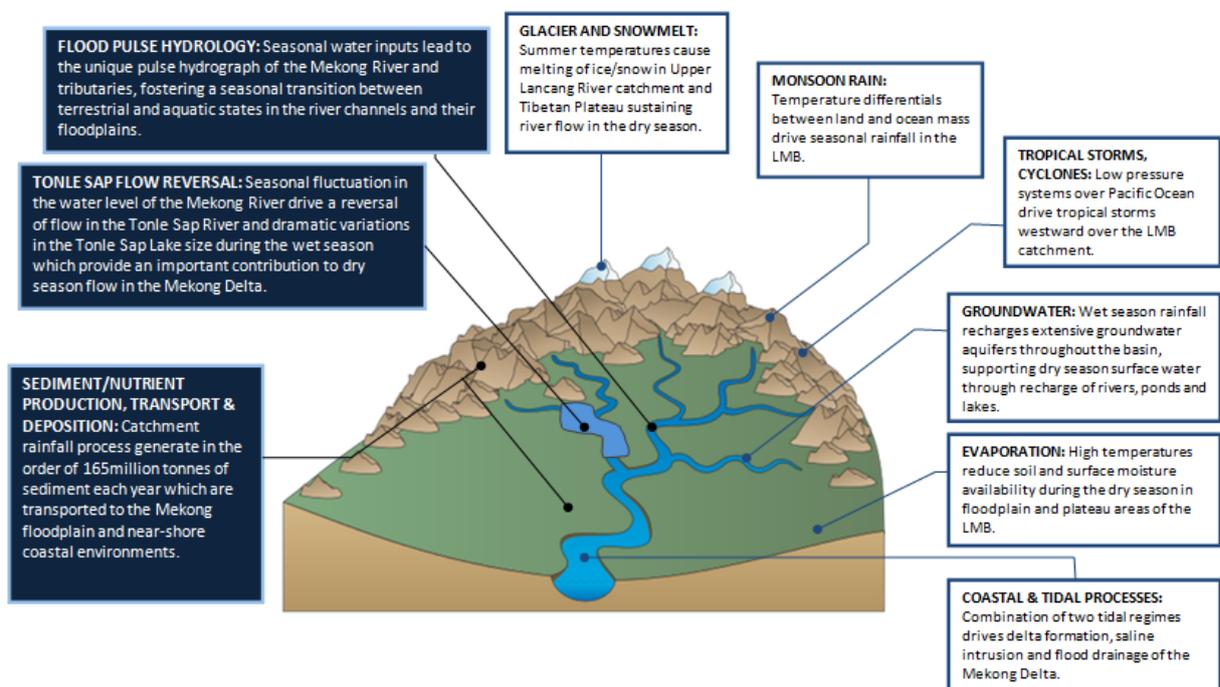
The study reviewed impacts on different sectors in Mondulkiri Province, bringing potential links into sharper focus. More extreme flooding, for example, would damage roads and reduce access to and from communities during and after floods. Limited road access reduces capacity to obtain support services and food supplies, and floods may be a driver of water-borne disease. [5.8]

¹² As in all climate change analysis, levels of threat vary with the detailed parameter—Kien Giang, for example—will experience average change in *max flood depth* typical of most of the Delta. For flood duration >1 m the change is lower than most other Delta provinces. The provinces surrounding the main channels of the Mekong River will experience greater changes due to the fresh water flood pulse. Kien Giang was chosen as a hotspot province, however, based on its exposure to salt water intrusion and extensive flooding with strong seaward influences.

5 MEKONG BASIN HYDROCLIMATE

The Mekong hydroclimate plays a critical role in landscape processes, driving sediment and nutrient production in the upper catchment and transporting it downstream to fulfill a multitude of ecological and economic functions (Figure 8).

Figure 8: Hydroclimate features of the Mekong Basin



A combination of two monsoon regimes is the fundamental driver of the Mekong hydroclimate. The Indian Ocean Monsoon¹³ occurs during the northern hemisphere summer when temperature differences between the land and the Indian Ocean force moisture-laden air to fall over the Mekong's mountains. It divides the calendar year into the wet (May–September) and the dry (October–April) seasons. During the dry season, air-flow over the Mekong is reversed as a high pressure system over the Asian land mass forces dry continental air flow over the basin.

The East Asian Monsoon¹⁴ from December to March originates in the Pacific Ocean. It contributes minimal and erratic rainfall as most of the LMB lies in the rain shadow of the Annamite Mountains. Tropical storms and cyclones are also major contributors to Mekong rainfall. Over the past 50 years more than 100 tropical storms and cyclones have crossed into the LMB from the Pacific. [2.2]

¹³ Also known as the summer or Southwest Monsoon.

¹⁴ Also known as the winter or Northeast Monsoon.

6 CLIMATE AND HYDROLOGY PROJECTIONS

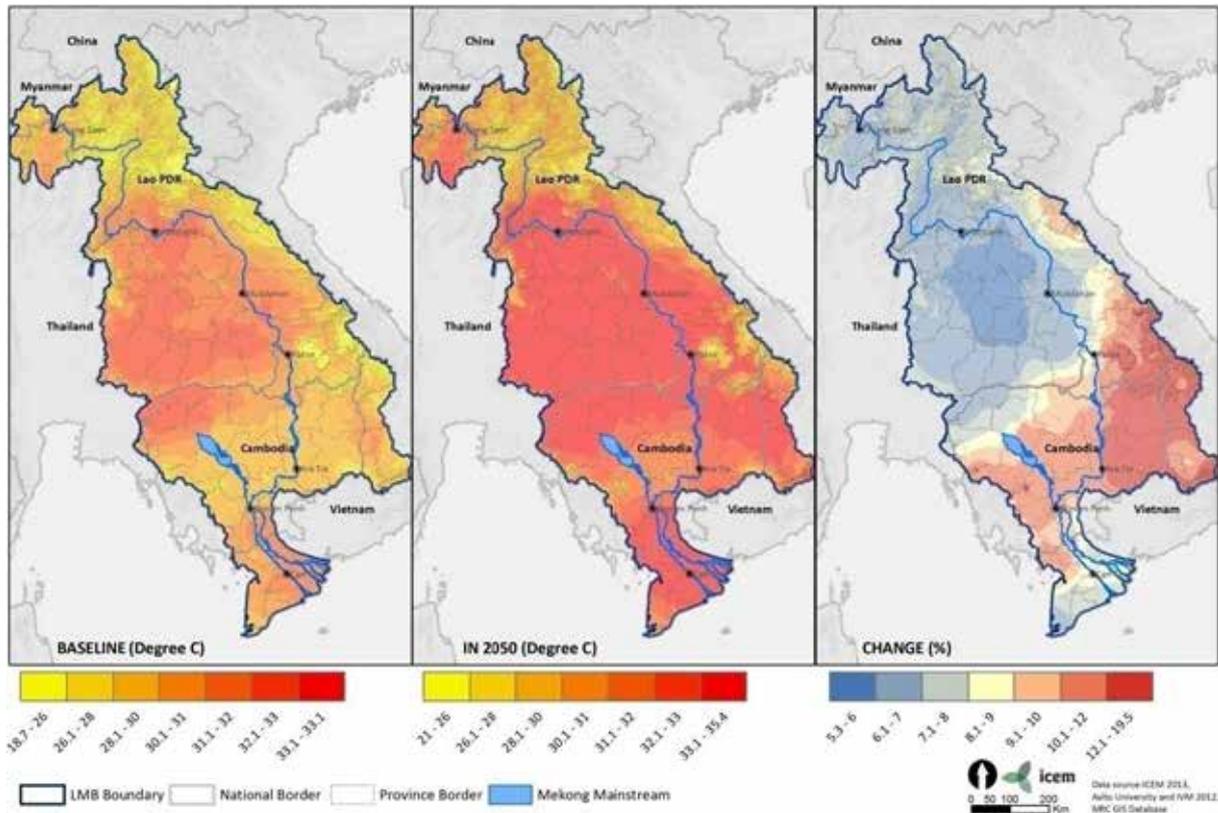
The original aim of the study was to assess the impacts of a global mean surface temperature rise of 2°C and the expected scale of impacts for time slices at 2030 and 2050. A rise of 2°C has long been considered as a tipping point of the global climate system above which catastrophic impacts such as destabilization of the Indian monsoon and collapse of the Greenland and Antarctic ice sheets become realistic possibilities. However, while 2°C remains the target for climate negotiations and agreements, the likelihood of keeping temperature increases below this threshold is implausible. The USAID Mekong ARCC study needed to move beyond 2°C and consider more drastic warming of 4°C plus by the end of the century. [3.2.1.2]

The study used a 25 year baseline period of 1980–2005 for all analysis. It focused on the 2050 time slice to assess changes in a number of hydroclimate variables, including temperature, rainfall, runoff, erosion, stream flow, flood depth and duration, saltwater intrusion, soil moisture, and tropical storm events. Robust causal links between those changes and aspects of natural and agricultural systems were then identified, such as the link between extreme temperatures and the spread of disease among livestock. [3.2.2]

According to the 2007 IPCC Fourth Assessment Report, approximately 20% to 30% of the Earth's plant and animal species are likely to be at increased risk of extinction if increases in global average temperatures exceed 1.5°C to 2.5°C. This study shows that by 2050, 30% of the LMB will experience temperature increases greater than the 2.5°C threshold. In the wet season increases greater than 3°C will affect close to 25% of the LMB. The synergistic effects of climate change with habitat fragmentation and destruction through development will place significant additional pressures on species and their habitats. [7.5]

By 2050, the largest increases in temperature will occur to the southeast of the LMB throughout the Srepok, Sekong, and Sesan (3S) river basins, including a small area of the Srepok catchment with an increase of over 4°C (Figure 9). Another hotspot area will be the Mekong Delta of Vietnam and Cambodia. [4.1] Average maximum daily temperature increases in the wet season will be especially significant ranging from 1.7°C to 5.3°C. Dry season temperatures will increase from 1.5°C to 3.5°C.

Figure 9: Average maximum daily temperature increases in the wet season¹⁵



It is important to communicate climate change modeling results in a format that is easily understandable to the intended audience, in this case: communities, policy makers, and specialists from other disciplines. The study team recognizes that calculating percentage changes in temperature as is shown in Figure 9 using the Degrees Celsius scale is not technically precise. Yet, we opted to use this method as one clear way to report temperature changes so that they are easily understandable and accessible to the intended audience. Box I discusses this concept further.

¹⁵ Box I describes the reasons behind using percent temperature change as one of the various ways that results of the USAID Mekong ARCC study were presented.

Box 1: Communicating Climate Change

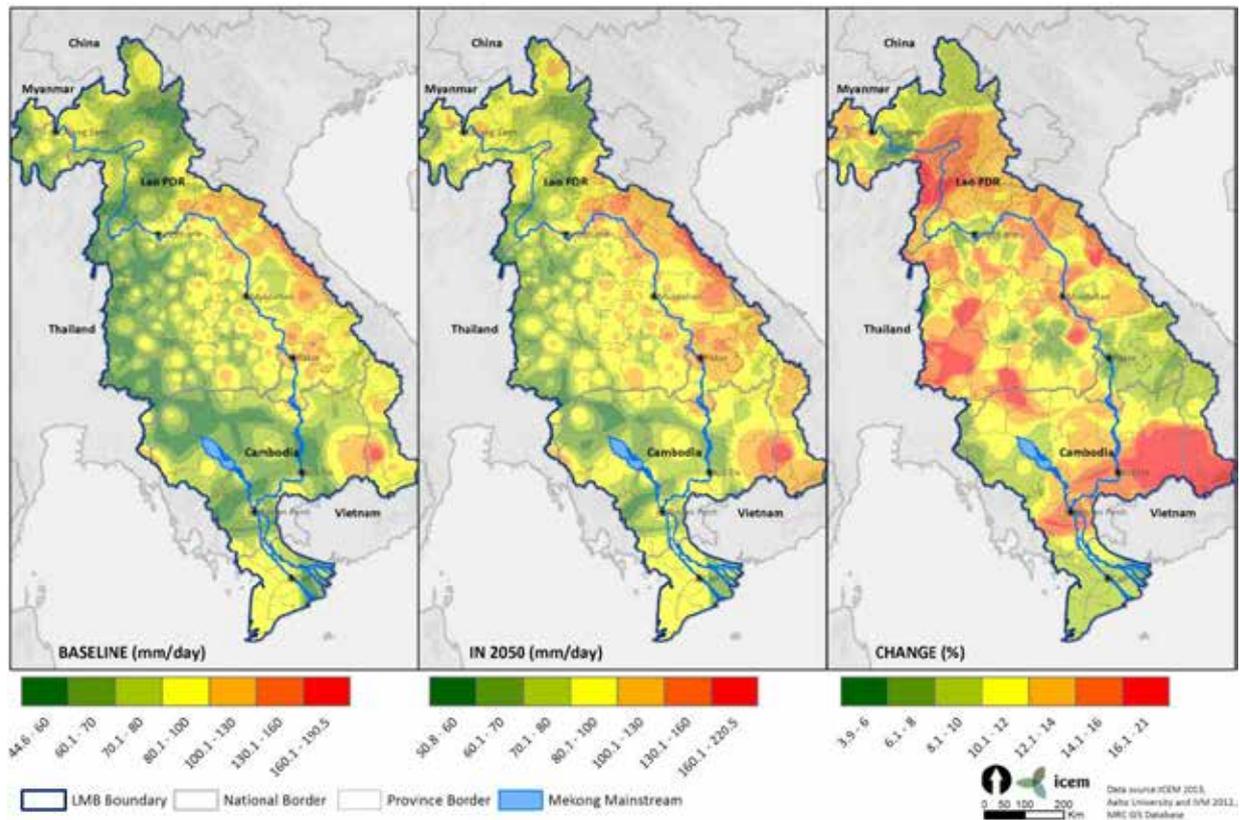
Globally it is convention for the scientific community to present changes in temperature in absolute terms such as +2°C. However, the significance of an increase in temperature varies from region to region, or even within regions—the impact of an increase of 2°C in the Tibetan plateau will vary significantly from a 2°C increase in the Mekong Delta. This is because the significance of change in a hydroclimate parameter is largely relative to the baseline conditions. For most hydroclimate parameters, percentage change is the best way to capture the relative magnitude of change and is widely used throughout this report to complement the quantification of absolute change (e.g., in stream flow, flood extent, precipitation, etc.). However, when expressing a temperature change as a percentage, we technically must use a temperature scale whose zero point is the temperature of absolute zero¹⁶, called the Kelvin scale. All other temperature systems, like Fahrenheit and Celsius, have arbitrary "zero points," and calculations of percent temperature change using these scales give arbitrary results. At the same time, the Kelvin scale is hardly used outside the scientific community and as climate scientists it is important to communicate climate change modeling results in a way that is easily understandable to the intended audience, in this case communities, policy makers, and specialists from other disciplines.

