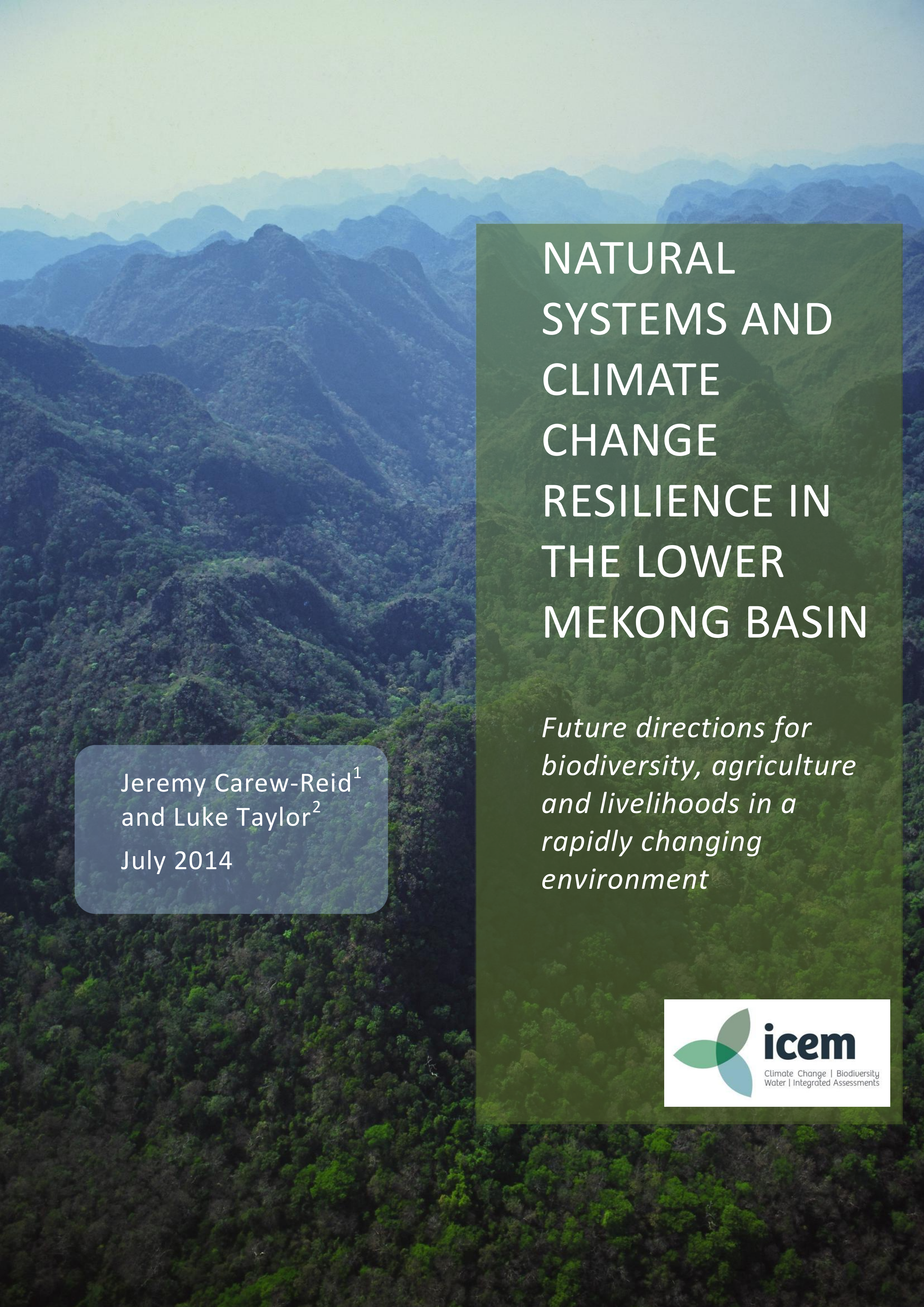

NATURAL SYSTEMS AND CLIMATE CHANGE RESILIENCE IN THE LOWER MEKONG BASIN

Future directions for biodiversity, agriculture and livelihoods in a rapidly changing environment

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July 2014

icem
Climate Change | Biodiversity
Water | Integrated Assessments

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Produced by ICEM Asia

Citation Carew-Reid, J. and Taylor, L. 2014, *Natural Systems and Climate Change Resilience in the Lower Mekong Basin: Future directions for biodiversity, agriculture and livelihoods in a rapidly changing environment*. ICEM - International Centre for Environmental Management, Hanoi, Vietnam – www.icem.com.au

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Image Cover image: Phou Hin Poun National Biodiversity Conservation Area, Lao PDR (source: Stuart Chape 2002)

Inside page: Mekong River, Lao PDR (source: Stuart Chape 2002)

Acknowledgements ICEM would like to acknowledge the projects and partners that contributed to this paper: Mekong Adaptation and Resilience to Climate Change (Mekong ARCC) project: *Climate Change Impact and Adaptation Study*. Prepared for the United States Agency for International Development (USAID) by ICEM in partnership with DAI - www.mekongarcc.net; Basin-Wide Climate Change Impact and Vulnerability Assessment for Wetlands of the Lower Mekong Basin for Adaptation Planning project: *Synthesis paper on adaptation of Mekong wetlands to climate change*. Prepared for the Mekong River Commission (MRC) by ICEM in partnership with IUCN, World Fish and SEA Start – www.icem.com.au/portfolio-items/wetlands-synthesis

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1 INTRODUCTION

The Lower Mekong Basin (LMB) is experiencing a total transformation of its social, economic and natural environment. Exceptional advances have been made in reducing poverty, in expanding infrastructure networks, in trade and commerce and in improving the quality of life in many of the region's diverse communities and cultures. That progress has come at a substantial cost with long-term implications for its sustainability. Much development is proceeding without adequate knowledge of its impacts. The information available to decision-makers has been insufficient to avoid and mitigate unplanned and unwanted social and ecological effects.

Some 80% of families in the region are small scale farmers dependent on healthy natural systems for their livelihoods and subsistence. Throughout the LMB average farm size is 2.8ha with about 70% ranging in area from 1.5 to 3ha.[1] Small scale farmers 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. Agricultural crops are supplemented by wild fish, forest products and other natural resources (ICEM 2014a). LMB natural systems contribute to the food security and well being of all people of the region by supporting agriculture production and in the provision of ecosystem services, and to people worldwide through legal trade in wild products, tourism, science and intrinsic values. Also, they provide resilience and options for adaptation to climate change. In a degraded state, resilience of Mekong communities is reduced and vulnerability[2] to climate change increases.

Here, the concept of farming ecosystems recognises that farms and their surrounding areas are integrated systems in which all the habitats, species and their genetics interact with each other and the physical environment, and contribute to farm productivity. In the Mekong region, farming ecosystems consist of human modified and natural environments which both provide services and products essential to farming livelihoods and subsistence. Understanding and carefully managing that relationship is essential to the sustainability of Mekong farms, to continued poverty reduction and to building adaptive capacity to climate change.

Natural systems refer to areas that are in a relatively natural state. They may be impacted or degraded but still maintain a high level of integrity and functionality in supporting biodiversity and ecosystem services. The focus here is on protected areas (PAs) and on biodiversity beyond them including wetlands, captures fisheries, Non-Timber Forest Products (NTFPs) and Crop Wild Relatives (CWRs) – all critical to the maintenance and productivity of the region's farming ecosystems.

Natural systems in the LMB are degrading and changing at a rate and scale never before experienced. For example, over the past 15 years, for the first time since human habitation in the region, the hydrodynamics and geomorphology of the Mekong River and its tributaries are being fundamentally and permanently altered by development – in this case mainly by full channel dams for hydropower (ICEM 2010). The Mekong forest 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 10-20% of original cover will remain by 2030 (WWF 2013). Large connected areas of "core" forest – defined as areas of at least 3.2km sq of uninterrupted forest – have declined from over 70% in 1973 to about 20% in 2009 with negative implications for the species they can sustain (WWF 2013).[3] 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.[4]

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[1] For example, in Lao PDR, 36.4% of farm holdings are medium sized (1.0 – 2.0 ha), 27.4% are large (over 2 ha), 23.8% are average (0.5 – 1.0 ha) and only 12.5% are "small" (less than 0.5 ha).

[2] Climate change vulnerability refers to the degree to which an ecological system or species is likely to experience harm as the result of changes in climate. Vulnerability is a function of (ICEM 2014):

- exposure to climate change: the magnitude, intensity and duration of the climate changes experienced;
- the sensitivity of the species, community or asset to these changes; and
- the adaptive capacity of the system to adapt to these changes.

[3] WWF, 2013, Ecosystems in the Greater Mekong: past trends, current status, possible futures

[4] UNEP (United Nations Environment Programme) and TEI (Thailand Environment Institute). 2007. *Greater Mekong environment outlook 2007*. Bangkok

The links between healthy ecosystems, economic development and human wellbeing are not understood, appropriately valued or reflected in adequate investment in conservation actions. Many of the changes taking place are irreversible and the costs high. In those situations where the benefits and costs of development are not entirely known a precautionary approach is needed (MEA 2005).

Altered natural systems can recover or be rehabilitated. They have an inherent capacity for renewal. Yet, as an added threat in the region, climate change could push already degraded natural systems beyond their capacity to adapt. Changes in precipitation, temperature and sea level rise with associated water availability, flooding, drought and storm surge impacts are likely. Natural systems, which have adapted to climatic changes in the past need to be given the best possible chance of maintaining their overall productivity and functionality in the face of future changes of increased severity and frequency in extremes. Ecosystem services including disaster reduction, water, food and public health benefits to local communities will become even more important as the incidence of extreme events associated with climate change increases (Dudley et al. 2010). Climate change impacts on agricultural and other economic sectors may require adaptation options found within or provided by natural systems.

Reducing the existing threats to natural systems, restoring their integrity and implementing any additional climate change adaptation measures are important for the benefits they provide now and for storing and maintaining resources and services which will be needed as the region's climatic regime alters.

2 NATURAL SYSTEMS AND RESILIENCE

There is no hard distinction between natural and human-modified systems. Rather, there is a continuum of degradation and alteration of system characteristics and function (Figure 1).

Typically, with increasing modification to natural systems, *resilience*[5] decreases and there is *simplification* in terms of biodiversity[6] and interactions between components and functions. When natural or traditional rural ecosystems are modified through development, species composition and the structure of ecosystems tend to become simplified, contributing to reduced adaptability to future change (Hashimoto 2001). Ecosystems retaining their original complexity are more resilient, with species and habitat diversity offering more flexibility and buffers to change (Turner et al 2013). For example, removing just one of many species of fish from a river can worsen freshwater quality (Taylor et al 2006). Other relationships are more complex - for example, eliminating biodiversity from landscapes contributes to Lyme disease and hantavirus pulmonary syndrome can become epidemic, opening pathways for human infection on a large scale (Keesing et al 2010).

Also, ecosystem simplification leads to reduced cycling of inputs and outputs (of nutrients for example) from the more cyclical operation of less altered systems. An industrial agricultural system (e.g. mono-culture cropping) is a highly altered system, much simplified (i.e. less biodiversity and fewer ecosystem functions) and more linear (large external inputs required to maintain outputs) than a subsistence or agro-ecological based system having higher biodiversity and more functions with greater cycling of nutrients and internal self-regulation.

In general, as natural systems become increasingly altered, their vulnerability to climate related or other environmental shocks increases as resilience decreases and significant human intervention and investment is required to maintain or rehabilitate functionality. Conversely, systems with low alteration tend to be more resilient and require less intervention and investment to maintain functionality.

Overall - most responses of highly altered systems to climate change will rely on technology or systems interventions and will involve increasing costs as changes become more extreme. The benefits or options provided by natural systems may be free or considerably more cost effective.

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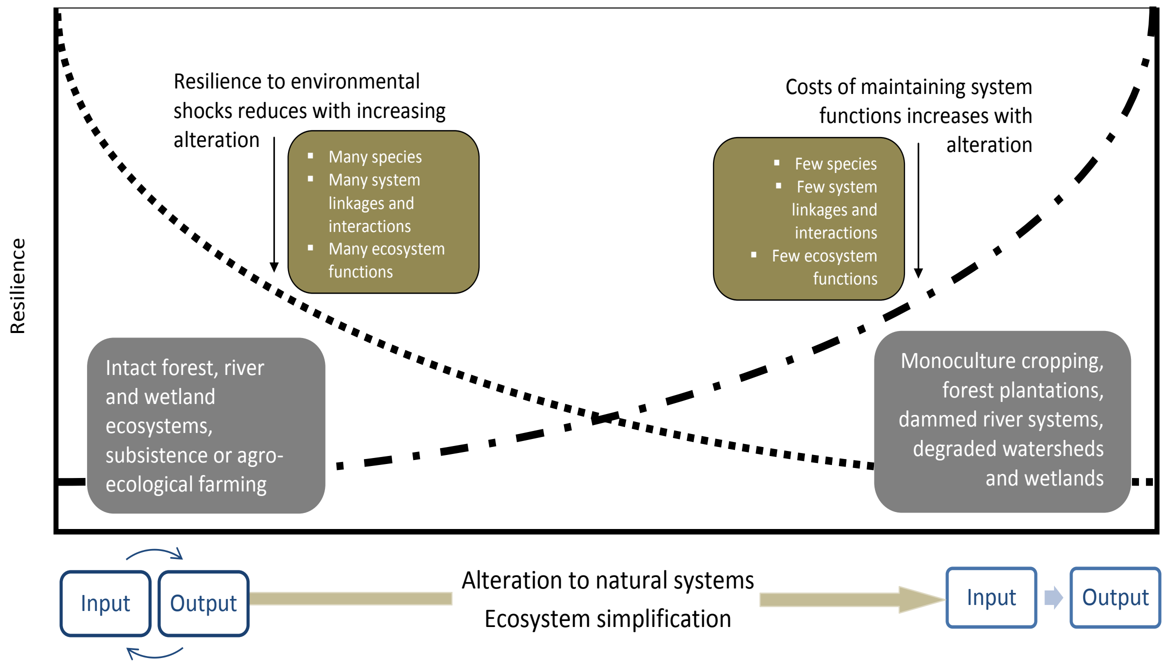
[5] Resilience is a stability property of ecosystems that reflects the capacity of a system to absorb shocks (Perrings 1995), or the rate at which a system variable returns to the reference state after perturbation (Schlapfer et al 2002).

[6] The genetic, species and habitat diversity of biota including microorganisms, plants and animals.

Figure 1: Relationships between alteration of natural systems, resilience and maintenance cost



In some cases the productivity of a particular output or service from a natural system is increased with alteration, for example, when species competition is reduced allowing one to thrive. However usually this is unsustainable or detrimental for other important functions or for the system as a whole potentially leading to collapse.[7] There is a need to reach a balance that maintains broader productivity and benefits as well as resilience over the long term.

3 NATURAL SYSTEMS OF THE LMB – IMPORTANCE, TRENDS, AND EXISTING THREATS

The biodiversity of the Mekong River Basin is of exceptional significance for international conservation and to Mekong country economies and local livelihoods. The region has some 20,000 plant species, 430 mammals, 1,200 bird species, 800 reptile and amphibian species and 850 fish species (ICEM 2013a). Between 1997 and 2007 at least 1068 new species were discovered for science.[8]

The immense species biodiversity is supported by a diversity in terrestrial and aquatic habitats which can be combined into eight ecozones - high, mid and low elevation forests; upper, mid and lower floodplains and wetlands; Tonle Sap swamp forests and the Mekong Delta (Figure 2) (ICEM 2013b). The Mekong river system itself connects them all. Understanding some of the trends and existing threats to natural systems and their significance to LMB livelihoods is a necessary foundation for assessing the additional impacts of climate change.

[7] When humans modify an ecosystem to improve a service it provides, this normally results in changes to other ecosystem services. For example, actions to increase food production can lead to reduced water availability for other uses. As a result of such trade-offs, many services can be degraded, for instance fisheries, water supply, and protection against natural hazards. In the long term, the value of services lost may greatly exceed the short-term economic benefits that are gained from transforming ecosystems (MEA 2005).

[8] http://m.wwf.org.au/?5821/Extraordinary-new-species-discoveries-in-the-Greater-Mekong

3.1 FORESTS

Over the past 50 years, forest cover has changed dramatically in all the countries of the region driven by shifting cultivation, legal and illegal logging, conversion to agriculture and forest plantations, and infrastructure development (ICEM 2013d). Few stands of primary forest remain and the degradation, fragmentation, and conversion of secondary forest to alternate land uses and monoculture forest stands across the region is widespread (Stibig et al 2007; WWF 2013).

In Laos in 1940s natural forest cover was over 70% reduced to 41.5% by 2002[9] and 40.3% by 2013. The national targets for agricultural land expect to see an increase from 1.2 million ha in 2002 to over 2 million ha by 2020 potentially leading to further forest clearing, although the government aims to increase forest cover to 70% by 2020.