The study team decided to complement the quantification of absolute changes in temperature within this report with percentage changes using Degrees Celsius. These percentage changes in the report are therefore qualitative and meant only to compare the relative significance of change between different areas within the basin as a guide for setting adaptation priorities. Actions taken in response to these priorities should always refer back to the absolute changes.

Annual precipitation is projected to increase by 3% to 18% (35–365 mm) throughout the basin (Figure 10). That trend is due mostly to increases in wet season rainfall. Southern parts of the LMB will experience increased seasonal variability in rainfall with wetter wet seasons and drier dry seasons— which when combined with higher temperatures will have especially significant effects on species and ecosystems.

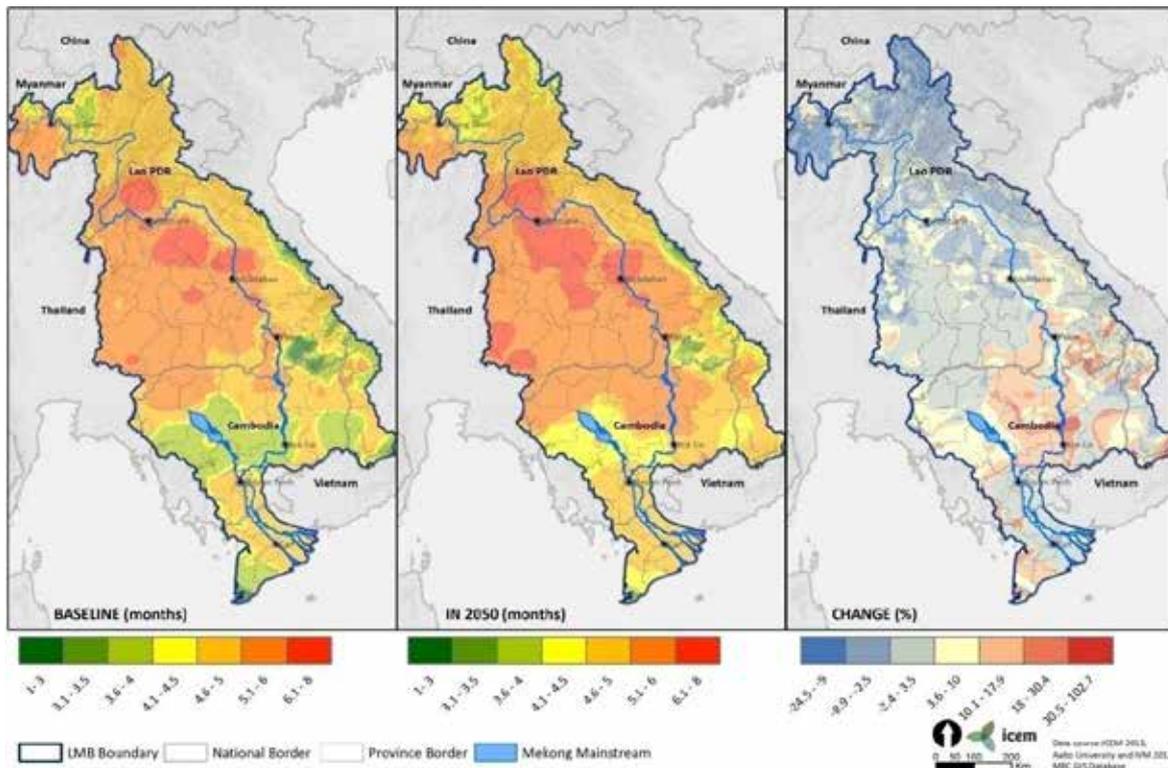
¹⁶ Absolute zero or 0 K is approximately equivalent to -273°C.

Figure 10: Average rainfall in the wet season—baseline and 2050



Although climate change involves incremental change in regular climate patterns, the LMB is projected to experience increased magnitude and frequency of extreme events such as storms, floods, and drought. The period of agricultural drought per year is likely to significantly increase in large areas in the south and east of the LMB by 2050. [4.3.4] Projections for severe droughts are centered on NE Khorat Plateau in Thailand, but the largest increases in drought will occur in the Mekong floodplain in Cambodia & Southern Lao PDR (Figure 11).

Figure 11: Number of drought months per year—baseline and 2050 in the Lower Mekong Basin



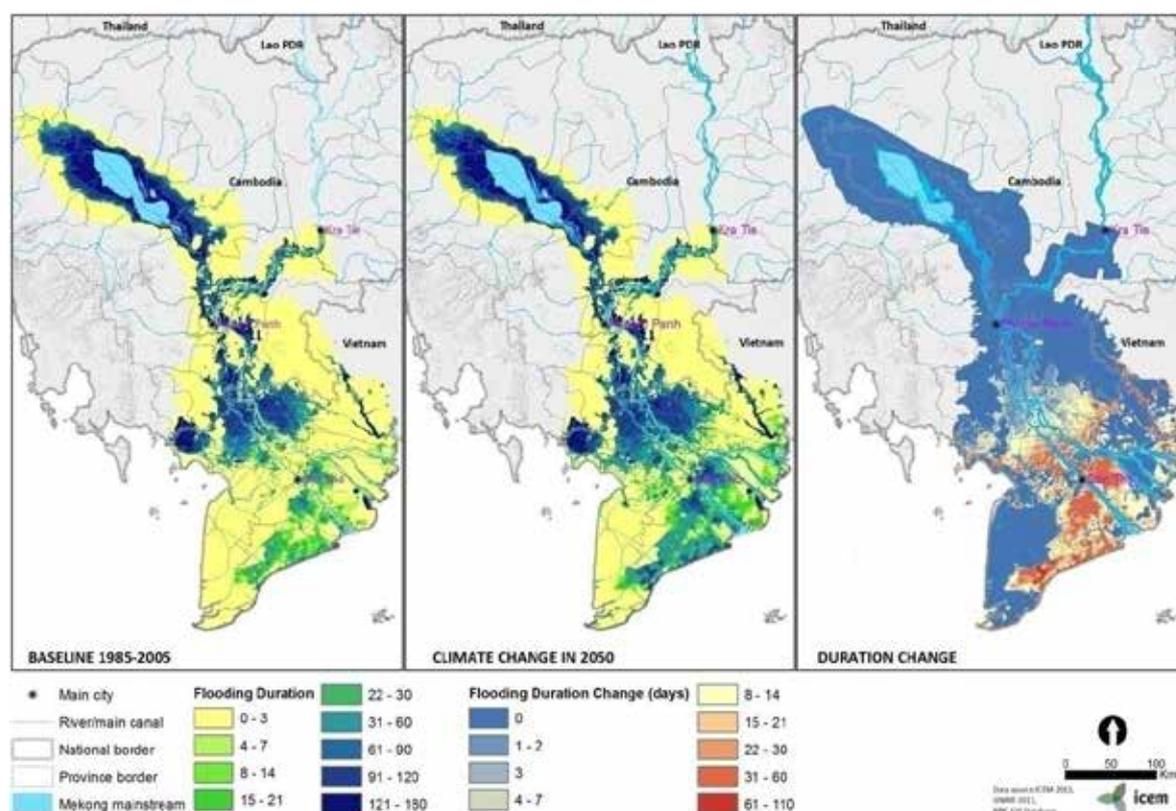
Seasonal variation is projected to become more extreme, setting limits to certain species and ecosystems. The annual increase in precipitation could be compounded by increasing cyclone intensities. Increased precipitation during storms will lead to increased runoff and flows in the Mekong mainstream and its tributaries.

Flash flooding and landslides are expected to increase in higher elevations, in steep terrain and along Mekong tributaries. The depth, duration, and frequency of extensive floods will increase in the lowlands. Both sea level rise and increasing average and extreme flood volumes will increase the depth and duration of floods in the Vietnamese delta and Cambodian floodplains. [4.3.6.1]

There is considerable variability in the projected changes in climate and hydrology by geographic area. In the Vietnam Delta, for example, Kien Giang is threatened by inundation caused mainly by seaward influences such as sea level rise and storm surge, whereas inland delta provinces such as An Giang and Dong Thap will experience increased height and duration of freshwater flooding due to the combined pressures of the Mekong River flood pulse and seaward influences.

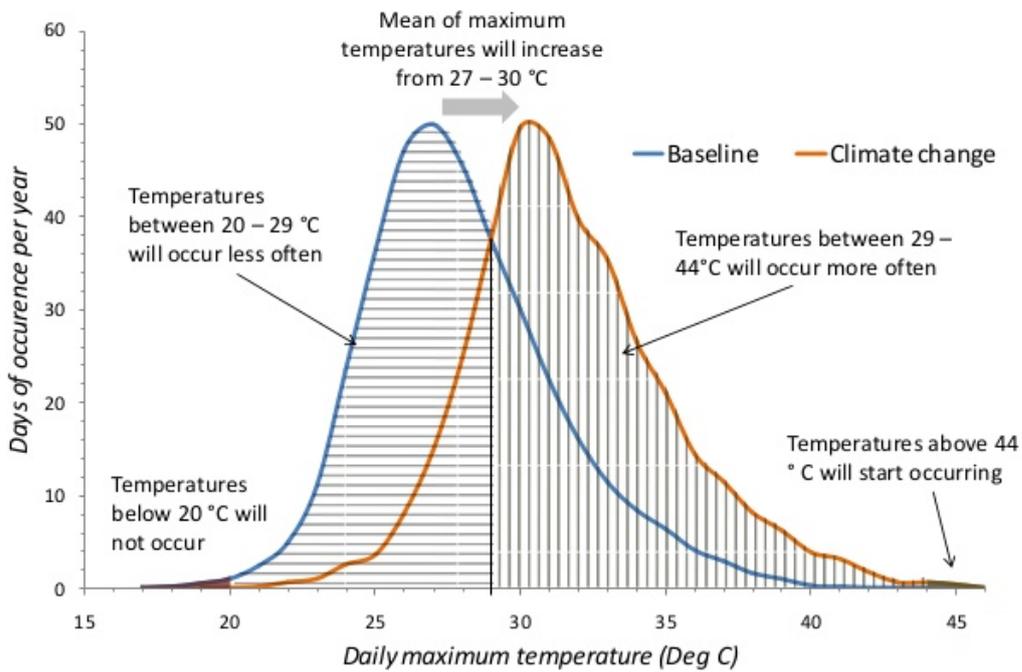
Maximum flood depths across the delta of more than 1.0 m will increase from 45% to 57% (over 650,000 ha)—mostly within the provinces of Bac Lieu and Ca Mau. Moreover, 1.0 m floods of greater duration than four months annually will expand to over 75,000 ha—mostly in Can Tho, Vinh Long, Soc Trang and Bac Lieu (Figure 12).

Figure 12: Average flood duration (>1.0 m) in the Mekong Delta—baseline and 2050



Chiang Rai Province in Thailand is projected to experience some of the largest relative increases in precipitation with annual precipitation increasing by 9% to 18%. In Cambodia, provinces in the east will experience large increases in temperature. Monduliri Province, for example, will experience greater daily maximum temperatures (2.5°C to 5°C) and greater minimum temperatures (1°C to 2°C) throughout the year. The highland area of Monduliri is projected to experience some of the largest increases in temperature within the LMB with annual maximum temperatures rising by 12% to 16% including increases over 5°C during April. The mean of maximum temperatures will increase from 27°C to 30°C (Figure 13). Monduliri is likely to experience reduced rainfall during the dry season of up to 3 mm per month (12% lower) and increased rainfall of up to 70 mm per month (14% higher) during the wet season.

Figure 13: Modulkiri—average daily maximum temperature shift



Projected changes in salinity intrusion under a 30 cm sea level rise during the 2045–2069 period are expected to be moderate during the wet season but significantly more severe during the dry season. During the wet seasons, salinity intrusion levels are projected to be close to 1980–2005 levels, both in terms of maximum salinity and duration at a level of 4 g/l. During the dry season, salinity is expected to increase over 133,000 ha of the Mekong River Delta. Maximum salinity concentration is projected to increase by more than 50% compared to the reference period, with the salinity level projected to exceed 4 g/l.

7 THE IMPACT OF CLIMATE CHANGE ON LIVELIHOOD SECTORS

7.1 AGRICULTURE

This study carried out crop yield and suitability modeling and vulnerability assessments for Robusta coffee, rubber, rainfed rice, maize, soybean, and cassava—all crops that, since 2000, have significantly increased in production and cultivated area.

An assessment of crop suitability with climate change shows both positive and negative shifts for the crops tested (Table 2). [5.1.2] However overall impacts of climate change are projected to lead to a decrease in crop yields and, more specifically, in rice yields. Climate change will seriously affect the lives and livelihoods of more than 42 million people in the basin who depend entirely on agriculture and major shifts in crop suitability will be seen by 2050.