Cambodia's forests are also under intense pressure and about 55% of forest area (including 45% of forests in PAs) is degraded (EU 2012). In 1973 approximately 72 percent of Cambodia was covered by forest. More recent images suggest that today's forest cover is closer to 46 percent, inclusive of tree plantations.[10] Since the year 2000, Cambodia lost more than 7 percent of its forest cover, making it the fifth fastest rate in the world.[11]

In 1961, forest covered over 53% of Thailand. Since then 11.5 million ha of forest has been lost, about 256,000 ha/year with 31% remaining in 2009 (ICEM 3013d).

In the Mekong Delta in Vietnam, some estimates range from 25% to 40% of original forest cover[12] now reduced to 5%. Today the landscape has been transformed into a man-made agricultural landscape. The national plan to 2020 is to develop the Mekong Delta into a focal commercial agriculture and aquaculture production area with a high economic growth rate. The targets to 2020 are to maintain 1.8 million hectares of rice, 0.5 million hectares of aquaculture, and to increase the forest cover to 9%.[13]

3.2 PROTECTED AREAS

Protected areas now represent the last vestiges of the original plant and animal assemblages of the region. They have become areas of last resort for many species and habitats. Protected areas are a form of conservation management tenure which aims to protect specific natural features, species and habitats in their natural state with their benefits extending far beyond their physical boundaries.

In the Mekong basin alone Lao PDR, Thailand, Cambodia and Vietnam have established 115 protected areas covering almost 10,000km^2 or 16% of the basin and most of its remaining biodiversity rich forests and intact upper watersheds (Figure 2) (ICEM 2013a). Nationally, the number is far greater. For example, Thailand has 141 protected areas of various categories.

By world standards, the percentage of national area set aside for PAs is exceptional – at least in Cambodia, Laos and Thailand where it is more than 20% on average. In 2003 about half of the remaining forest estate in all four countries was to be found within PAs. In the past decade, that figure has significantly increased – likely closer to 70% due to continuing losses in forest cover and quality outside PAs, especially if quality and biodiversity importance is considered, (ICEM 2013a).

Other important trends have been shaping the PA systems. During the 1990's, the number of PAs increased rapidly as did the total PA coverage as a percentage of national land area. In the decade to 2010, Cambodia and Thailand continued to add to their nationally established PAs while in Laos and Vietnam the nationally designated area remained the same.

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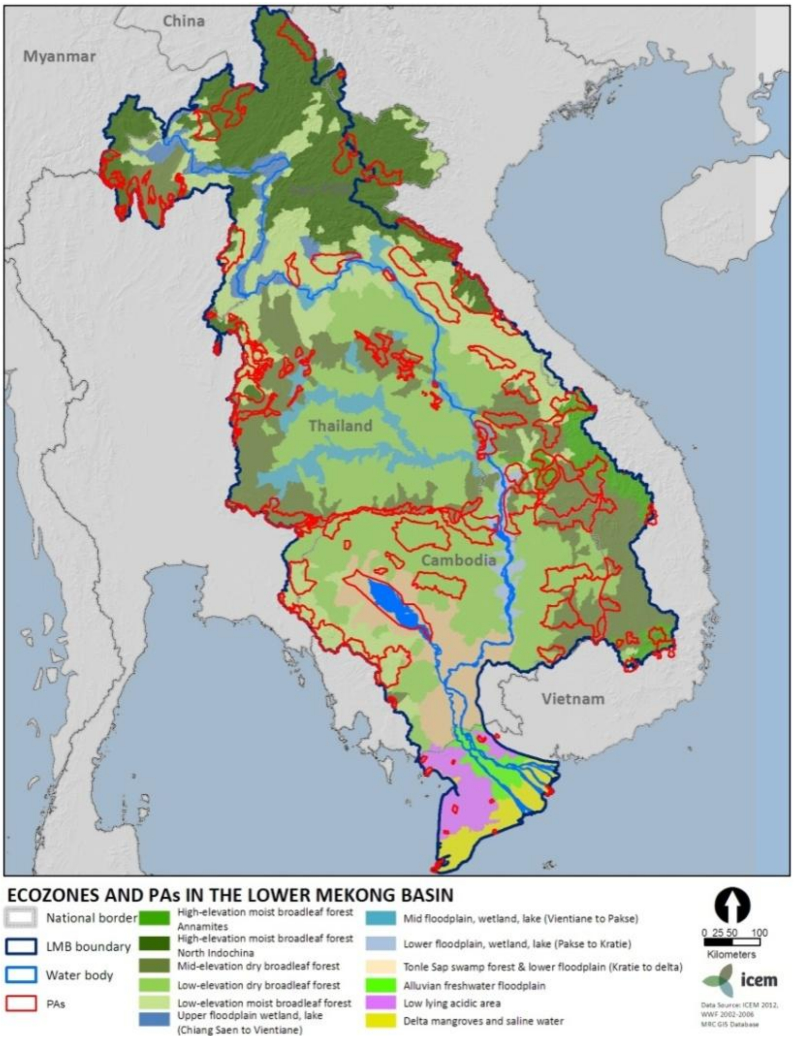
[9] Chanhsamone Phongoudome, Bounphom Mounda, Khamphay Manivong, Silavanh Sawathvong, Saykham Bouthavong and Boualy Phamuang (2009) *Report On The National Program Assessment on Forest of Lao PDR.*
[10] http://www.opendevelopmentcambodia.net/briefings/forest-cover/
[11] http://www.forestcarbonasia.org/in-the-media/loss-forest-cambodia-among-worst-world/
[12] Pamela McElwee and Micheal Horowitz (1999). prepared for the Mekong River Basin Research and Capacity Building Initiative, Oxfam America SEA 15 197-99 by the Institute for Development Anthropology 1999.
[13] Decision of the Prime Minister 939/QD-TTg dated on July 19, 2012 on approving the master plan for socio-economic development of the Mekong Delta to 2020.

Figure 2: Protected areas and ecozones in the Lower Mekong Basin



The decade saw significant increases in the number and coverage of locally established and managed PAs in Cambodia, Lao PDR and Thailand. For example, the growth of local PAs in Cambodia has been remarkable – by 2010 more than 980 were in place. Some 60% of those were specially designated areas within existing nationally established PAs but 40% are in new areas representing a significant increase in the PA estate, particularly important given their critical importance to local livelihoods.

A very significant issue is that around 90% of the LMB's protected areas have communities living within them – and most are experiencing growing populations. More than 25% of the area within LMB PAs is used for agriculture, 30% for grazing, 30% for fisheries and 90% for hunting, gathering and extraction (ICEM 2013a). Also, PAs in all countries except Thailand are open for major infrastructure development such as hydropower schemes, roads, mining, plantations and tourism facilities.

All LMB protected areas and linked natural areas of forest and wetlands are an essential part of healthy productive farming ecosystems – increasing in importance as populations grow and as access to arable land diminishes. There is a direct correlation between population density and the intensity of use of protected areas. Most LMB protected areas tend to fall into the least populated and less accessible locations – although this is changing with increasing migration towards regions of biodiversity wealth. 80% of protected areas are situated in regions of medium to high poverty incidence and there is an increasing dependence of poor on PAs as a food security safety net.

Environmental degradation and habitat fragmentation is common within PAs of the LMB. Despite conservation efforts, some habitats have become seriously degraded, invasive species are now common in many areas, and the populations of many large flagship species have continued to decline (i.e. Nekaris et al 2008; Lynam 2010). With over 60 million people living in the region (Sunderland et al 2012), and persistent poverty within communities living in and around natural areas (Sunderlin 2006), PAs are exposed to escalating threats particularly population growth, infrastructure development, land concessions, wildlife trade, agriculture expansion, unsustainable logging and poorly managed tourism.

3.3 WETLANDS AND CAPTURE FISHERIES

3.3.1 The Mekong River

In terms of productivity and diversity, the Mekong River is one of the richest river systems on Earth, particularly for migratory fish species (ICEM 2013b and e). It's exceptional productivity and basin-wide fish migrations are driven by its connectivity and the natural variability of flows (Coates et al 2003). For example, the productive Mekong Delta is sustained by inflowing sediments and nutrients[14] and generates more than 50 per cent of Vietnam's staple food crop production and marine fisheries and aquaculture, worth up to US$2.7 billion annually (ICEM 2010; WWF 2011).

The Mekong's seasonal hydrological cycle has shaped the evolution of its diverse ecosystems and rich animal and plant life. In particular, the transition seasons between flood and dry and the changes in flow during these times have great biological significance including triggering migration in certain species of fish (MRC 2009).