Industrial crops which are economically important such as coffee and rubber will become less suitable in eastern Cambodia, the Vietnamese Central Highlands, and the Annamites due to temperature increases, excessive rainfall, and periodic drought. New areas at higher altitudes in the Vietnamese Central Highlands and northern Lao PDR will become more suitable for cassava, rubber, and coffee, due to temperature increases. Maize, soybean, and cassava will be less suitable across Cambodia and northeastern Thailand's plains and plateaus along the Mekong corridor due to increased rainfall and temperature.

Table 2: Summary of findings per crop and ecozone and relevance for current agrosystem

Crop	Main change in Suitability	Location	Ecozone	Example of changes
Rubber	Increased suitability due to increased precipitation	Northern Thailand (Chiang Rai) and Northern Lao PDR (Louang Namtha, Phongsali; Oudomxai)	<ul style="list-style-type: none"> High-elevation moist broadleaf forest 	5,500 km ² of increase suitability in Northern Thailand
	Increased suitability due to higher temperature	Northern Thailand (Chiang Rai), Lao PDR (Loaung Namtha, Phongsali; Oudomxai), Central Highlands (Kom Tum)	<ul style="list-style-type: none"> High-elevation moist broadleaf forest Mid elevation moist broadleaf forest 	
	Decreased suitability due to increased rainfall	Cambodia (Kratie, Preah Vihear) and Central and Southern Lao PDR (Champasack) and Chi Bun Basin In Northeast Thailand (Ubon Ratchatani)	<ul style="list-style-type: none"> Low-elevation dry broadleaf forest (Mid floodplain, wetland, lake) (Mid-elevation dry broadleaf forest) 	7,000 km ² decreased suitability in Chi Bun basin
Cassava	Increased suitability due to higher temperature	High and mid elevation eco-zone (Northern Lao PDR in Louang Prabang, Louang Namtha, Xayaburi and Central Highlands, Kontum)	<ul style="list-style-type: none"> High-elevation moist broadleaf forest (Low-mid elevation moist broadleaf forest) 	14,000 km ² of increased suitability in Northern Lao PDR
	Decreased suitability due to higher temperature	Low elevation eco-zones (Lao PDR, Cambodia and Central Highlands)	<ul style="list-style-type: none"> Low-elevation dry broadleaf forest Low-elevation moist broadleaf forest 	25,000 km ² in Cambodia shift to lower suitability
	Decreased suitability due to increased precipitation	Lao PDR in Champasack and Cambodia - Stung Treng, Preah Vihear, Battambang; and Central Highlands - Gia Lai	<ul style="list-style-type: none"> Mid-elevation dry broadleaf forest Low-elevation dry broadleaf forest Low-elevation moist broadleaf forest (Floodplain, wetland, lake) 	
	Increased suitability due to increased precipitation	Northern Thailand (Chiang Mai, Chiang Rai)	<ul style="list-style-type: none"> Mid-elevation dry broadleaf forest High-elevation moist broadleaf forest Low-mid elevation moist broadleaf forest 	
Maize	Decreased suitability due to increased precipitation	Louang Namtha; Vientiane, Khamouane and Phongsaly province (Lao PDR), Dak Lak in Central Highlands (Vietnam)	<ul style="list-style-type: none"> Low-mid elevation moist broadleaf forest High-elevation moist broadleaf forest Mid-elevation dry broadleaf forest 	5,000 km ² shift to lower suitability in Dak Lak province
Soya	Decreased suitability due to increased precipitation	Kampong Chhnang, Battambang, PreahVihear, Pursat, Kampong Cham Siem Reap, Kratie and Kampong Thom (Cambodia)	<ul style="list-style-type: none"> Low-elevation dry broadleaf forest Low-mid elevation moist broadleaf forest 	More than 60,000 km ² will experience decreased suitability for soybeans, due to increases in precipitation.
Robusta Coffee	Increased suitability due to higher temperature	Chiang Mai, Chiang Rai, North Lao PDR	<ul style="list-style-type: none"> High-elevation moist broadleaf forest Mid-elevation dry broadleaf forest 	2,500 km ² in Chiang Mai and Chiang Rai will shift to higher suitability
	Increased suitability due to increased	Chiang Mai, Chiang Rai, North Lao PDR	<ul style="list-style-type: none"> High-elevation moist broadleaf forest Mid-elevation dry 	

Rubber

Rubber is one of the oldest commercial crops in the LMB. Projected increases in temperature and precipitation would open new upland areas for industrial rubber plantations cultivation. *However, rubber plantations are projected to experience large negative shifts in production in Western Cambodia, the Vietnamese Central Highlands, and in recently planted areas like Champasak Province in Lao PDR due either to increased rainfall or prolonged drought.* Those changes in climate suitability should be considered in future planning of commercial crop development and land concessions. [5.1.2]

In **Thailand**, Chiang Rai is already an important source of rubber. By 2050, an area of 5,500 km² in that province will shift from medium to good and high suitability. Yet, in Ubon Ratchatani Province of the Chi and Mun Rivers Basin in Northeast Thailand, projected increases in rainfall will mean this area is less suitable for rubber with more than 7,000 km² of land shifting from high suitability to moderate/good suitability.

In **Lao PDR**, the northern provinces of Luang Namtha, Phongsali, and Oudomxai will experience increased suitability for rubber due to projected increases in temperatures. Central and Southern Lao PDR—Champasack in particular—will be less suitable for rubber due to increased rainfall.

In **Cambodia**, suitability for rubber will remain good for high in Kratie and Preah Vihear Provinces of Cambodia. Although there will be a marginal decrease in suitability due to projected increasing drought conditions. Almost 2,500 km² of high suitability land in Kratie will change to moderate or good suitability.

In **Vietnam's** Central Highlands' Kon Tum Province, 1,000 km² of land currently of only moderate suitability for rubber will shift to good suitability. That potential gain will be offset by a decreased suitability in 1,200 km² of currently high and very high suitability to good suitability.

Robusta Coffee

Changes in suitability for Robusta coffee are both positive and negative across the LMB but overall there will be a reduction in accessible areas suitable for the crop. Current high yield and production areas in the Vietnamese Central Highlands will decrease in suitability, e.g., by 5,000 km² in Dak Lak, while suitability will increase north of the basin, e.g., by 2,500 km² in Chiang Mai and Chiang Rai (Figure 14).

Lao PDR will experience the extremes for Robusta. Most of the positives changes will happen in Northern Lao PDR where expected changes in temperature and rainfall will increase suitability by more than 20% in areas of high elevation.

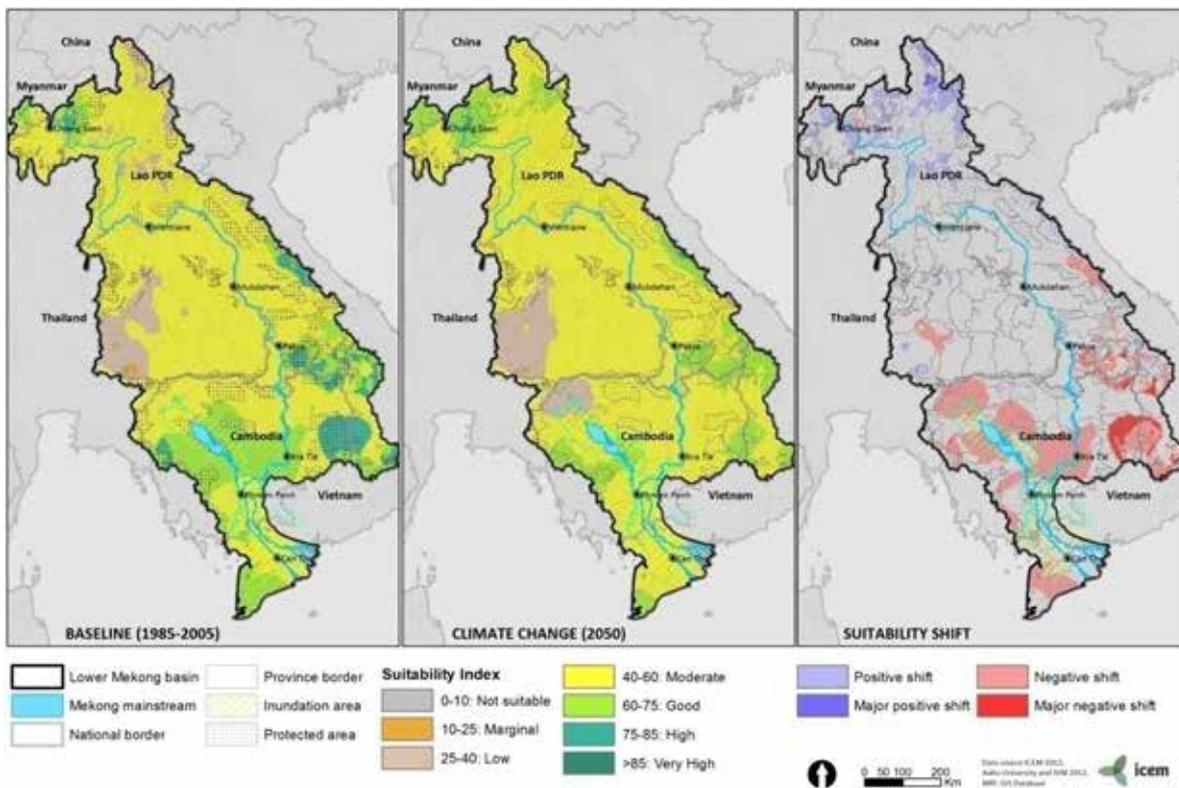
But the Bolaven Plateau in Lao PDR will contain the largest area of negative change in the basin, with a decrease of 9,000 km² of highly suitable land and a decrease of 180,000 km² of land of good suitability. The negative shift of climate suitability for coffee affects Champasack and Attapeu Provinces in particular with almost 1,000 km² and more than 285 km² of land of good suitability respectively shifting to lower suitability classes due to projected increases in both annual rainfall and temperature.

In **Eastern Cambodia and the Vietnamese Central Highlands**, the increase in annual rainfall and temperature will reduce the suitability for Robusta coffee culture. Areas of very high and high suitability will shift to moderate suitability. This change concerns about 30,000 km² of crops, mostly in the eastern region of the basin in Cambodia, Southern Lao PDR, and Vietnam. Areas of good suitability will decrease by more than 20,000 km² in the same regions.

Vietnam will lose 10,000 km² of very highly and highly suitable area in its Central Highlands. Dak Lak Province will have more than 1,000 km² of highly suitable land shifting to moderately suitable land.

In **Cambodia**, more than 70,000 km² will shift from very highly and highly suitable land, including 22,000 km² in Mondulkiri Province. While 3,036 km² and 1,703 km² of land will move from high to moderate suitability in Mondulkiri and Ratanakiri respectively.

Figure 14: Baseline and 2050 land suitability for Robusta coffee in the Lower Mekong Basin



In **Thailand**, high-elevation areas of Chiang Mai and Chiang Rai will experience increased suitability for Robusta coffee due to projected changes in temperature and rainfall. An area of 2,500 km² will shift from moderate to good suitability.

Cassava

Cassava is a major crop for animal feed and starch, with smallholder plantations throughout the basin. There are growing numbers of contract farms and industrial plantations in Cambodia and Lao PDR.

At the basin level, change in rainfall and temperature will decrease the highly suitable area for cassava (52,000 km²). Increased precipitation and extreme rainfall events with more floods will reduce yields in low-lying areas. Mostly, this change will affect Cambodia (25,000 km²) and Thailand (16,000 km²) in particular; Stung Treng, Preah Vihear, and Battambang in Cambodia, and Ubon Ratchatani in Thailand.

Also, large areas in Champasak in Lao PDR and Gia Lai in Vietnam will experience similar decreases due to projected increases in rainfall. However, changes will be from very high to high suitability classes and therefore are unlikely to significantly affect the crop's growth.

In some parts of the LMB an increase in temperature will allow for higher suitability in higher altitudes where current cultivation is limited by low temperature. For example, in Northern Lao PDR—Luang Prabang, Luang Namtha, Xayaburi, and in Kon Tum in the Vietnamese Central Highlands there will be increased suitability due to temperature rise with an area of 14,000 km² shifting from low to very high suitability for cassava.

Similarly, in Northern Thailand provinces Chiang Mai and Chiang Rai, drier areas will have increased suitability for cassava due to projected increases in rainfall.

Maize

Maize is a major commercial upland crop due to demand for bio-fuel and livestock feed. *Increasing temperature and rainfall during planting, and erratic rainfall throughout the crop cycle will seriously affect production.* By 2050, maize yield across the hotspot provinces will decrease by 3% to 12% due to increased rainfall or temperature.

Vietnam's Gia Lai Province area is expected to be particularly hard hit with reductions in maize yields greater than 12%. Dac Lak Province, also in the Central Highlands is one of the most heavily cultivated areas for maize. Slightly reduced suitability for growing maize is projected there, with 5,000 km² shifting from good to moderate suitability due to increased temperature and rainfall in the wet season.

Similarly, Northern Lao PDR will experience slightly reduced suitability for maize due to projected increases in temperature and rainfall.

Soybean

Soybean crops are of increasing importance in the region due to demand for bio-fuel and livestock feed. *Cultivation will be negatively affected by increased rainfall and more extreme rainfall events before harvest. Also, increased temperatures will have a negative impact on yields.*

Decreased suitability is projected for Cambodian provinces Kampong Chhnang, Battambang, Preah Vihear, Pursat, Kampong Cham, Siem Reap, Kratie, and Kampong Thom, all of which have seen significant expansion of soybean cultivation in the last decade. More than 60,000 km² will have decreased suitability for soybeans due to increases in precipitation.

Lowland Rainfed Rice

Rainfed rice is vital as a staple and the most important crop in the LMB. A yield drop of 3% to 12% is projected across the basin. Lowland rainfed rice and irrigated rice will experience reduced yields due to temperatures higher than 35°C during the growing stage in the dry season. The increase of the minimum temperature during the night will also affect rice yield. A decrease in average rice yields of just a few percent per hectare would have dramatic impact on LMB food security and food production. Northeastern Thailand is an exception to that trend where yields will increase due to the higher rainfall.