The flood pulse characteristic of the Mekong is very important in supporting the diversity and productivity of its ecosystems – both aquatic and terrestrial. The transfer of organic matter from the terrestrial to the aquatic phase supplies energy to the aquatic food webs, which in turn, increases overall aquatic secondary productivity and results in highly productive ecosystems (Koponen et al 2010). In particular, the productivity of the Tonle Sap lake and floodplain ecosystem in Cambodia is mainly driven by the flood pulse and most of the water involved originates from the Mekong River entering the lake via the Tonle Sap River (Junk et. al. 1989, Lamberts 2001, Sarkkula et. al. 2010, Koponen et al 2010)

The key threat to the Mekong River in delivering the flood-pulse and other functions is the development of hydropower dams. In particular, the delivery of sediments and associated nutrients may be significantly impacted. Many reaches and ecozones of the Mekong and its flood plain would be affected. Modelling by the Mekong River Commission has found that tributary and mainstream dam sediment trapping would decrease sediment input to the Cambodian and Vietnamese Delta by around 50%, and possibly up to 90% as the Lao PDR and Cambodian mainstream dams are implemented. Sediment trapping would reduce bio-available phosphorus input to the Cambodian floodplains and Delta by 10'000 - 18'000 tonnes/year. Tonle Sap's primary productivity would decrease by 50% or more in large areas of the lake. Fisheries, soil fertility and primary productivity in the floodplains would be reduced leading to agricultural and fish capture losses (Koponen et al 2010, ICEM 2010).

Those changes along with periodic flushing of reservoirs will have significant impacts on aquatic, terrestrial and costal ecosystems and organisms (Sarkkula et al 2010, ICEM 2010).

3.3.2 Wetlands

About 42% of the LMB is wetland (seasonal and permanent) and of 254,144 sq km of land classified as wetland, only 55,498 sq km or 22% is natural wetlands. The large majority are man-made or converted wetlands, most of which are associated with agriculture, especially paddy rice fields. Many of the wetlands are seasonally or temporarily inundated – some 85% of flooded forests experience temporary flooding, as do 67% of grasslands and marshes, and 70% of the estuarine and coastal wetlands (ICEM 2012). The MRC's database includes 94 wetland sites of national and international importance for their biodiversity. In 2012, ICEM identified another 8 which need to be added to the list (ICEM 2012). Wetlands are underrepresented in the LMB conservation estate, with only 0 to 6% of the 6 wetland ecozones in the region represented within protected areas (Figure 2). Over 60% of the specific wetland sites listed by MRC fall outside the LMB PA system - with around 50% benefiting from some sort of natural resource or conservation management.

Numerous development impacts place the wetlands of the LMB at risk and they continue to shrink in area and health. Even within PAs the hydrological regimes that are essential to the maintenance of

[14] "…it is highly likely that the annual addition of new sediment to the delta-plain surface has a maintaining or a protective effect on soil fertility and structure, namely by retarding the leaching of nutrients from the existing soil attributable to subaerial weathering, and by preventing excessive compaction of the near-surface soil, which may lead to poor soil aeration and H_2S toxicity in crops" (Hashimoto 2001).

healthy wetlands are impacted by actions occurring outside PA boundaries (Gopal 2013). Expansion of agriculture and hydropower projects places wetlands under increasing pressure. The MRC identified changes in flow, water quality and flooding patterns in the floodplains as major sources of future impacts on the wetland ecosystems of the Mekong Basin (MRC 2010). Environmental impacts that may result include changes in productivity, the provisioning of environmental services and biodiversity conservation, all of which have direct and indirect impacts on local livelihoods (MRC 2010).

3.3.3 Capture Fisheries

The Mekong supports the most productive freshwater fishery in the world – about 2.6 Mt of fish per year in 2000, of which 1.9 million tonnes came from the capture fishery and the rest from aquaculture (ICEM 2014b and 2014e). The people of the Mekong have the highest per capita consumption of fish in the world – up to 50 kg/head/year in some parts of the basin. Most protein requirement for the Basin's population is provided by capture fisheries - therefore it is central to livelihood development and a major area of risk when the Basin's delicate ecosystems are disturbed (ICEM 2014e).

The Mekong fisheries are dominated by small-scale and seasonal fishers operating a wide range of traditional gear types. Women are actively engaged in fisheries throughout the Mekong Basin, particularly in post harvest activities. Many children are also closely involved in fishing and fisheries related activities, mainly for household food security. Despite the seasonal abundance of fish, many of these households remain desperately poor and, having few other livelihood opportunities, a decline in the Mekong capture fishery would have far reaching consequences for their wellbeing.

The fishes of the Mekong can be grouped broadly according to their ecology and migration behaviour (ICEM 2014e). Of the Mekong fish species nearly 200 are migratory "white" fish, some of them travelling long distances from the Tonle Sap or the Delta up the Khone-Phapheng Falls and further up the Mekong in Laos and Thailand.[15] The 'White Fish' group account for around 87% of Mekong fish species and 50% of the total catch. Most White fish species require high water quality conditions in terms of dissolved oxygen and alkalinity and have low temperature tolerance, particularly at maturation and fry stages.

The 'Black Fish' group covers those species with short lateral migrations from the river onto the floodplains and no longitudinal migrations upstream or downstream. They do not leave the floodplains and wetlands, and spend the dry season in pools in the rivers or floodplains. Most Black fish species are able to survive poor water quality conditions, harsh dry season environments and have limited migratory habits.

The fishes of the small streams in the upland area of the Mekong basin inhabit the cool clear waters of upland forests. The upland reaches of the Mekong tributary systems have exceptional endemism with small populations of fish species occupying unique ecological niches often cut off from the wider catchment by full channel obstructions. These small fisheries are very important to upland communities - more so as other hunting options become less available.

Estuarine fish are found in the lower reaches of the river system and include many species tolerant of a wide range of salinities due to the great variation in annual freshwater flows. 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.

In certain parts of the Mekong Basin, exotic fish species, have become established and now form growing feral populations.

At present the Mekong fishery remains in a very productive state and there is no evidence of declines in overall productivity.[16] However, there are clearly serious declines in the stocks of certain species and in certain ecozones, including some of the giant fish species, e.g. *Catlocarpio siamensis.* In

[15] For example *Pangasius Krempfi* migrates many hundreds of kilometers from the South China Sea to Northern Laos where it spawns.

[16] The Cambodian Fisheries Administration's monitoring of the Dai fishery on the Tonle Sap (now in its 8th year) is a useful proxy for the general health of the Mekong system. The study shows a fairly strong correlation between water levels, flood durations and fish yields. Yet, the available data do not support the view that there is a decline in the total production from the fishery.

addition*,* the average size of some species is reducing, suggesting stocks are being over-fished or changes to habitats are affecting life cycles.

The greatest threat to capture fisheries is the alteration of river morphology and hydrology caused by hydropower projects, or the excavation of channels to aid navigation and the extraction of ground and surface waters for irrigation (Kottelat et al 2012). The productivity of the Mekong capture fisheries is inextricably bound up with the seasonal pulse between dry and wet seasons, and the connectivity of the rivers, streams and floodplains (ICEM 2014a). Developments that affect these characteristics will reduce productivity and biodiversity of the fishery, with knock on effects to the millions of people depending on the fishery for their livelihoods.

3.4 NTFPs AND CWRs

3.4.1 Non-Timber Forest Products

NTFPs and Crop Wild Relatives (CWRs) are species which form part of and rely on the continuing health of natural systems. They also represent a clear and measurable link between natural systems and LMB livelihoods as a provisioning ecosystem service and also in ensuring the long term sustainability of agriculture. They are a useful focus for understanding the role, significance and health of natural systems in the LMB.

NTFPs "include all the materials collected from natural or man-made forests and riverine habitats and used to support local livelihoods. These include items such as forest and aquatic vegetables, fruit, traditional medicine products, wild animals and aquatic organisms such as fish, mollusks, insects and crustaceans. While the term NTFP implies non-timber items, it does include wood products for home construction, fuel wood and charcoal and handicraft products."[17]

In the Mekong region, NTFPs are critical for all rural communities of the basin, contributing significant proportions of food and nutrition, especially during seasons of rice shortage, and contributing to the household economy through the sale of high-value products (ICEM 2014a and d). They are essential for food security, medical remedies, fibre and furniture and provide resins and essential oils - the raw materials for pharmaceuticals, fragrances and other chemicals.

NTFPs also make a significant contribution to national and local economies, typically contributing to over 30% of the income of individual LMB farming families and corresponding to 9.2 % of the GDP of Lao PDR in 2009 (ICEM 2014 a and d). Therefore, there is a strong financial incentive for sustainable management of this resource.

The main threat to NTFPs is forest clearing and changes in land use for agriculture and agro-forestry. A forest moderates extremes in temperature and maintains a higher humidity within it than can open fields of crops. Forests provide "refuges" against the extremes of temperature and drought. As that forest cover and integrity is lost – as a result of logging, clearance, and over harvesting for example – then the protection it offers decreases, and NTFP and CWR species will be less able to cope with the stresses of climate change. In the LMB, PAs are the heartland for NTFPs and CWRs – for many species, PAs are the areas of last resort (ICEM 2014 a and d).