Saltwater intrusion and sea level rise will affect both irrigated and rainfed rice due to water quality constraints, shorter growth period, and higher flood level and duration. Water logging and increases in intensity of rainfall during the critical harvest and post-harvest period are likely in 2050.

Increased temperature was found to be a common threat across the basin (Table 3). In addition, 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.

Table 3: High vulnerability of crops to changes in temperature and precipitation in the eight hotspots

Provinces	Rainfed rice	Irrigated rice	Cassava	Maize	Soya	Sugar-cane	Coffee	Rubber
Chiang Rai	High (temp)			Medium	Medium			High (temp)
Sakon Nakhon	High (temp)		High (rain, flood)			Medium		High (temp)
Kham-mouane	High (temp, storm)	Medium	High (rain, storm)	High (rain, storm)		High (rain, storm)		Medium
Cham-pasak	High (temp, storm)	High (temp)	High (rain, storm)	High (rain)			High (temp, rain, storm)	Medium
Mondulkiri	High (Storm)		High (storm)		High (rain, storm)			Medium
Kampong Thom	High (temp, flood)	High (temp, flood)	High (flood)		High (lower water, temp, flood)			Medium
Gia Lai	High (temp)	High (temp)	High (flood, flash flood)	High (storm, flash flood)		Medium	High (temp)	Medium
Kien Giang	High (SLR, salinity)	Medium-High (SLR, salinity, temp)						

7.2 LIVESTOCK

Average maximum ambient temperature increases of up to 4°C or 5°C, projected for parts of the LMB, will reduce productivity and increase behavioral problems, morbidity, and mortality in the majority of livestock units without investment in cooling systems. Productivity losses and increased mortality rates, particularly among young and immuno-compromised stock, will negatively affect farmer incomes and may increase prices of livestock-derived products, and/or drive heightened demand for imported products. [5.2.2] The overall vulnerability assessment results for livestock in the LMB are summarized in Table 4.

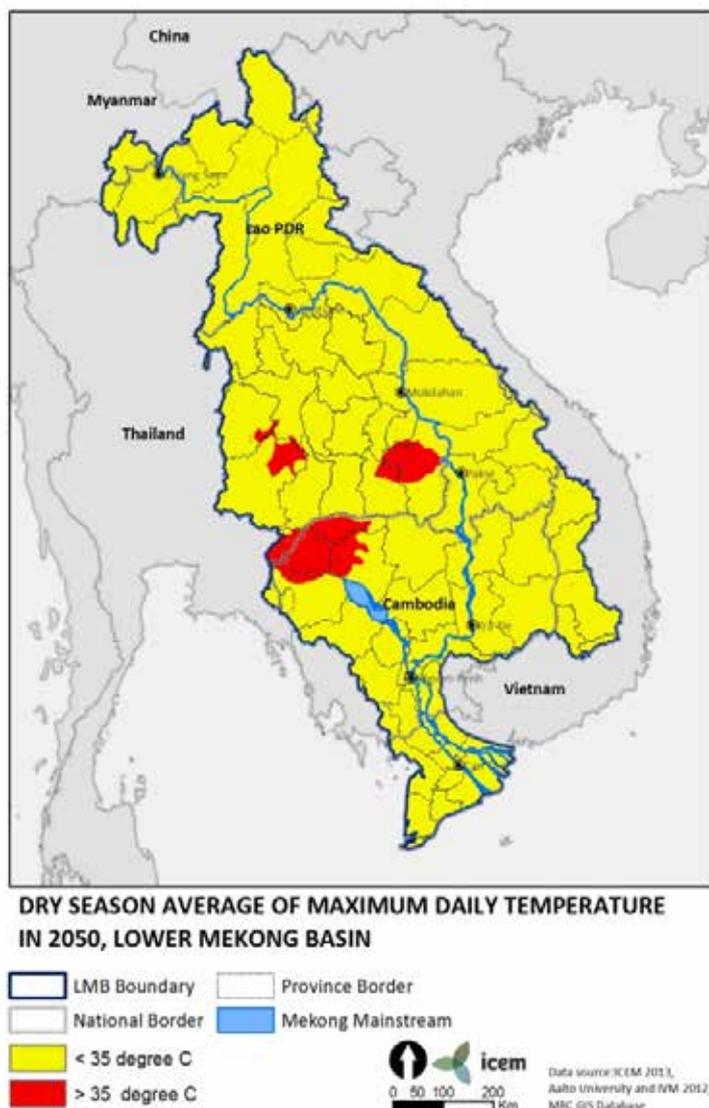
Table 4: LMB Livestock Systems Vulnerability

Livestock category	Impact	Adaptive capacity	Vulnerability
Smallholder cattle/buffalo	Low	Low	Medium
Dairy/large commercial	Very high	High	High
Small commercial pig	High	Medium	High
Smallholder low input pig	Low	Low	Medium
Small commercial chicken	Very high	Low	Very high
Scavenging chicken	Low	Low	Medium
Field running layer duck	Very low	Low	Low
Wild species vulnerability			
Banteng (esp. Mondul Kiri)	High	Very low	Very high*
Eld's Deer (esp. Mondul Kiri)	High	Very low	Very high*
<i>Sus Scrofa</i>	Low	Very low	High
Wild Poultry	Medium	Very low	High

*Assuming greater human and domestic stock incursion into habitats with climate change and ↑ disease risks and stresses due to hunting and competition.

For example, *Bos indicus* (humped cattle) breeds are by all measures the dominant cattle in the region. *Bos indicus* cattle are comfortable in high temperatures, as high as 35°C before any notable effect on production. However, temperatures above 35°C may lead to heightened stress, reducing immunity and feed intake, which will likely be exacerbated by work. Projected temperature increases show that the *Bos indicus* comfort zone will be exceeded in 30,100 km² of Cambodia and Thailand (Figure 15). If the animals are left un-shaded and not adequately watered, their capacity for work could be significantly reduced, negatively affecting household livelihoods through loss of draft power for rent and reduced support to subsistence farming.

Figure 15: Hotspot areas for *Bos indicus* above 35°C



Commercial production systems are increasingly prominent in the LMB where they tend to be concentrated in the low-lying areas. They are most prominent in Vietnam and Northeastern Thailand but are also increasingly prevalent near Phnom Penh and Battambang in Cambodia. *High-performance breeds managed in high-density systems will be negatively affected by expected climate changes.* Temperatures beyond the upper critical value for specific animals will impact productivity and increase behavioral problems in intensely-stocked systems. This effect will be most notable among poultry and pigs housed in higher-stocking densities in more commercially oriented systems.

Drought, extreme temperatures, and even increases in rainfall, will likely affect the availability and price of local feed sources and ingredients, which will have significant impacts on smallholders. Drier dry seasons will likely

increase the length and severity of low-feed periods for grazing stock and those fed predominantly on local raw feeds—systems, which are already generally stressed with stock scoring low on body condition. [5.2.2.2]

Negative impacts on feed availability caused by drought and flooding will reduce stock condition and resilience to disease challenges. The quantity and quality of disease-vector breeding sites will be altered by changes in the environment, particularly water availability. Greater climatic variability may include unseasonable rainfall in some areas, increasing the depth and duration of stagnant water providing increased availability of breeding grounds for mosquitoes. The need for greater feed preservation and storage options may also encourage rodent and related disease problems.

Changing weather systems will influence the likelihood of pathogen transmission through fomites. Wetter wet seasons are likely, overall, to exacerbate current internal and external parasite problems. For example, nematode infections are a common constraint to livestock production in the basin; and parasitic infestation is typically seasonal and associated with wetter conditions, which are expected to increase. [5.2.2.3]

Climate change is also expected to increase weather extremes which will have negative impacts on livestock-raising. For example, more livestock will be lost as a result of extreme events. Flash and heavy flooding events already claim significant numbers in the region annually. The heavy floods in Cambodia in September/October 2011, for example, caused severe losses among all livestock. Two-thirds of households with livestock reported losing animals as a result of the flood (FAO and WFP 2012).¹⁷ Stock losses were estimated at 70% for poultry, 23% for pigs, and 5% for cattle (CARE et al. 2012).¹⁸ In Thailand, over 55,000 head of livestock were lost during the 2009 floods (MRC 2010).¹⁹ In Lao PDR during the 1996 floods, households lost—on average and across wealth categories—half their cows and/or buffaloes (WFP 2012).²⁰

In conclusion, for **low-input systems**, 'local' breeds have greater *internal* adaptive capacity to climate change but lower *external* adaptive capacity. Climate change will exacerbate nutritional problems reducing value and increasing disease risk in many areas. **Small and medium 'commercial' systems** are raising higher-performance breeds under greater stress. They have a lower *internal* adaptive capacity but typically greater *external* capacity to adapt to climate changes.

Projected temperature increases will increase costs of livestock production in the LMB. Climate change will alter disease risks for all livestock systems; in concert with other developments disease risk is likely to increase. Wild species in the LMB are most threatened by changes in bovine production practices not climate change. For example, more grazing of protected areas will increase the risk of disease transmission and threats from hunting.

7.3 FISHERIES

Capture Fisheries

Capture fisheries in the basin are buffered against climate change to an extent by an exceptionally large aquatic biodiversity. But increased temperatures, changes in rainfall and river flows, increased CO₂ levels, sea level rise and storm intensity will all affect fish biodiversity and productivity. The climate change threats should not just be considered in isolation or in a single farming context. Increased temperatures plus decreased water availability, for example, equates to tough conditions for fish. In coastal areas, increased sea levels combined with higher rainfall is likely to exacerbate conflicts between shrimp farmers and rice farmers.

Reduced rainfall in the dry season and higher temperatures as projected for southeastern areas of the Basin will create harsh conditions for some fish species to survive. Changes to habitat temperature will influence metabolism, growth rate, production, reproduction—and efficacy, recruitment, and susceptibility to toxins and diseases. This will affect the natural ranges of some species, resulting in changes in biodiversity abundance in some areas (Table 5).

¹⁷ FAO (Food and Agriculture Organization) and WFP (World Food Programme). 2012. *Crop and Food Security Update Mission to Cambodia: Report*. Rome.

¹⁸ CARE (Cooperative for Assistance and Relief Everywhere), Catholic Relief Services, Oxfam and Pact. 2012. *Drowning in Debt: The Impact of the 2011 Cambodia Floods on Household Debt: A Survey of Poor Households in three affected provinces*.

¹⁹ MRC (Mekong River Commission). 2010. *Proceedings of the 8th Annual Mekong Flood Forum Vientiane, Lao PDR, 26–27 May 2010*.

²⁰ WFP. 2012. *Risk and Vulnerability Analysis: Lao PDR*. <http://www.foodsecurityatlas.org/lao/country/vulnerability/risk-analysis>

Table 5: Vulnerability to climate change threats by capture fisheries and aquaculture species

Capture fisheries		Aquaculture	
Species	Threat	System & species	Vulnerability
1. <i>Tor tambroides</i> UPLAND FISH, SOME MIGRATION, IMPORTANT FOR FOOD SECURITY IN SOME AREAS	Increase in temperature	INTENSIVE POND MONOCULTURE OF CLARIAS CATFISH	high
	Increase in precipitation		low
	Decrease in precipitation		medium
	Decrease in water availability		very high
	Increase in water availability		-
	Drought		very high
	Flooding		very high
2. <i>Cylocheilichthys enoplos</i> MIGRATORY, MEDIUM, WHITE FISH IMPORTANT FOR FOOD SECURITY	Storms and Flash floods	SEMI-INTENSIVE POND POLY-CULTURE OF TILAPIA, SILVER BARB AND CARPS	high
	sea level rise		high
	increasing salinity		-
	Increase in temperature		Very high
	Increase in precipitation		medium
	Decrease in precipitation		high
	Decrease in water availability		medium
3. <i>Trichogaster pectoralis</i> NON MIGRATORY, SMALL BLACK FISH, IMPORTANT FOR FOOD SECURITY.	Increase in water availability	EXTENSIVE POND POLY-CULTURE OF CARPS & TILAPIA	-
	Drought		medium
	flooding		-
	Storms and Flash floods		medium
	sea level rise		-
	increasing salinity		-
	Increase in Temperature		medium
Increase in precipitation	Increase in precipitation	Increase in temperature	medium
	Decrease in precipitation		low
	Decrease in water availability		medium
	increase in water availability		high
	Drought		high
	flooding		high
	Storms and Flash floods		medium
sea level rise	-		
increasing salinity	-		

Vulnerability analysis of the five hotspot provinces suggests that both upland fish species and migratory white fish will be most vulnerable to climate change in Chiang Rai, Gia Lai, and Mondulkiri. Migratory white fish will also be highly vulnerable in Khammouan (Table 6).