Over-exploitation has led to significant reductions in some NTFP species. Overharvesting can be managed if the natural habitat remains, but if the natural habitat disappears; the only option would be cultivation and domestication of the NTFPs with untested and uncertain results for most species.

3.4.2 Crop Wild Relatives

A Crop Wild Relative is a wild plant closely related to a domesticated plant, whose geographic origins can be traced to regions known as Vavilov Centers.[18] It may be a wild ancestor of the domesticated plant, or another closely related taxon. South East Asia includes and lies between the Indo-Burma and

[17] NAFRI, NUoL, SNV (2007) *Non-timber forest products in the Lao PDR. A manual of 100 commercial and traditional products*. The National Agriculture and Forestry Research Institute, Vientiane, Lao PDR. Quoting Mollot et al (2004)

[18] Vavilov Centers are named after Dr. Nikolai Ivanovich Vavilov who first developed the theory of centers of origin of domesticated plants. A Vavilov Center is a region of the world considered to be an original center for the domestication of different plant crops.

Siam-Malaya-Java subcenters and the China center – yet, CWRs in this region are little known and little studied.

The wild relatives of crop plants are an increasingly important resource for improving agricultural production and for maintaining sustainable agro-ecosystems. They do not necessarily have an immediate value as NTFPs, but provide an important source of genetic materials for improving the resilience, productivity and value of existing crops, including the development of resistance to disease and extremes of temperature, flooding and drought. CWRs exist side by side with NTFPs in forests and in small patches of unused land.

The ecological requirements of NTFPs and CWRs are complex. Most species grow in forest or wetland plant assemblages and often depend on symbioses, synergies and interactions with the other flora and fauna in these assemblages; thus the importance of ecosystems as well as complementary species focused climate change vulnerability assessments. Whilst secondary and recovering forests can be very productive sources of NTFPs and CWRs, plantations for rubber and other crops lead to an almost sterile environment for most species. Therefore pressures on land and natural resources have meant that the remaining sources for these natural products are primarily protected areas (ICEM 2014a and d).

4 CLIMATE CHANGE PROJECTIONS AND IMPACTS ON ECOSYSTEMS AND SPECIES

4.1 OVERVIEW

At a global scale, approximately 20 to 30% of plant and animal species are at risk of extinction due to climate change associated temperature increases (Fischlin *et al.* 2007). Although many ecosystems are expected to have some ability to adapt naturally to changes in climate (Gitay *et al.* 2001), limited information is available regarding critical thresholds beyond which ecosystems will be driven into novel states that are poorly understood (Fischlin *et al.* 2007). Loss of species can have knock on affects for ecosystem functioning and services (Hooper *et al.* 2005), and limit options for natural and social adaptation responses.

Climate models for the LMB project continued warming across the region and a range of other changes, including decreased precipitation in the dry season, increased precipitation in the wet season, decreased soil water availability, and an increased frequency and severity of extreme events (ICEM 2014b). Those new conditions will induce fundamental changes in natural systems.

Projections for the LMB to the year 2050 led to the identification of eight hotspot provinces and linked PA clusters experiencing significant changes in temperature, precipitation and flooding. The provinces are: Chiang Rai and Sakon Nakhon in Thailand; Khammoune and Champassak in Laos; Mondulkiri and Kangpong Thom in Cambodia; and Gia Lai and Kien Giang in Vietnam. The five highest ranked provinces and clusters were Chiang Rai, Mondulkiri, Khammouane, Gia Lai, and Kien Giang (Figure 3).

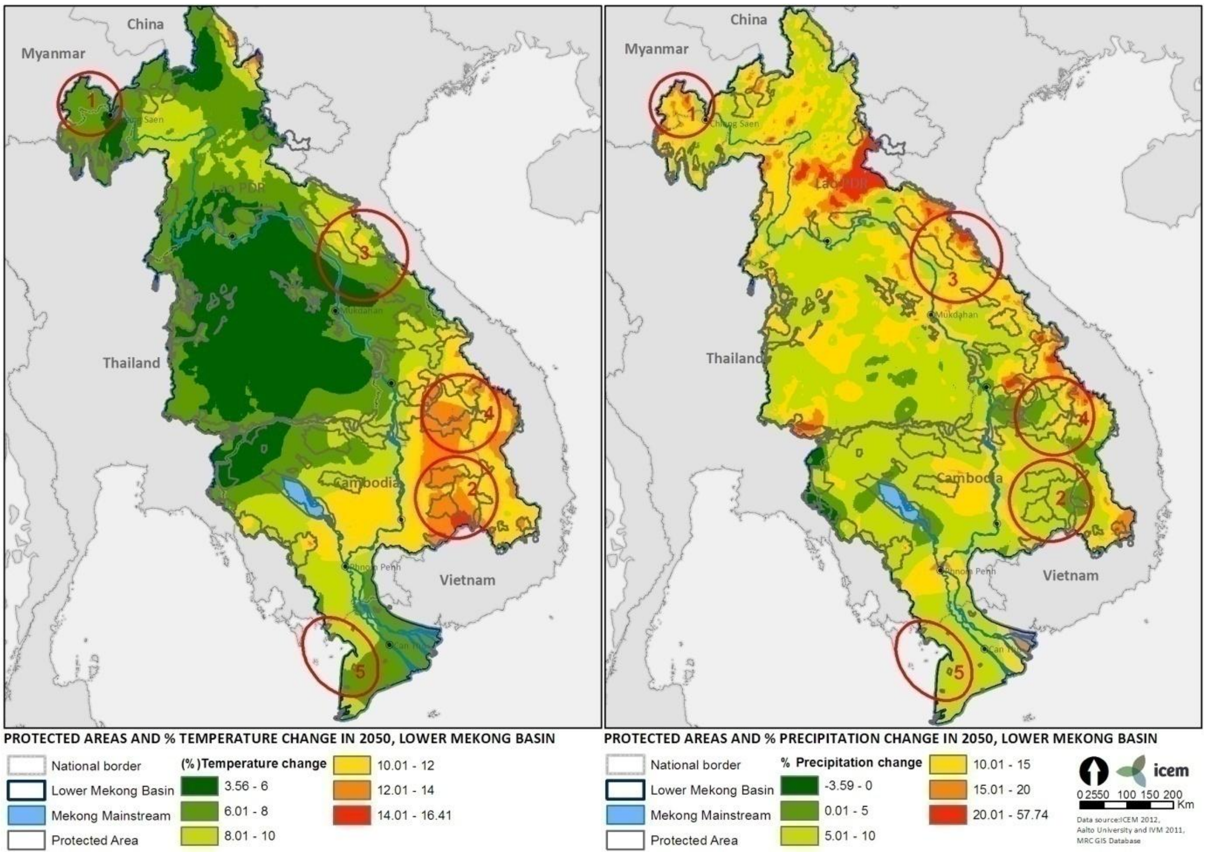
Projected changes in climatic conditions by 2050 vary across the LMB (ICEM 2014c). In summary the changes in seven key indicators are expected:

- **Temperature projections** – Generally, temperature in the LMB is expected to rise significantly over the next four decades. However, the level of warming will vary between PAs from 1 to 5° C. In many cases, temperature projections show that exposure to extreme temperatures will increase in duration and PAs will be exposed to conditions never before encountered.
- **Rainfall projections** – Both the quantity and seasonality of precipitation is projected to change. There is an expected reduction of rainfall in the dry season and, in many areas, an expected increase in the wet season.
- **Water availability projection** – Across most of the PAs overall water availability is predicted to decrease with climate change. This modelled output is mostly a factor of higher temperatures

and subsequent higher rates of evapotranspiration. Reduction in water availability is likely to be most severe in areas that also are projected to experience less rain during the dry season.

- **Drought** – Higher temperatures and decreasing relative humidity in the dry season is a common projection for PAs. As a result, droughts are projected to occur more often and for longer durations.
- **Flooding** – Increases in the intensity and volume of rainfall and runoff in the wet season is projected to increase the frequency of flooding events during this period. For PAs in more mountainous terrain, flash flooding will be a more frequent and destructive force. For PAs in the Mekong Delta and coastal zones large scale flooding is predicted to be more severe in duration and depth due in part to the additional effects of sea level rise and storm surge.
- **Sea level rise projections** – Sea level is projected to rise by approximately 15 cm by 2030 and by approximately 30 cm by 2050. Sea level rise will likely cause changes to flooding patterns, drainage, salinity exposure, coastal erosion, and storm impacts.
- **Storm surge projections** – Projections regarding storm severity are uncertain, however the frequency of very strong storms is expected to increase and individual occurrences of very high rainfall events is expected to increase.