Table 6: Vulnerability of fisheries in five hotspot provinces

Chiang Rai	
Capture fisheries	<ul style="list-style-type: none"> ○ Upland fish species most vulnerable to increased temperatures, decreases in rainfall and flash flooding. ○ White fish species most vulnerable to increased temperatures and decreases in rainfall. ○ Black fish species less vulnerable to the changing conditions.
Aquaculture	<ul style="list-style-type: none"> ○ Intensive catfish pond systems vulnerable to increased water temperatures decreased water availability, droughts flooding and flash flooding ○ Semi - intensive polyculture systems vulnerable to increased water temperatures, decreased water availability, droughts flooding and flash flooding ○ Extensive polyculture systems vulnerable to decreased water availability, droughts and flooding.
Gia Lai	
Capture fisheries	<ul style="list-style-type: none"> ○ Upland fish species most vulnerable to increased temperatures and decreases in rainfall ○ White fish species not identified ○ Black fish species less vulnerable to the changing conditions.
Aquaculture	<ul style="list-style-type: none"> ○ Intensive catfish pond systems vulnerable to flooding and flash flooding ○ Cage aquaculture of cyprinids vulnerable to storms
Khammoune	
Capture fisheries	<ul style="list-style-type: none"> ○ Upland fish species less vulnerable to changing conditions ○ White fish species most vulnerable to increased temperatures. ○ Black fish species less vulnerable to the changing conditions.
Aquaculture	<ul style="list-style-type: none"> ○ Intensive catfish pond culture vulnerable to decreases in water availability, flooding and storms and flash floods ○ Extensive pond culture of carps vulnerable to decreases in water availability, flooding and storms and flash floods ○ Extensive pond culture of tilapias vulnerable to storms and flash floods
Kieng Giang	
Capture fisheries	<ul style="list-style-type: none"> ○ Estuarine species most vulnerable to increased temperatures and flash flooding ○ Invasive aquatic species such as the Golden Apple Snail will benefit from the changing conditions, possibly at the expense of some indigenous species.
Aquaculture	<ul style="list-style-type: none"> ○ Semi extensive inland pond aquaculture of prawns vulnerable to increased temperatures, increased precipitation, decreased water availability and drought ○ Intensive coastal aquaculture of shrimp vulnerable to increased temperatures, increased precipitation, Storms and flash flooding and sea level rise
Mondulkiri	
Capture fisheries	<ul style="list-style-type: none"> ○ Upland fish species vulnerable to increased temperatures, decreases in rainfall and flash flooding ○ White fish species vulnerable to increased temperatures and decreases in rainfall. ○ Black fish species less vulnerable to the changing conditions.
Aquaculture	<ul style="list-style-type: none"> ○ Semi intensive catfish pond aquaculture vulnerable to flooding and storms and flash floods ○ Extensive pond polyculture aquaculture vulnerable to increased temperatures, decreased water availability, flooding and storms and flash flooding.
Stung Treng (Hydrobiology)	
Capture fisheries	<ul style="list-style-type: none"> ○ Large migratory species are not very vulnerable to the anticipated changes ○ Small migratory white fish species do not appear to be vulnerable to the anticipated changes
Aquaculture	N/A

On the other hand changes in rainfall will increase river flows and strengthen the pulse effect which will benefit many migratory white fish species. Some species adapted to particular habitats will be negatively impacted, for example, minimum dry season water levels in the mainstream Mekong around Vientiane, Luang Prabang, and Chiang Saen are projected to increase by 30 cm. This will result in important in-river habitats being submerged for longer periods each dry season—eventually reducing the extent and productivity of this key seasonal wetland habitat and its capacity to support specialist migratory fish.

Estuarine species will be most vulnerable in Kien Giang and one invasive rice pest species, the Golden Apple Snail, will become more widely distributed in this area. Black fish species such as snakeheads and catfish do not look particularly susceptible in any of the hotspot provinces. In certain parts of the Mekong Basin, exotic fish species such as the Common Carp and Rohu have become established feral populations, increasing pressure on indigenous fish species. [5.5.1]

Aquaculture

Intensive aquaculture will come under pressure from climate change, for example, catfish culture in Vietnam (Tables 5 and 6). Farmers have already pushed production levels of this fish to the limit that the environment and their systems allow. Higher temperatures will place additional stress on these systems, forcing farmers to reduce stocking densities and feeding rates further, resulting in lower production.

Aquaculture is more vulnerable to climate change than capture fisheries, although it tends to have a high adaptive capacity because of the high management inputs and extension supports. Intensive, semi-intensive, and extensive aquaculture systems all appear to be vulnerable to climate change. Intensive aquaculture looks particularly vulnerable in lowland and coastal areas. Intensive systems have a high risk of failure but have the greater adaptive capacity. Semi-intensive and extensive systems have a lower risk of failure but also have a lower adaptive capacity. *While aquaculture may become possible or more viable in new (higher-elevation) areas, this will not come close to compensating for the production losses from lowland areas.*

7.4 NATURAL SYSTEMS

An interesting finding for the vulnerability assessment of natural systems was the distinction in results between the ecosystem or protected area focus and the species specific assessments. Assessing an individual species disconnected from its overall habitat tended to show lower levels of vulnerability than when the cumulative and multiplier impacts were considered on species and their relationships across an entire ecosystem. The study focused on five protected area “clusters” or groups in areas showing the highest climate change threat (Figure 16). Because of the huge diversity of NTFPs and CWRs in the LMB (mainly within protected areas), the study also examined a relatively small number of commonly used NTFPs from the same five areas for their individual tolerance and responses to climate changes. Species of wild rice were selected as examples of CWRs. Table 7 summarizes the results for the ecosystem assessments which all showed moderate to very high vulnerability. Table 8 summarizes the results for the 18 species of NTFPs and CWRs from the same areas with most showing moderate vulnerability, the exception being species found in dry broadleaf forest ecozones.

The main reason for the distinction in results depending on the focus level is that the species specific assessments tended to be narrower in the issues which were taken into account—mainly the biological resilience of the species. The threats to the species outside of climate change were considered but not the overall condition and trends in the host ecosystem. The ecosystem assessments, on the other hand gave considerable weight to the overall condition of the system and trends. A system which is degraded, diminishing in area and under increasing stress from various pressures is less resilient to climate changes and shocks. It has less capacity to withstand or recover from them.

These results reinforce the central conclusion—that *the integrity of forest and wetland ecosystems is of critical importance to the natural resilience and adaptive capacity of most of the NTFP and CWR species*—without the protection that these provide, their vulnerability would be much greater.

Figure 16: Five target protected area clusters in areas highly threatened by climate change

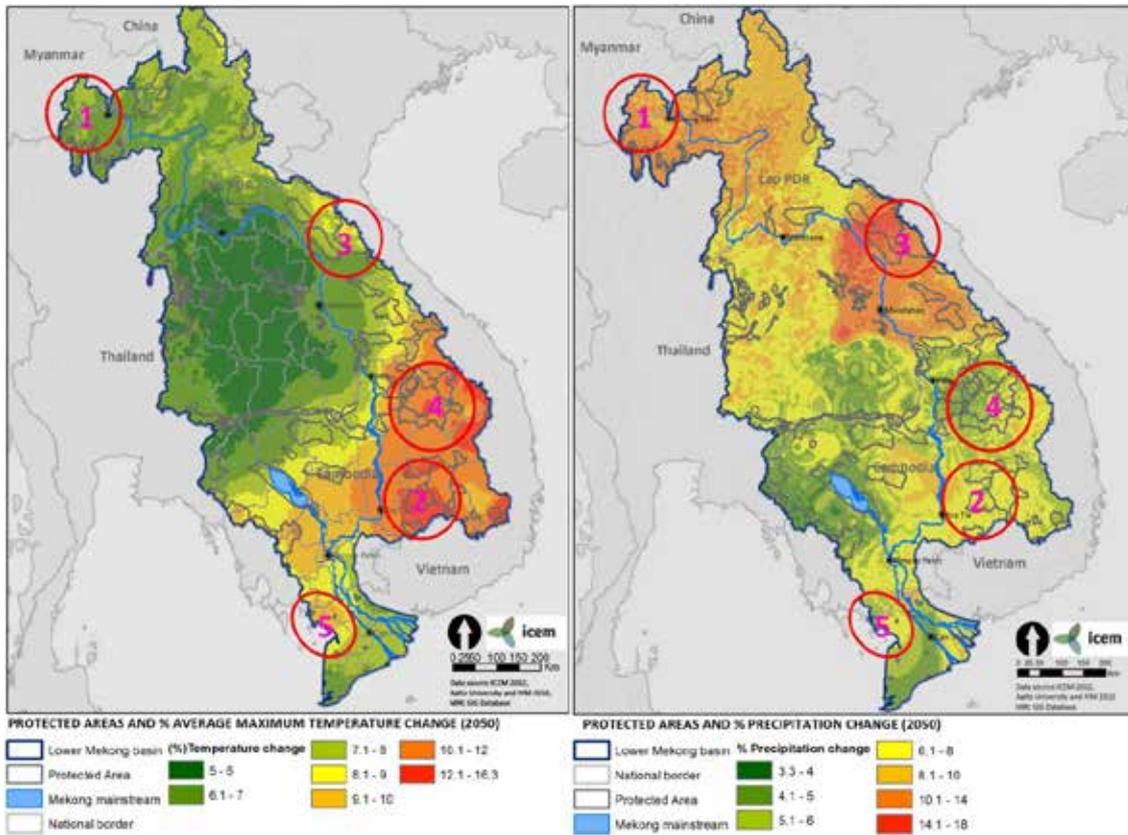


Table 7: Vulnerability of ecozones and linked protected areas

Ecozone	Province	Protected Areas	Temperature	Precipitation	Water availability	Salinity	Sea level rise	Drought	Flooding	Storm
Upper floodplain wetland, lake	Chiang Rai, Thailand	Nong Bong Kai - Non Hunting Area	High	Moderate	Moderate	Low	Low	Moderate	High	Moderate
Mid and low elevation dry broadleaf forest	Monduliri, Cambodia	Monduliri PA cluster in Cambodia	High	High	High	Low	Low	High	High	Moderate
High elevation moist broadleaf forest	Khammouane, Laos	Nakai-Nam Theun NBCA	Moderate	Moderate	Moderate	Low	Low	Moderate	High	Moderate
Low-mid elevation moist broadleaf forest	Khammouane, Laos and Gia Lai, Vietnam	Hin Namno, Phou Hin Poun, Corridor Nakai-Nam Theun, Phou Hin Poun, Chu Prong	Moderate	Moderate	Moderate	Low	Low	Moderate	High	Moderate
Delta mangroves and saline water and Delta Low lying acidic area swamp forest	Kien Giang, Vietnam	Kien Giang PA cluster	High	High	Moderate	Low	High	Moderate	High	High

CC Vulnerability				
Very high	High	Moderate	Low	Very Low

Table 8: Climate change vulnerabilities of different NTFP and CWR species in different provinces

Province			Kien Giang	Mondul Kiri	Gia Lai	Chiang Rai	Khammouan
Ecozone			3. Delta Low lying acidic area swamp forest	6. Low-elevation dry broadleaf forest	9. Mid-elevation dry broadleaf forest	4. High-elevation moist broadleaf forest - North Indochina	7. Low-mid elevation moist broadleaf forest
NTFP Category	Species	Common name	2. Delta mangroves and saline water	9. Mid-elevation dry broadleaf forest		12. Upper floodplain wetland, lake (CS to VTE)	4. High-elevation moist broadleaf forest - North Indochina
Mushroom	Russula sp	Russula mushroom		x	x	x	x
Grasses/herbs	Ammomum spp	False Cardamom		x	x	x	x
Aquatic plants	Sesbania sesban	Egyptian pea	x			x	
	Typha orientalis	Oriental rush					
	Lepironia articulata	Lepironia Sedge					
Climbers	Dioscorea hispida	Bitter yam		x	x	x	x
Orchids	Dendrobium lindleyi	Orchid		x	x	x	x
Rattans	Calamus crispus	Rattan		x	x	x	x
Shrubs	Broussonetia papyrifera	Paper mulberry		x	x	x	x
Trees	Dipterocarpus alatus	Resin tree		x	x	x	x
	Sonneratia casseolaris	Mangrove apple	x				
Insects	Apis dorsata	Giant honeybee	x	x	x	x	x
	Oecophylla smaragdina	Red Ants		x	x	x	x
Invertebrates		Earthworms	x	x	x	x	x
CWRs							
Wild Rice	O. nivara		x	x	x	x	x
	O. officinalis		x	x	x	x	x
	O. rufipogon		x			x	
Landrace rice	O. sativa/prosativa	Floating rice	An Giang				

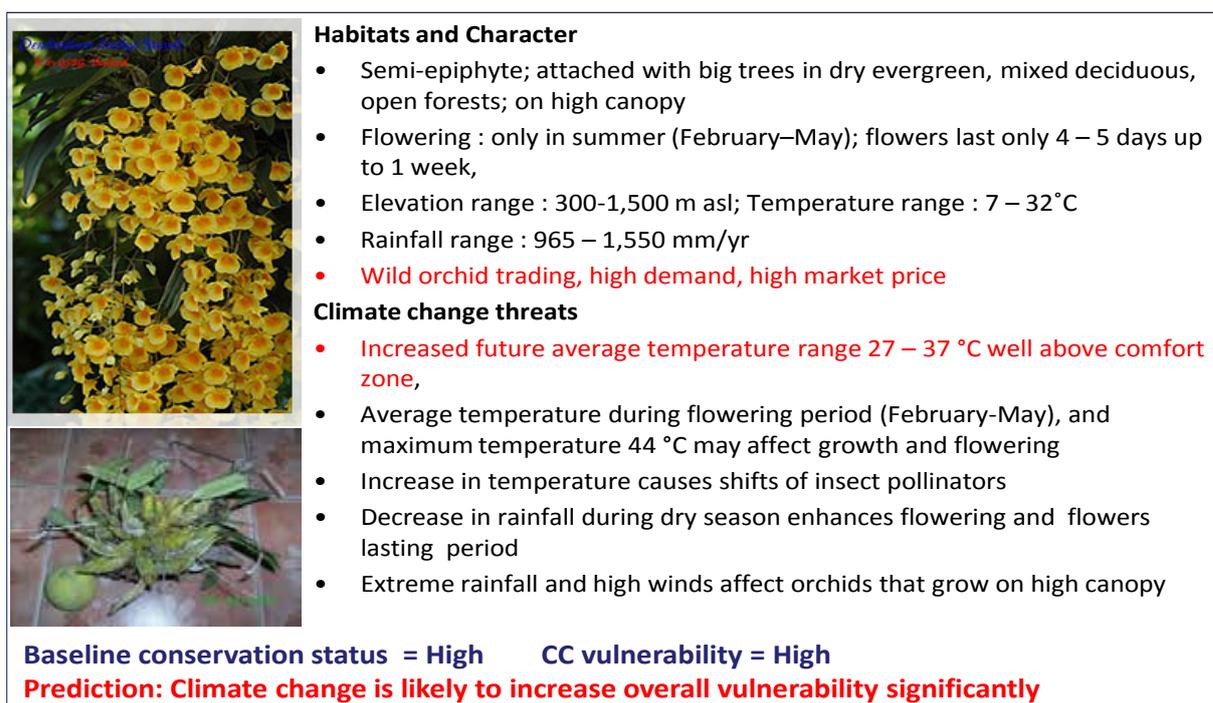
CC Vulnerability

Very high (red) High (orange) Moderate (yellow) Low (light green) Very Low (dark green)

Of all the climate changes considered in this study, the increase in **temperature** is the most important for NTFPs and CWRs—particularly when it occurs during the flowering, fruiting, and seed dispersal times of year. Wild rice species, for example, are highly vulnerable to projected increases in temperature, especially in Mondul Kiri. For the ecosystem as a whole the increased frequency, depth, and duration of **flooding** would likely induce more fundamental shifts in the plant and animal assemblages as a whole.