Figure 3: Climate change in the Lower Mekong Basin (red circles show hot spot provinces with their PA cluster)



4.2 PROTECTED AREAS

In general, degraded PAs under significant external pressures are more vulnerable to climate change impacts. PAs and zones within them that are heavily utilised for ecosystem services may enter a negative feedback cycle in which ecosystem services impacted by climate change become more valuable and intensely exploited and steadily more vulnerability to climate change.

In its assessment of PA and natural system vulnerability in the LMB, ICEM selected areas based on the following criteria (ICEM 2014b):

- PAs located within priority climate change 'Hotspot' provinces;
- Highly ranked PAs in terms of % change in climate conditions to 2050;
- PAs within the priority provinces that were representative of one or more ecozones;
- PAs within a province that formed part of a PA cluster or shared a contiguous boundary; and,
- PAs with a substantial provisioning and servicing function for local communities as part of their farming ecosystem.

Natural systems - basin wide conclusions on potential impacts of climate change

- Climate change, in concert with other stresses will lead to losses in productivity of NTFPs and loss of species from the basin and specific areas.
- Similarly, losses in CWR species are likely from the basin
- Ecosystem shifts (transformations will occur throughout the basin resulting in different species mixes and population distributions).
- Some protected areas will degrade to the point of losing their conservation value – others will change to the extent they no longer represent critical habitats

PA clusters were chosen in preference to individual PAs because they represent large areas of each ecozone and allow better demonstration of a range biological adaptation responses and strategies. Also, PA clusters have the potential to offer more secure and stable conditions for biodiversity in the face of climate change and other threats – mainly because of their size and diversity in habitats and bio-geography. All individual and PA cluster vulnerability assessments are available in the ICEM protected areas report (ICEM 2014c). In recognition of the large array of assets within each PA and the variability across all PAs in the LMB, climate change impacts and vulnerabilities were also categorised using an ecosystem services approach.

4.2.1 Provisioning Services

Climate change impacts have negative consequences for a number of key provisioning services and assets of PAs. Provisioning services are most vulnerable in buffer zones, in community use areas and in the peripheries of PAs where NTFPs, suitable agricultural land, and water sources are most heavily used, and where exposure to climatic change would be most pronounced. Services were found to be impacted in a number of ways, including:

Decline in plant and animal productivity - drought in the dry season, increased flooding and soil saturation in the wet season will lead to changes in pollination and flowering, spread and incidence of disease;

Decline and loss of NTFPs - reducing habitats and increased reliance and pressure on NTFPs in areas where agricultural production is impaired by climate change; and,

Decline in water quantity and quality - clean water is a key provisional service of PAs. Increased drought, reduced land cover, and changes in species composition and soil structure may affect the quantity and quality of water entering streams, ponds and lakes. The Trapeangs throughout Mondulkiri Province of Cambodia, for example, are shallow ponds and lakes that will be exposed to droughts of great duration and severity with increased temperatures and reduced rainfall during the dry season. Changes in surface water temperature, sedimentation and flood regimes will impact on water quality and aquatic systems generally.

4.2.2 Regulating Services

Climate change impacts were found to affect many PA regulatory services such as water cleansing, waste breakdown and nutrient recycling, soil erosion, climate (microclimate) control, pest control, and flooding control. Identified vulnerabilities of regulatory services in the PAs included:

Decreased regulation of erosion and sedimentation - an increased occurrence and decreased interception of sediment in water sources due to more extreme dry and wet conditions exposing and then flushing sediment into waterways;

Decreased regulation of flash flooding and landslides - projected increased precipitation in the wet season and increased runoff could lead to degradation of habitats, riverbank erosion, bank collapse, and localized landslides;

Decreased pest control functions - biological control services are expected to decrease in reliability and effectiveness when various ecological linkages are disturbed such as insect co-dependence and pest/predator relationships between insects, birds, amphibians, plants and mammals. Dramatic changes are likely to favour invasive species, displacing native predators, for example, and allowing corresponding native or introduced pests to flourish. In many cases increased ponding and stagnant water is likely in the wet season - thereby increasing breeding habitat for mosquitoes and other disease vectors. Likewise drought conditions favour pests and already have been the cause of increasing damage to crops during drought years; and,

Decreased nutrient recycling functions - drier surface litter from higher temperatures will lead to slower decomposition processes and build up of otherwise recycled products. Losses or decline in certain insect activities may also reduce waste recycling, decomposition processes, and hence, nutrient recycling services.

4.2.3 Habitat or Supporting Services

Climate changes were found to be a cause of ecosystem shifts within PAs reducing the supports for some species to thrive and survive. Identified vulnerabilities of Habitat or Supporting Services in PAs included:

Shifts/changes in habitat - ecosystems are expected to shift or alter under climate change. The "movement" of certain species to higher elevations or latitudes because of changed temperature and rainfall regimes, for example, could change conditions and symbiotic linkages for other species, as well as lead to the appearance of competing species. In summary, key climate change induced ecosystem shifts in LMB PAs include: i) geographic shifts in species ranges due to shifts in regular climate; ii) substantial range losses for individual species; iii) seasonal shifts in life cycle events such as advances in flowering due to changes in temperature, (iv) changes in animal migration patterns, (v) changes in fish migration due to changes in the onset of the flood season; vi) body size changes such as decreased body size due to higher temperatures; vii) community composition changes, for example species adapted to higher temperatures will become more predominant; and viii) genetic changes such as tolerance shifts. Ecological shifts will lead to fundamental changes to the make-up of LMB PAs;

Loss of habitat - human settlement and infrastructure will limit the movement of ecosystems and, in some circumstances, prevent ecosystem shifts altogether causing permanent loss of habitats. Also, increased risk and incidence of fire is likely to reduce habitat and to disrupt support services;

Reduction/degradation in biodiversity - in some PAs, some species are expected to disappear under climate change; others that are better adapted to new rainfall and temperature regimes will replace them. This will change the make-up of ecosystems and create opportunities for more hardy and aggressive native or exotic species, such as bamboo and other grassland species in degraded forests, or exotics in wetlands. Some species may experience a reduction in reproductive cycles and an altered period between flowering and maturing of seeds and propagules; and,

Reduction in species population size - higher levels of stress on PAs from a combination of influences including climate change is expected to lead to an overall loss in diversity and simplification of plant and animal assemblages. The number of species and the populations in some remaining species is expected to reduce. Migratory species would seek other areas more suitable for breeding and nesting. Reduction in top soil moisture would reduce micro flora and fauna suppressing decomposition and nutrient recycling affecting regeneration and plant growth.

4.2.4 Cultural Services

Changes to ecosystems are expected to affect tourism, recreation, mental and physical health, and spiritual experiences associated with PAs, as well as the inspiration for culture, art, and design. Identified vulnerabilities of cultural services in the PAs include:

Declines in tourism - reduced habitat is expected to cause losses in flagship species such as elephant, tiger and other cats – and subsequent losses in tourism. Increased intensity and regularity of flooding and storms may destroy tourist facilities and reduce access to tourist sites;

Damage to infrastructure - flooding, storms, and sea level rise will damage infrastructure and cultural assets in and around the PAs, including roads, bridges, temples, and tourism facilities; and,

Reduced community well being and health - the overall losses in the condition of some PAs will have an impact on human well being, especially traditional communities with strong ties to the affected areas. Diseases may spread more easily in hotter and wetter climates un-moderated by diverse natural systems.

4.3 WETLANDS

A small percentage of wetlands in the region fall within protected areas. For this reason and their distinctive ecosystem characteristics, wetland vulnerability was assessed separately as an important category of natural system and source of livelihoods (ICEM 2012). Climate change threats most significant for wetlands include changes to the magnitude, onset and duration of hydro-meteorological conditions which will alter the functioning of wetlands and their seasonal shift between aquatic and terrestrial environments. Direct climate threats include changes in precipitation, temperature, hydrology and sea levels, which will affect the source, transport and fate of water in the wetland system.

Precipitation - both local and upstream catchment precipitation are important factors in determining the nature and extent of wetland habitat. Mekong Basin rainfall is expected to increase in the wet season throughout the basin, while dry season rainfall will increase in northern and eastern areas and decrease in some parts of the vast Mekong floodplain-Delta and the majority of the Sesan, Srepok, Sekong ("3S") river basins. At the basin level, mean annual precipitation will increase by 100 – 300mm/yr depending on the GCM used (ICEM 2012). The highest increases are predicted in the central and northern Annamites to the east of the basin. This will result in greater variability in the Mekong moisture budget with the highest level of exposure correlated with increasing elevation.

Temperature plays an important role in wetland species productivity as well as surface water availability. There is considerable variability in temperature changes throughout the LMB. The average annual maximum temperature will increase by 2-3^{o}C with greater increases in the southern and eastern regions of the basin, with the largest change in temperature occurring in the 3S catchments including a small area of the Srepok catchment with an increase of over 4^{o}C (ICEM 2012).

The hydrological regime plays a major role in shaping and maintaining wetland systems, through the seasonal input of water and by determining the morphological features of the wetland. Alterations of these regimes will influence biological, biogeochemical, and hydrological functions of wetlands. Projected climate changes pose four key hydrological threats to Mekong wetlands:

(i) Increase in flood magnitude and volume;
(ii) Increase flood duration;
(iii) Shortening of transition seasons; and,
(iv) Increase in dry season water levels.

Based on those threats, of all Mekong wetland types, flooded forests are most exposed to climate change – especially those at higher elevations (ICEM 2012). Riverine, freshwater, mangrove and peat wetlands in the LMB are all moderately exposed to climate change with precipitation threats dominant for riverine and coastal wetlands and temperature dominant for peatlands. Grasslands, scrub and lakes/ponds of the LMB are on average amongst the least exposed wetlands to changes in temperature and rainfall.

Coastlines and deltas are among the most dynamic areas of river basins with complex processes balancing marine encroachment with landmass expansion. Sea level rise will enhance the effectiveness of marine processes shifting the balance and resulting in permanent inundation, and increased erosion over a greater proportion of the deltaic environment and an inland migration of coastal wetland environments where unimpeded. If movement inland is constrained by dykes and other developments, as is the case in most coastal areas of the LMB, then mangroves will become highly vulnerable with large areas of forest lost (ICEM 2012)**.**

4.4 CAPTURE FISHERIES

Capture fisheries in the LMB is buffered against climate change to an extent by an exceptionally large aquatic ecosystems biodiversity (ICEM 2014e). Some species would benefit from changing conditions, possibly maintaining the overall fisheries productivity, while other species will not fare well through direct effects and through losses in habitat - probably leading to an overall loss in biodiversity.[19]

Changes to **habitat temperature** will influence metabolism, growth rate, production, reproduction, (seasonality and efficacy), recruitment and susceptibility to toxins and diseases affecting the natural ranges of some species resulting in changes in biodiversity abundance in some areas.

Changes in **rainfall** patterns are likely to affect fisheries in a number of ways. Erratic rainfall will affect the flood pulse cycle of the Mekong River, affecting the hydrology of the Tonle Sap Great Lake and fish migrations, reproductive success and fish production that result. Shifting rainfall patterns, including longer dry periods could affect the survival of fish through the dry season, particularly in upper Mekong floodplain areas, already under pressure from hydropower development, over fishing and agriculture intensification.

Increased erosion in catchments will affect river floodplain water quality reducing fish reproductive success and productivity. Increased runoff from inland areas could also result in the flooding of coastal lowlands, altering salinities and increasing fluvial deposition. Reduced rainfall during the dry seasons will reduce the capacity of upland streams to hold water for maintaining upland fish stocks. Flash flooding through increased rainfall during the wet season may affect habitats and the reproductive success of some species. Only those species able to handle these new extremes will proliferate.

Increased sea levels are likely to affect coastal fisheries through the migration of coastal mangrove areas northwards. **Storm intensity and frequency** will result in saline inundation of freshwater areas farther inland, resulting in periodic fish kills.

Upland fishes look particularly vulnerable to a wide range of pressures, including climate change. Black fish may be less vulnerable to wetlands and riverine fragmentation due to their limited migratory habits. As a result, this group of fish species may be less affected by climate change. White fish species are more vulnerable to reductions in water quality conditions (in terms of DO and alkalinity) and are more vulnerable to increased temperatures. The effects of climate change on some of these species may be severe. Estuarine species will be vulnerable to certain aspects of climate change, e.g. temperature increases in shallow coastal areas, but less vulnerable to others, such as sea level rise. Exotic species may benefit from the projected climate change conditions, increasing pressure on indigenous fish species.

In summary (ICEM 2014e):

- Upland fish would be most vulnerable to climate change;
- Migratory white fish would also be vulnerable to climate change;
- Black fish would be more ‘climate-proof’ than other fish types; and,
- Invasive species will become more prevalent through climate change.

4.5 NTFPs AND CWRs

An analysis of the potential climate change vulnerabilities of and impacts upon NTFPs and CWRs highlights considerable variation between different plant species and locations within the LMB (ICEM 2014d).

Of all the climate changes considered, 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.

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[19] Assessing the vulnerability to climate change ‘signal’ in the Mekong fisheries is challenged by the ‘noise’ from other factors (ICEM 2014e). The largest single threat to the diversity and productivity of the Mekong fishery is the alteration of river morphology caused by hydropower projects. However, a wide range of other threats exist.

- Physical barriers, (even small-scale) which constrain the migration of fish species
- Overfishing, resulting from increased numbers of fishers and sizes of gears.
- Aggressive fishing methods, e.g. explosives
- Loss of productivity through habitat destruction/change
- Radical changes in land use patterns that change run off patterns from upland areas.
- Establishment of exotic fish populations from aquaculture escapees

For example, wild rice species are highly vulnerable to projected increases in temperature. This CWR is already under threat from genetic erosion – mixing of genes with cultivated rice – and habitat loss with rapidly increasing pressure of land development for agriculture, urbanization, plantations or more general forest clearance. In some areas (such as Mondulkiri and Ratanakiri), climate change would enhance the risks of forest fire through more intensive drying and accumulation of litter**.** If NTFPs and CWRs are not given the space and time to recover between incidents of forest fire they will die out.

Mondulkiri Province in Cambodia stands out as being the most extreme in terms of the climate changes and the species vulnerabilities. Chiang Rai in Northern Thailand stands out as the province where the vulnerability of NTFPs and CWRs to climate change is the least. Gia Lai and Khammouan have an intermediate position. Kien Giang is in a very different situation, and whilst the threat of sea level rise and storms affects the vulnerability of mangroves, the vulnerabilities of aquatic plants and wild rice species remain low. 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**.**

5 FARMING ECOSYSTEMS AND CLIMATE CHANGE

Natural systems are the foundation of agriculture and livelihoods in the LMB through the goods and services they provide and by building climate change resilience through reducing vulnerability to climate shocks. They regulate pests and diseases,[20] maintain soil productivity and improve water quality. They also directly provide significant nutrition, medicinal requirements[21] and income (for example, through NTFPs including capture fisheries), and the long-term adaptability and productivity of agricultural systems and fisheries (for example, through supporting CWRs and wild fish species).

NTFPs lie at the heart of traditional farming systems in the Lower Mekong Basin and even have strong links with more commercial and industrial farming systems. Both NTFPs and CWRs rely on the intact[22]

Agriculture - basin wide conclusions on potential impacts of climate change

- Increase in temperatures will reduce yield
- Increase in temperatures will generate altitude shift
- Increasing rainfall will be beneficial to crops in dryer areas but detrimental to crops in already wet areas
- Increased crop damage will be generated by increasing extreme events (flood, flash floods, storms or dry spells)
- Climate change will increase food security risk in the basin for subsistence and commercial systems

Livestock - basin wide conclusions on potential impacts of climate change

- Nutritional problems will increase for low-input 'local' breed systems reducing value
- Increase in risk of infectious disease affecting overall productivity
- Temperature increases will increase costs of production, in small/medium 'commercial' systems, particular for high performance breeds
- Climate change coupled with increasing grazing of domestic animals in protected areas will increase incidence of disease outbreaks in wild species

[20] There is a growing literature (e.g. Ash and Jenkins 2007) documenting how biodiversity reduces risk of exposure to several types of infectious diseases (such as malaria, Japanese encephalitis and rabies). "Biodiversity at the ecosystem level produces the appropriate balance between predators and prey, hosts, vectors and parasites which allows for appropriate controls and checks for both the spread of 'endemic' infectious disease as well as resistance towards invasive pathogens (from humans, animals or insects)" (Vira *et al* 2013).