The climber Bitter Yam (*Dioscorea hispida*) is one of the least vulnerable species, having wide climatic tolerances and well-developed mechanisms for surviving prolonged dry seasons. By contrast, orchids, e.g., *Dendrobium lindleyi*, are highly vulnerable, especially in Mondul Kiri and Khammouan, where future increase in temperature and decrease in dry season rainfall will affect its growth and will increase wild fire risk. Increased frequency of storms could also have an impact upon the orchids growing high in trees. Wild orchids often have complex pollination systems dependent on insects that may be affected by climate change (Figure 17).

Figure 17: Vulnerability assessment of Wild orchid: *Dendrobium lindleyi* in Mondulkiri



The resin tree species, *Dipterocarpus alatus*, is highly vulnerable in most of the hotspot provinces apart from Gia Lai. It is a long-lived species of great importance to local communities, with low reproductive rate and is vulnerable to forest fire which can kill seedlings and saplings. Increases in temperature at the crucial flowering period are likely to reduce the reproductive rate further.

The mangrove, *Sonneratia spp*, is the only species studied here likely to be affected by sea level rise, strong winds, and storm surge. It is considered vulnerable, but if allowed to migrate inland as the seas rise, then it can survive. *Mangroves will become highly vulnerable to climate change with large areas of forest lost if movement inland is constrained by dykes and other developments as is the case in most coastal areas of the LMB.*

Wild rice species are highly vulnerable to projected increases in temperature, especially in Mondulkiri. Already, they are under threat from genetic erosion (i.e., mixing of genes with cultivated rice) and habitat loss with rapidly increasing pressure of land development for agriculture, urbanization, plantations, and general forest clearance. Increased temperature from climate change is another significant threat to an already highly threatened group of species.

At the protected area cluster level, the vulnerability assessments found significant impacts of climate change on ecosystem services. *Provisioning services in particular could be reduced through an overall decline in plant and animal productivity in areas such as Mondulkiri, experiencing more extensive drought during the dry season and increased flooding and soil saturation in the wet season. That may lead to changes in pollination and flowering, and spread and incidence of disease. Impaired agricultural production in those areas would lead to reducing habitats and increased reliance and pressure upon NTFPs. The region can expect to see continuing decline and loss of NTFPs and CWRs.*

Regulating services are also expected to decline in the hotspot protected area clusters assessed. For example, decreased pest control functions through disturbance of pest and predator relationships between insects, birds, amphibians, plants, and mammals are expected. Aggressive and hardy invasive species would tend to be favored as would mosquitoes and other disease vectors. More extensive drought conditions favor pests, increasing damage to crops.

Fundamental changes are anticipated for ecosystem supporting services. *The hotspot areas would experience an overall reduction and degradation in biodiversity.* Some species are expected to disappear under climate change and be replaced by others. For other vulnerable species there would be a reduction in population size. Higher levels of stress on already strained protected areas would lead to an overall loss in diversity and simplification of plant and animal assemblages. The number of species and populations are expected to be reduced. Migratory species would seek other areas more suitable for breeding and nesting. Also, a reduction in top soil moisture during drought periods would reduce micro flora and fauna suppressing decomposition and nutrient recycling affecting regeneration and plant growth.

7.5 HEALTH AND RURAL INFRASTRUCTURE

Human Health

The most prominent threats to human health identified across hotspot provinces were temperature rise, flooding, flash flooding, and landslides (Table 9). Key health issues most likely to arise in the basin are heat stress, water-borne disease, vector-borne disease, injury, death, or other health issues caused by extreme weather or other events related to climate change. [5.7.5]

Table 9: Vulnerability assessments for health by threat, province and livelihood zone

Province/ Livelihood Zone	Temperature	Precipitation	Drought	Flooding	Flash floods	Landslides
Chiang Rai						
<i>Intensively used uplands</i>	Medium	Medium	Low	Medium	High	High
<i>Lowland plains and plateaus</i>	High	Medium	Medium	High	Medium	Medium
<i>Floodplain</i>	High	Medium	Low	Very High	Medium	Low
Gia Lai						
<i>Intensively used uplands</i>	Very High	Medium	Low	Medium	Very High	Very High
<i>Lowland plains and plateaus</i>	High	Medium	Low	Medium	Medium	Medium
Khammouane						
<i>Forested uplands</i>	Medium	Low	Low	Medium	Very High	Very High
<i>Lowland plains and plateaus</i>	Medium	Low	Medium	Very High	High	High
<i>Floodplain</i>	Medium	Low	Low	Very High	Medium	Medium
KienGiang						
<i>Delta</i>	High	Low	Medium	Very High	Low	Low
Mondulkiri						
<i>Forested uplands</i>	Very High	Medium	High	Medium	High	High
<i>Lowland plains and plateaus</i>	Very High	Medium	Very High	Very High	Medium	Medium

Rural Infrastructure

The most prominent threats to infrastructure identified across hotspot provinces were flooding, flash flooding, and landslides (Table 10). In four hotspot provinces, Chiang Rai, Khammouan, Mondulkiri, and Kien Giang, flooding was identified as a major threat in low-lying areas where communities and infrastructure are commonly located nearby water bodies. A key issue in each case is the accessibility and integrity of roads during and following flood events. This threat is exacerbated in Mondulkiri and Khammouan where the roads are mostly unsealed. In those provinces loss of assets and longer-term damage is likely from extreme flood events. The limited number of assets also exacerbates the impact on communities who, under present conditions, may be cut off from external food and water sources for several days or longer.

Table 10: Vulnerability assessments for infrastructure by threat, province, and livelihood zone

Province/ Livelihood Zone	Precipitation	Flooding	Flash floods	Landslides
Chiang Rai				
<i>Intensively used uplands</i>	Medium	Medium	High	High
<i>Lowland plains and plateaus</i>	Low	High	Medium	Medium
<i>Floodplain</i>	Low	Very High	Medium	Low
Gia Lai				
<i>Intensively used uplands</i>	Medium	Medium	Very High	Very High
<i>Lowland plains and plateaus</i>	Low	High	High	High
Khammouane				
<i>Forested uplands</i>	Medium	Medium	Very High	Very High
<i>Lowland plains and plateaus</i>	Medium	Very High	Medium	High
<i>Floodplain</i>	Medium	Very High	Medium	Medium
KienGiang				
<i>Delta</i>	Medium	Very High	Low	Low
Mondulkiri				
<i>Forested uplands</i>	Medium	Medium	High	Very High
<i>Lowland plains and plateaus</i>	Medium	Very High	Medium	Medium

Another issue for low-lying areas relates to water supply infrastructure. Storage reservoirs, distribution systems and uncovered groundwater wells may be contaminated by floodwaters. After floodwaters have receded, affected communities may still be unable to access safe drinking water. Other identified vulnerabilities include damage to household buildings, such as grain storage; lack of access to health facilities, markets, and other communal infrastructure; and damage or destruction of irrigation infrastructure.

In the intensively-used upland zones of Gia Lai and Chiang Rai, road and building infrastructure is likely to be at very high risk of flash floods and landslides. Aside from adverse climate shifts, this vulnerability reflects the prevalence of land clearing for agricultural on sloping land that has caused

instability and reduced the capacity of soil to retain water. Ongoing deforestation in forested uplands areas of Mondulhiri and Khammouan is also reducing infrastructure resilience.

Roads, buildings, irrigation channels, and key communal buildings, such as health facilities, may all be exposed to the destructive force of more prevalent and stronger flash floods and landslides in the sloping and riparian areas of upland zones. [5.7.5]

8 ADAPTATION STRATEGIES

8.1 AGRICULTURE

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

1. *Improved varieties and risk management practices* such as using multiple varieties to spread the risk;
2. *Adopting improved water-use efficiency practices*, such as water harvesting and small-scale; irrigation in drought-prone areas. Water harvesting directs and concentrates rainwater through runoff to the plants and other beneficial uses;
3. *Improving soil fertility and soil management* in cash and subsistence systems in the plains, plateaus, and uplands; and
4. *Promoting agricultural diversification* and mixed farming systems and reducing the reliance on monocultures.

Climate change adaptation strategies will need to improve the overall adaptive capacity of farmers and farming systems and not just address a specific threat to a specific crop. In this study, broad adaptation measures are considered, focusing on the biophysical aspects of farm management (Table 11). The many institutional, policy, and market mechanism reforms which need to happen as part of an integrated adaptation response in agriculture were not considered.

Table 11: Adaptation options for uplands, lowland rainfed, and lowland irrigated farming systems

Climate change	Uplands	Lowland Rainfed	Lowland Irrigated
Increased Temperature	<ul style="list-style-type: none"> ▪ Altitude shift ▪ Heat tolerant varieties 	<ul style="list-style-type: none"> ▪ Heat Tolerant varieties ▪ Shift in cropping calendar to avoid peak temperature ▪ Early maturation varieties ▪ Shading 	<ul style="list-style-type: none"> ▪ Heat tolerant varieties ▪ Shift in cropping calendar to avoid peak temperature ▪ Early maturation varieties
Drought	<ul style="list-style-type: none"> ▪ Mulch/Permanent cover 	<ul style="list-style-type: none"> ▪ Mulch/Permanent cover ▪ SRI technique ▪ Small scale water storage ▪ Intercropping ▪ Conservation agriculture ▪ Drought tolerant varieties ▪ Drip irrigation 	<ul style="list-style-type: none"> ▪ SRI technique ▪ Drip irrigation
Increased rainfall, storms and extreme events	<ul style="list-style-type: none"> ▪ Mulch/Permanent cover ▪ Shift cropping calendar 	<ul style="list-style-type: none"> ▪ SRI technique ▪ Improve drainage ▪ Shift to water logging tolerant varieties ▪ Rain water collection 	<ul style="list-style-type: none"> ▪ SRI technique ▪ Improve drainage ▪ Shift to water logging tolerant varieties
Floods	<ul style="list-style-type: none"> ▪ Shift cropping calendar 	<ul style="list-style-type: none"> ▪ Shift cropping calendar ▪ Early maturation varieties ▪ Submergence tolerant varieties 	<ul style="list-style-type: none"> ▪ Shift cropping calendar ▪ Early maturation varieties ▪ Submergence tolerant varieties ▪ Shift to dry season crop only ▪ Fish culture in flooded rice fields ▪ Flood protection infrastructure
Saline intrusion		<ul style="list-style-type: none"> ▪ Shift to rice shrimp system ▪ Early maturation and saline tolerant varieties 	<ul style="list-style-type: none"> ▪ Shift to rice shrimp system ▪ Early maturation and saline tolerant varieties

Rice

Rice cultivation will require the development of new varieties for tolerance to higher temperatures, floods, and dry spells. New flood- and submergence-tolerant rice varieties developed by the International Rice Research Institute are now available. Heat-tolerant varieties will be required for rainfed rice in Kampong Thom, Monduliri, Khammouan, Champasack, Sakon Nakhon, and Chiang Rai; and for irrigated rice in Kampong Thom, Champasack, and Kien Giang. In some cases, such as in Kien Giang, a shift of the cropping calendar to avoid the peak heat period will be sufficient to limit the temperature stress.

Drought-tolerant varieties will be needed in Cambodia and Northeast Thailand to reduce the risk of dry spells. Early maturing crops, and/or submergence-tolerant varieties can be used in Kampong Thom, Kien Giang, Monduliri, Khammouan, Champasack, Chiang Rai, and Sakon Nakhon in flood-prone areas.

Rice-based systems in the coastal zones will require additional infrastructure to face sea level rise, storms, and saltwater intrusion. However, “hard” dykes and other engineering structures have been shown to have negative effects on productivity after initial increases due to losses in soil fertility and the need for increased chemical inputs. Traditional and bioengineering (i.e., plant-based) measures are needed which are more flexible, cheaper, easily maintained, and locally managed. Salt-tolerant and short-growth duration rice varieties with high yields and good-grain quality will be part of a longer-term adaptation approach.

A shift to a rice-shrimp system will be required in areas where saltwater intrusion will constrain a second rice crop. However, shifting land use from rice to shrimp would reduce women’s income opportunities. Shrimp farming is a more physically and mentally demanding activity, culturally perceived to be more appropriate for men.

In flood-prone areas like Khammouan, Kampong Thom, and the Cambodian floodplain, rainy season rice crops will be vulnerable. In those areas, a shift to a dry season crop and recession rice will be required if feasible in the new conditions. Also, with the development of small-scale irrigation, integration of fish culture could diversify income and add nutritional benefit at the household level. In flooded rice fields, community-managed dry season fish refuge ponds can support productive fisheries. [7.2.1]

Improvement of Water Use Techniques

Access to irrigation from groundwater, rainwater collection, and small-scale water storage can provide opportunities for dry season crops, supplementary irrigation, or diversification with homestead intensive gardening. This diversification strategy in areas that are well-connected to markets can provide a new source of income while building resilience and stability in the farming system.

Water storage or efficient water use techniques, such as low-cost drip irrigation, mini-ponds, and rainwater harvesting in ponds or tanks can help to diversify agriculture production and secure rainfed crops. For the poorest and especially landless, rainwater harvesting associated with drip irrigation in homestead gardens is a potential option to diversify income. This adaptation strategy can target women with homestead garden vegetable production and marketing activities. Vegetable

production can be oriented to specific niche markets, for example, where there is growing demand for organic products around city centers and tourist areas. [7.2.2]

Soil Management and Fertility

The negative impact of climate change can be reduced by better fertility management at the plot level. One option is to develop a cropping system that includes the rotation of crops with permanent vegetal cover and limiting or abandoning tillage to improve the quality of soil organic matter and increase nutrients. Continuous vegetal cover, bioengineering methods with tree plantation, and physical barriers are options for uplands in response to extreme rainfall events and storms.

Those adaptation options would apply in several hotspots facing erosion issues due to extreme rainfall events (e.g., Khammouan, Gia Lai, Mondulikri, and Champasack). They would also be helpful in hotspots where commercial crops such as cassava, soya, and maize use larger quantities of chemical inputs (e.g., Northeast Thailand, Western Cambodia, and along the Mekong River corridor in Lao PDR). [7.2.3] “Urea deep placement” for a better efficiency in fertilizer use and “conservation agriculture”²¹ methods to improve soil structure, increase organic matter in the soil, and promote nutrient availability for the crop are important ingredients in the soil management adaptation strategy.

Shifting Farming Systems or Crops

In some cases, climate change will require a shift of crop or system. In waterlogged areas and those receiving extreme rainfall, cassava culture might require a shift to more water-tolerant crops and/or improved drainage systems. These adaptation strategies may be required in hotspots such as Mondulkiri, Khammouan, and Sakon Nakhon provinces. Similarly, soya culture (Mondulkiri and Kampong Thom), and sugarcane and maize culture (Khammouan) may require shifts to more flood-tolerant crops. Soya will also need more heat-tolerant crop varieties. [7.2.4]

Altitude Shift

Rubber will need to shift in altitude in several provinces, such as Mondulkiri and Chiang Rai, to avoid increasing temperature. Altitude shift will also concern other perennial plantations in specific spots within the basin, such as litchi production in northern Thailand (Chiang Rai) and Robusta coffee in the Vietnamese Central Highlands. These shifts will be needed in the medium to long term. Production in current areas might be replaced by more heat-tolerant crops. [7.2.5]

Agricultural Diversification and Mixed Farming Systems

Farmers face many risks such as climatic factors (including climate change), pests and diseases, price uncertainties, and changing government policies. Farm diversification is a response to avoid and minimize those risks.

²¹ Conservation agriculture is defined as minimal soil disturbance (no-till) and permanent soil cover (mulch) combined with rotations (FAO: Conservation Agriculture web site: <http://www.fao.org/ag/ca/1a.html>).

The main purpose of diversification in agriculture is to maintain an optimal level of overall production and return by selecting a mixture of activities which buffer the farmer against shocks affecting individual crops. Already smallholder farming in the LMB is extremely diverse and flexible. Yet, the trends are for consolidation of holdings and a shift to highly productive monocultures.

Farm diversification is a key principle which needs to guide climate change adaptation in agriculture.

Another closely linked principle for adaptation is **optimizing biodiversity in farming**. That principle means more than increasing the range and number of crops grown on a farm—although that is critical for stability in output. It is about the overall enhancement and maintenance of ecosystem health on farms. The aim is to steadily increase the number of living components on the farm in a way that is ecologically more diverse and stable and which provides optimum growing conditions for a greater diversity of produce. Resilient farms include healthy soil microfauna and flora; trees, shrubs, palms, bamboos, and other woody perennials and well-managed and maintained waterways—all offering a range of produce and ecosystem services as an integral part of the crop and livestock system. In fact, a diverse and biodiversity-rich farming system builds on traditional practices with improvements from modern technologies and approaches.

8.2 LIVESTOCK

Improving livestock nutrition, health, and market access will improve household and stock resilience to climate change throughout the basin; at the same time promoting economic development and reducing food insecurity, poverty, and vulnerability. There are five broad strategies to improving livestock systems and increasing resilience to climate change:

Nutrition: The quality and quantity of feed production and storage, and the nutritional balance of diets should be increased to reduce undernourishment. [7.3.2] This goal involves improving the use of available resources such as crop residues and wild forages, while at the same time increasing forage cultivation. More effective technology transfers are required in the areas of seed conservation, cultivation practices, and feed preservation. An additional important but difficult measure to implement is reducing grazing pressure on protected areas, which would reduce contact with wild populations and corresponding risk of disease. This adaptation strategy applies particularly to smallholder bovines and low-input pigs. Key hotspots are Mondulkiri and Khammouan Provinces.

Disease resistance: Enhanced internal disease resistance through higher nutrition, better overall body condition, and increased vaccination levels, is necessary to reduce the threat of disease. In addition, improved biosecurity prevents the movement of diseases onto and off the farm and reduces the risk of pathogens entering the herd or flock. [7.3.3] Controlling and limiting the movement of livestock is recognized as the most important biosecurity measure for most diseases, but many significant disease hazards are also transported via contaminated clothing, equipment, and vehicles. EcoHealth approaches are needed, which view managing livestock health in terms of the overall health and stability of the entire farming ecosystem. This priority adaptation strategy of improving disease resistance applies to all livestock systems and especially to the hotspots—Kien Giang and Chiang Rai Provinces.

Housing: Housing location and design should maximize natural ventilation and minimize exposure to extreme events. [7.3.4] This strategy applies especially to small commercial pig and poultry systems. Hotspot provinces are Kien Giang and Chiang Rai.

Production planning and off-take: Production planning and reproduction management in breeder herds/flocks should be improved—reducing inbreeding, recognition of estrus, and earlier weaning, for example. Increased off-take rates, where beneficial, promote controlled destocking to reduce pressure on stock, land, and/or nucleus herds and flocks with the additional benefit of increasing household incomes. [7.3.5] Flood and drought-prone areas will benefit most. Low-input cattle, pig, and poultry systems are a primary target for this strategy. Hotspot provinces include Gia Lai, Mondulkiri, and Khammouan.

Access to markets: Improved access to markets and producer organizations should reduce input costs, increase prices received, and reduce price volatility. [7.3.6] The main targets for this strategy are livestock producers in remote areas and, once again, the hotspot provinces include Gia Lai, Mondulkiri, and Khammouan.

In conclusions, the priority adaptation strategies for livestock relate to nutrition, animal health, and market access. The focus should be on improving animal nutrition among smallholder low-input systems, particularly bovines; reducing disease risks for all livestock systems by increasing disease resilience and minimizing disease challenges; and increasing smallholder access to and information on inputs, services and product markets.

8.3 CAPTURE FISHERIES AND AQUACULTURE

Capture Fisheries

There are four main challenges to effective adaptation in capture fisheries. The first is the predominant influence of physical structures and barriers. The second is that capture fisheries are open systems and their productivity is strongly influenced by natural variations, more than by management. Also, the sheer size of the capture fisheries areas in the LMB means that truly effective adaptation actions would need to be large scale and therefore probably expensive and involve many authorities and agencies. Finally, given the extensive ‘noise in the system’, measuring the impact or effectiveness of any adaptation effort will be difficult.

Despite those challenges, adaptation measures for capture fisheries are feasible. They are best defined for fish grouped broadly according to their ecology and migration behavior. [7.6]

Upland fish: The adaptation priority in uplands is to retain or rehabilitate forest cover to protect the stream environments. Protection of the small valley catchments is needed to reduce the effects of flash flooding so that the specialist upland fish species can remain prolific.

Migratory white fish: For the migrators it is critical to maintain and improve their access to spawning grounds and habitats. This includes restoration of the flooded forests around the Tonle Sap and lower Mekong, which are vital to the health of the fishery and the migratory species that live there.

Black fish: For the more sedentary black fish, adaptation measures must ensure their biodiversity remains intact and their contribution to productivity remains high. The single most important management intervention for these fish species is the creation and management of dry season refuge areas, from which they can repopulate the flood plains each wet season.

Estuarine species: Maintenance of habitat is the priority for estuarine fish. Of particular importance is the replanting of mangrove forests in coastal areas to protect against erosion resulting from sea level rise, storms, and increased rainfall. The restoration of natural mangrove systems is integral in maintaining fish biodiversity and production. Additional habitat improvement measures include the rehabilitation of derelict shrimp farming areas. Non-interference with natural currents and tides is also required to ensure that mangrove areas remain healthy and able to support the estuarine fishery.

Invasive aquatic species: Invasive species should be monitored at community and government levels to plot the spread of those that are harmful to key native species and habitats. Eradication drives may be necessary to keep some invasive populations in check.

Special species specific adaptation plans: A number of key species, considered both highly valuable and especially vulnerable to climate change, will need specific protection and enhancement measures – for example, the Giant Mekong Catfish, *Pangasianodon gigas* and Julliens Golden Price Carp, *Probarbus jullieni*.

Aquaculture

Aquaculture is more vulnerable to climate change than capture fisheries, because fish in natural environments may be able to move to areas where environmental conditions suit them better. This is not the case with aquaculture where stocks are retained in a closed environment.

Cultured fish tend to be under more stress than those in natural environments, and climatic changes—increased temperatures, changes in rainfall patterns, increased storm intensities, and higher sea levels—will add to these stress levels, resulting in poorer stock performance. However, there is scope for individual system adaptation measures because aquaculture can be controlled and tightly managed, for example, in terms of the stocks raised and the feeds supplied.

The more intensive aquaculture systems generally have the greatest adaptive capacity due to the high level of investment and management. Yet, production has probably peaked and current levels will not be maintainable under the projected climate change scenarios. Some systems, such as *Pangasius* farming in the delta, are already pushing the limits of production from their systems, suffering regular losses through disease and water quality problems. These problems will only increase as climate change effects are felt. For super-intensive systems, the eventual solution may be to move fish production ‘inside’, i.e., within buildings where the environmental conditions can be completely controlled. [7.7]

Many aquaculture farms may have to invest in on-site water storage to lessen the risks of reduced water availability during the dry season. The strengthening of embankments to protect against flooding will be necessary for ponds in many areas. Changes in rainfall patterns make it more difficult to manage aquaculture systems, and flash flooding leads to stock losses, for example. Storm

intensity and frequency could affect coastal and reservoir aquaculture infrastructure and inland aquaculture farm flood-security systems.

In some middle and higher-elevation areas, aquaculture may benefit from the warmer temperatures and increased water availability anticipated through climate change. However, while aquaculture may become possible or more viable in higher-elevation areas, this will not come close to compensating for the losses from lowland areas.

In lower elevations, projected temperatures will be above optimum for many species and adaptive measures should be taken. This may mean shifting from carp species to tilapias, which are generally more tolerant of high temperatures and low dissolved oxygen levels. Farmers may have to adjust fish cycles and stocking densities to manage expected high temperature periods.

In coastal areas, farmers should be able to manage salinity levels quite well through their choice of species. The pond culture of shrimp, on the other hand, will be seriously compromised by climate change. These systems are already under threat from environmental factors and aggressive management practices, and climate change may well push them over the edge. Conflict between shrimp farmers and rice farmers may increase as sea levels rise and it becomes more difficult to manage salt water. Integrated water management plans will need to be implemented in many areas to contain these types of conflicts.

Giant freshwater prawn farmers in the delta may shift to penaeid shrimp culture as sea levels rise. Mangroves should be replanted in derelict shrimp farms for protection and to encourage siltation. Climate-friendly systems, such as tiger shrimp and crab production in mangrove-replanted areas of the delta, should be more widely promoted.

Many aquaculture farms may have to invest in on-site water storage to reduce the risks of reduced water availability during the dry season. The creation of small farm ponds, as promoted by Thailand's King Bhumibol Adulyadej for several decades, are an excellent local climate change adaptation strategy for a wide range of farming activities that are reliant on rainfall. However, embankments to protect against flooding will be necessary for ponds in many areas. [7.7]

It should not be forgotten that fishing and farming communities in the LMB are extremely resilient to the vagaries of the weather and seasons, which in the case of the Mekong River and floodplain are already extreme. However, climate change will test the limits of fishers' capacities to produce food and generate incomes. These communities must not be left to adapt by themselves. They need preemptive support to acquire awareness of the conditions to come and the techniques and innovations suitable for these changing conditions.

8.4 NATURAL SYSTEMS

Healthy natural systems underpin effective adaptation in all sectors in the LMB. They bring resilience and flexibility in adjusting to new conditions. There are two ways of viewing natural systems and climate change. First, from the perspective of the other livelihood sectors of agriculture, livestock, fisheries, and health and infrastructure—where maintenance of ecosystem services is a response to climate change in those sectors and a foundation, or critically important, adaptation strategy that underlies all others. Second, looking inward and taking natural systems as its own livelihood

sector—where better management is needed as an adaptive strategy for safeguarding NTFPs and CWRs. The natural system adaptation measures required to meet both requirements—i.e., resilience in other sectors and in NTFPs/CWRs—are the same. The first and foremost priority is the health and well-being of the natural systems themselves. Protected areas and maintaining intact connections between them should be targeted as a focus of natural system adaptation investment.

Expand and strengthen the protected area system to protect the full diversity of LMB habitats and increase opportunities for dispersal across the landscape. Protecting more habitats is one of the most effective ways to maintain viable populations of a wide range of species and the ecosystems of which they are a part. Actions to strengthen and expand the LMB protected area network to adequately conserve and represent all habitats and species is a foundation adaptation measure. It would require a better understanding of scientific knowledge on the gaps and condition of the current protected area system.

Build on and strengthen existing conservation management approaches which will continue to be important as the climate changes. Any of the good guides and manuals to effective protected areas management would identify many of the key measures required for foundation adaptation. These requirements typically include better and more proactive conservation management to meet what is termed in this study as the adaptation deficit—i.e., things which should be done now even if climate change was not happening. (For purposes of this study, ICEM refers to the gaps in capacity in dealing with current climate and social conditions as the adaptation deficit.)

Greater attention and resources to improving scientific understanding of climate change impacts on species and ecosystems. Effective adaptation strategies should be informed by up-to-date scientific evidence. Research and monitoring is needed to understand which species and ecosystems are most sensitive to climate changes and to distinguish climate change effects from those caused by other threats. Key areas of research and monitoring relate to rates and types of ecological change, patterns of geographic range shifts, and changes in other threats to biodiversity.

Strengthening of capacities and processes for protected area management planning and implementation. Two basic principles should be embraced in protected area legislation and strongly enforced at national and provincial levels. First, the principle of “one area one plan” is critical so that the protected area management plan has authority over and is respected by all sectors and their development plans. Second, the principle of “one area one authority” is also important, which ensures that the protected area managers are the recognized authority within their tenured territory and that they have a mandate respected across government.

Building functional connectivity across the landscape. Maintaining connectivity involves establishing linkages between habitats to enable the movement of plants and animals, and to provide the supports that allow them to function. With climate changes, corridors of natural systems should be available for organisms to move and relocate from one protected area to another. Creating corridors for adaptation is one of the most difficult but most important strategies facing the LMB countries in the decades to come. Options for delivering corridors include rehabilitation of degraded areas, enrichment planting and breeding programs for some threatened or critical species.

Building ecosystem resilience. There are clear links between ecosystem health and climate change: higher levels of biodiversity provide more options that enable existing processes to adapt

and, therefore, offer greater climate change resilience. Actions that maintain or expand biodiversity are part of the foundation adaptation strategy for livelihood sectors. All are management strategies which address the adaptation deficit, i.e., they are conservation priorities in their own right, which have become even more important for their role in responding to climate change. These strategies involve understanding the biological requirements of 'keystone' species that play a significant role in maintaining important ecological processes while at the same time mitigating threats from invasive species and pests.

Implement species conservation programs for some species important to rural livelihoods, such as wild orchids, floating rice, and wild honey bees including registration on national protected species lists, with linked regulations and penalties for illegal collection and trade. Seed banks may be required to provide seeds for future rehabilitation of species where they have become degraded, or for when climate change makes significant impacts on range. [7.4.6]

Effective plans, management, and enforcement for harvesting of NTFPs. Examples of these strategies include non-destructive, sustainable collection and harvesting guidelines, agreement of limits for collection each year, and setting aside areas of forest for regeneration. NTFP processing techniques that reduce wastage and improve quality so that smaller quantities of the plant need to be collected for higher value are an effective incentive for local community involvement in adaptation. [7.4.5]

8.5 HEALTH AND RURAL INFRASTRUCTURE

Health

Adaptation strategies in the rural health sector should seek to reduce exposure to extreme events such as drought, heat waves, and floods as well as reduce sensitivity to them and increase capacity to recover. Four main focus areas for adaptation relate to the key vulnerabilities in the health sector: water-borne and vector-borne disease, and maternal and child health.

Addressing the adaptation deficit in the health sector. Particularly important to maternal and child health is the continuing lack of adequate health service access for many poor households and/or remote communities. Addressing this lack of personnel, equipment, and affordability is the starting point for adaptation in the health sector. The significant adaptation deficit in health services (e.g., health personnel training, immunization programs, institutional capacity programs, and funding) should be supported and extended by governments and donors alike. Health underlies the effectiveness of other measures to build community resilience to climate change.

Warning, prevention, and response systems for vector-borne and water-borne disease. There are three key factors that limit the spread of water-borne and vector-borne disease associated with extreme rainfall and flood events: prior knowledge (e.g., weather forecasts) that enables communities and government agencies to take precautionary measures that reduce risk (e.g., storing water and food, establishing shelter locations, and stockpiling medicines); education and community awareness that reduce damage from the hazard (e.g., education regarding water-borne disease and use of safer water sources); and efficient deployment of response systems to identify and address the spread of disease (e.g., site monitoring in affected areas and operation of refuges and emergency health centers). Strengthening the capacity of local government and non-government

agencies to prepare for and respond to regular flooding events will be an important step to adapting to more extreme events in the future.

Considering climate change in the design, technology, and location of health-related infrastructure. A concern in a weather-related health emergency is the exposure of and damage to water supply and sanitation infrastructure, health facilities, and access roads. Failures in this supporting infrastructure have the capacity to magnify and extend the duration of health emergencies, particularly the spread of disease. The location and design of local health centers and associated access roads should account for projected flooding and other extreme events.

Protection of ecosystem services that support community health. Underlying all public health issues in poor and rural areas is the maxim—natural system health equates to human health. NTFPs (for food, medicines, and commercial use), fisheries (particularly for protein), and clean freshwater supply are central to rural health and livelihoods. During emergency situations, such as crop failures and flood events, access to those services or stores of them is essential to food security and health. Rural ecosystem services are under threat from development throughout the region and their degradation increases community vulnerability and reduces adaptive capacity. [7.8.1]

Rural Infrastructure

Adaptation strategies in the rural infrastructure sector aim to strengthen the capacity to withstand extreme events and to quickly recover from them. Two key components of the infrastructure sector were identified as particularly vulnerable to climate change: roads and water supply infrastructure (i.e., for irrigation and drinking water). High-priority adaptation strategies for each of the five livelihood zones include: (i) community-based bioengineering projects in riparian areas, (ii) revision of rural infrastructure design standards, and (iii) revision of infrastructure plans, particularly the location of key assets such as roads, community buildings, and dwellings to reflect projected climate changes. [7.8.2]

The adaptation measures that follow for each livelihood zone address both the priorities for health and for infrastructure.

Delta: Natural coastal protection from inundation needs to be strengthened through community-based rehabilitation and protection programs, particularly for mangrove ecosystems. Degradation of mangrove ecosystems is a major factor in the exposure of coastal zone livelihoods to climate change.

Low-elevation areas should be protected from inundation and from the more intense flooding identified in climate change projections. Some current responses to inundation threats may in the longer term constitute maladaptation. The construction of sea dykes using structural engineering methods, for example, may prevent a natural recession of mangroves and exacerbate coastal erosion in the longer term. Traditional and bioengineering approaches may be cheaper and more resilient.

The costs involved in protection may eventually outweigh the benefits. IPCC (2007) points out that a staged and managed retreat of infrastructure and communities from the coast may, in some cases, be a more efficient allocation of resources. This is an important consideration and any decision

would have to be informed by scientific evidence, as well as socio-economic analysis of the trade-offs involved.

Improvements to canal networks including an emphasis on maintenance are required to cope with more intense flood events, particularly to ensure effective drainage of fields and waterways. [7.8.3]

Forested uplands: The conservation of forests is one of the foundation adaptation strategies affecting all livelihood sectors. Stronger land tenure systems are needed that sharply define ownership rights, responsibilities, and authorities. That priority applies especially to protected areas and the overall authority and status of its managers within the government system. Also it relates to providing communities with incentives to protect forests for food, medicines, construction materials and other services such as reducing erosion and soil loss, and reducing the risk of flash flooding and landslides in upland areas.

A fresh approach to the planning, construction, and maintenance of rural road networks is needed, in particular those servicing remote communities. Required innovations include greater community input and management responsibilities through organizations such as road user-groups, emphasis on bioengineering approaches to stabilizing slope and draining areas using local materials and plants which can bring added benefits to communities, and more useful and precise information to communities on the projected changes in flow, flash floods, and landslide potential. [7.8.4]

Intensively-used uplands: Intensively-used uplands require increased investment in community-managed reforestation and bioengineering initiatives in riparian and sloping areas, especially those linked to strategic rural infrastructure. Such programs could include payments for ecosystem services and community-based incentive schemes to strengthen stability on erosion-prone slopes along roads, irrigation facilities, and rivers.

Climate-sensitive design, siting, and maintenance of major infrastructure are necessary for areas highly vulnerable to extreme events. The capacity for governments to meet demand for additional infrastructure is likely to rise over time and any new investments should incorporate future climate change in project design and supporting components such as drainage systems. A primary consideration is the location or relocation of strategic infrastructure, such as health facilities and major road links, away from vulnerable areas. [7.8.5]

Lowland plains and plateaus: Improved access to safe water and sanitation is essential in lowlands, such as covered groundwater bores, rainwater tanks, water treatment technology, and covered latrines.

Heat-respite community centers are needed for vulnerable groups: the young, elderly, and sick. Air-conditioned respite centers should be considered in areas where temperature rise is projected to be extreme and population density is sufficiently high. An option in off-grid areas would be the installation of air-conditioners powered by rooftop solar panels.

Watershed protection will reduce the threat posed by flooding; community-managed bioengineering projects using local resources offer a sustainable pathway to strengthening already degraded riparian areas. [7.8.6]

Floodplain: Climate change-sensitive bridge and culvert construction, road elevation and design, and other civil engineering programs are required to secure road access to flood-prone communities. National design standards and procedures should give increased flexibility to local engineers and communities to design and adapt measures that are tailored to local needs and conditions. Guidance rather than strictly applied standards and expert support in quality control should encourage softer-mixed measures where structural engineering is complemented or replaced by more innovative and durable methods and materials.

Institutional capacity for provision of forecasting, early warning systems, and effective response for flooding as well as water-borne and vector-borne disease should be strengthened. The extension of mobile phone networks to remote areas may be a critical component of this strategy. [7.8.6]

8.6 INTEGRATED ADAPTATION

The importance of integrated adaptation planning and implementation is a key theme of this study. The directions and mechanisms for achieving integration should be outlined within *integrating policies at the national level*—i.e., in strategies, plans, and laws—which are subsequently reflected within provincial policy frameworks—for example, requiring integrated river basin plans to be prepared.

There are *integrating structures* which should be established along with the incentives for making them work. For example, an intersectoral committee on climate change adaptation or integrated planning for a river basin should be supported with staff duty statements and performance evaluation systems that give value and reward to lateral working relations and sharing.

Then there are *integrating procedures and tools*—the most widely used and accepted being the environmental impact assessment (EIA). The EIA system in all LMB countries requires ongoing strengthening—its integrating force remains poorly developed. Strategic environmental assessment (SEA) has been promoted and important SEAs conducted but they need to become a strong integrating force for systematically applied adaptation in the region.

One critical tool and process for integration is *spatial planning*. It is one of the three key points which emerge from this adaptation chapter when the imperative for integrated adaptation is considered.

Spatial planning is the foundation for integrated adaptation. Adaptation is best planned and achieved on an ‘area-wide’ basis which facilitates understanding of potentials for integration across sectors and levels of government. The opportunities for adaptation and integration become clearer when considered for specific geographic areas—e.g., catchments, districts, or protected areas. Even adaptation planning for organizations such as line ministries whose activities are expressed locally should consider how their mandates and responses to climate change play out on the ground. In a spatial planning approach to adaptation it is possible to define zones and linked climate change safeguards/guidance as the backdrop for adaptation and development.

Area-wide adaptation plans are a first step in providing the impetus for different sectors to integrate climate change into their own development plans and to consider the linkages to other sectors in devising a response to projected impacts.

Provide structure and processes for recognizing and resolving conflicts and trade-offs in the adaptation planning process. Critical trade-offs between sectors and areas become evident when taking an integrated approach to adaptation; they are less obvious when focusing on only one sector. For example, a potential adaptation option identified for areas where rainfed rice is subject to more extreme flooding and increased dry season rainfall is a shift to a dry season irrigated crop. However, the irrigation water may be coming from wetlands that support aquatic NTFPs and livestock. Diverting water for irrigation in the dry season may undermine these other components of community livelihoods. Structures and tools are needed for recognizing and resolving conflicts and trade-offs of this kind in the adaptation planning process.

Seek complementary approaches across sectors. A prominent example of a cross-sector adaptation strategy is the conservation of natural forest resources. The complementary adaptation benefits are numerous: flood protection for agriculture, habitat preservation for fisheries, protection of NTFPs, supply of forage for livestock, and reliable water supply. Complementary approaches are more efficient in the use of resources, are likely to be mutually reinforcing and to generate sustainable adaptation, and are likely to be supported by a wider range of stakeholders. Only through an integrated, area-wide planning process will the full scope of such complementary adaptation opportunities be realized. [7.9]

8.7 THE UNDERLYING IMPORTANCE OF HEALTHY NATURAL SYSTEMS

Despite the great diversity of livelihoods and ecosystems in the LMB, the sectors of agriculture, livestock, fisheries, NTFPs, and health and rural infrastructure have one thing in common: their resilience to climate change is dependent on healthy, functioning natural ecosystems. [2.4.1]

This study refers to *the foundation adaptation strategy* for the LMB—i.e., the set of measures that underlie all other responses to climate change. That foundation strategy can be summarized as *bringing diversity and complexity back into the agricultural landscape*. Increased diversity in farming ecosystems means a broader range of species and a deeper genetic pool. Increased complexity means more mutually beneficial relationships and synergies between those components. These two foundation characteristics of a resilient farming ecosystem mean greater stability when confronted by climate change shocks. They also create more opportunities to recover by providing a broader range of adaptation options. Promoting diversity and complexity in farming ecosystems will require compromises on the nature, pace, and scale of development across many sectors. It means taking a more cautious approach which avoids and compensates for degrading natural systems. Most important it means all LMB governments need to give priority to building natural capital as a way of ensuring long-term consistency in farm productivity and incomes in the face of climate change.



Linking science and local knowledge to adaptation action

"Hae Ko Village, Chiang Rai, Thailand" by Josephine Green/IUCN



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