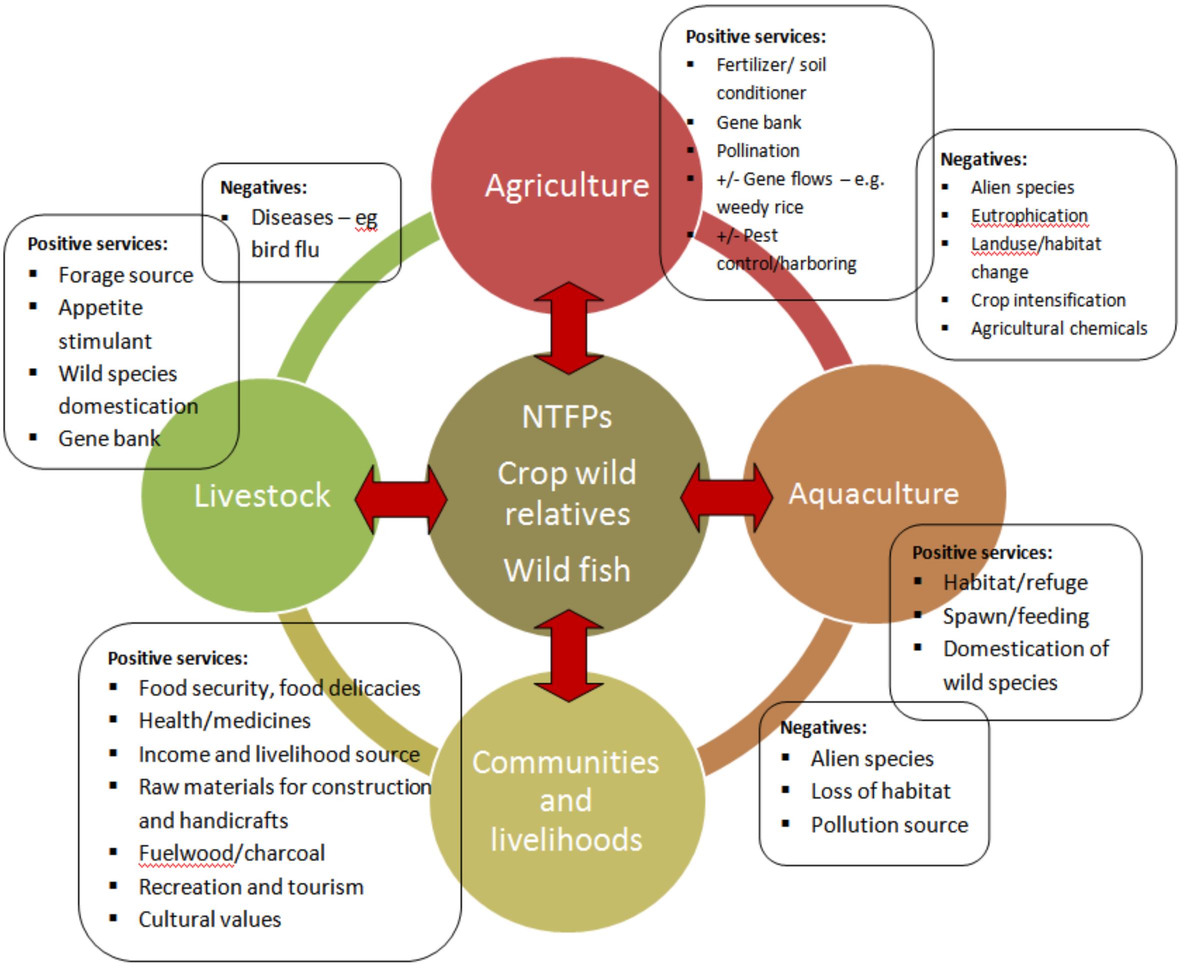
[21] Biodiversity is an important source of traditional medicines (such as herbal medicines) for people in developing countries, especially where they have little (if any at all) access to formal healthcare (Vira *et al* 2013).

[22] In *intact* ecosystems ''the majority of native species are still present in abundances at which they play the same functional roles as they did before extensive human settlement or use, where pollution has not affected nutrient flows to any great degree, and where human density is low'' (Caro *et al*. 2011).

ecosystems of the LMB - forests, the Mekong River and wetlands - in order to survive. Natural system health is a determinant of their diversity and adaptability.

Figure 4 illustrates the linkages between NTFPs, CWRs and wild fish (as part of LMB natural systems) and agriculture, livestock, aquaculture and livelihoods. It shows why viable and sustainable NTFP and CWR systems (i.e. the forests, wetlands and river systems) are so important in the face of climate change (ICEM 2014d). The traits of CWRs which make them important as a resource for communities and natural systems to adapt to climate change and other man made stresses include their capacity to adapt to high altitudes, cold and xerophytic conditions, their resistance to fugal, bacterial and virus diseases, and to insect pests; their drought, flooding and salinity tolerance, and their potential for improved agronomic traits and grain quality.

Figure 4: Links between NTFPs, CWRs and wild fish (as part of LMB natural systems) and agriculture, livestock, aquaculture and livelihoods.



Aquaculture farming is likely to be more vulnerable to climate change scenarios than capture fisheries (ICEM 2014e). More intensive aquaculture systems will have a much higher water quality and water quantity demand than more extensive systems, to keep problems such as pollution or diseases at bay (some of which may become more of a problem through increased temperatures). This would be particularly damaging for the Delta region that has become economically dependent on aquaculture in recent years. Increased costs of farmed fish resulting from climate change adaptation costs could therefore have a serious affect on the quality of poorer people's diet. No other obvious animal protein alternatives exist. This is another example where alteration to a natural system leads to rising maintenance costs in order to maintain stability with climate change.

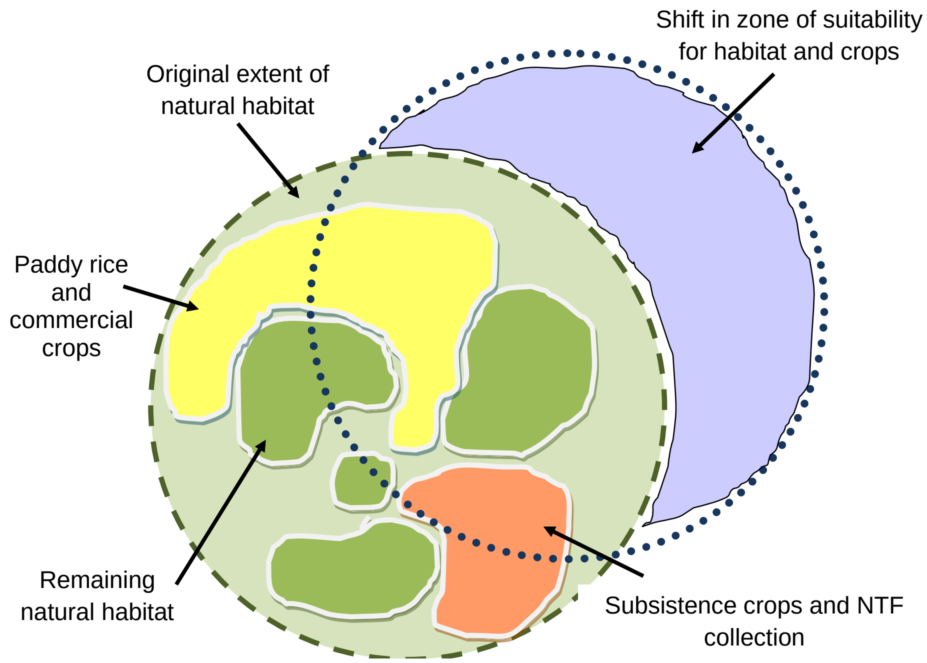
5.1 FARMING ECOSYSTEMS SHIFTS

Fisheries - basin wide conclusions on potential impacts of climate change

- Under projected climate change, the best we can hope for from Mekong capture fisheries is that current production levels will be maintained.
- The intensive lowland aquaculture systems will not be able to cope with the more extreme conditions, and will produce less.
- Although aquaculture will become more viable in new, higher elevation areas this is unlikely to compensate for the lost production from the lowlands.
- Total fish production in the Mekong basin is likely to decline over the next 30 years.
- With a regional population growth rate of around 1%, per capita fish consumption rates will also certainly fall
- Efforts must be made immediately to implement adaptation measures to offset the effects of climate change

Farming ecosystems rely on climatic and ecological services. Climate and linked ecological shifts will lead to fundamental shifts in LMB farming ecosystems (Figure 5). Climate change shifts are spatial or temporal changes in regular or extreme climate. Changes in climate will lead to ecological shifts as species and habitats adapt to the new climate regime; an ecosystem shift occurs when the assemblage of species and habitats in a location changes to accommodate a new climate regime. The knock on effects on LMB farming ecosystems will be profound (ICEM 2014a).

Figure 5: Effects of geographic shifts in climate



Crops, NTFPs and CWRs which once flourished in an area may be no longer suited to new conditions. Changes in climate mean new crop species, cropping patterns, fishing activities, and gathering and foraging habits become necessary, and a new balance in system components and inputs needs to be established in any one location. It can also mean that certain types of farming will need to shift to entirely new locations where conditions and natural system ingredients have changed to suit. This implies the need for flexibility and the ability of a system to adjust. Healthy, functioning and connected natural systems are much more flexible than if degraded and offer significant potential to assist farming systems to adjust and adapt.

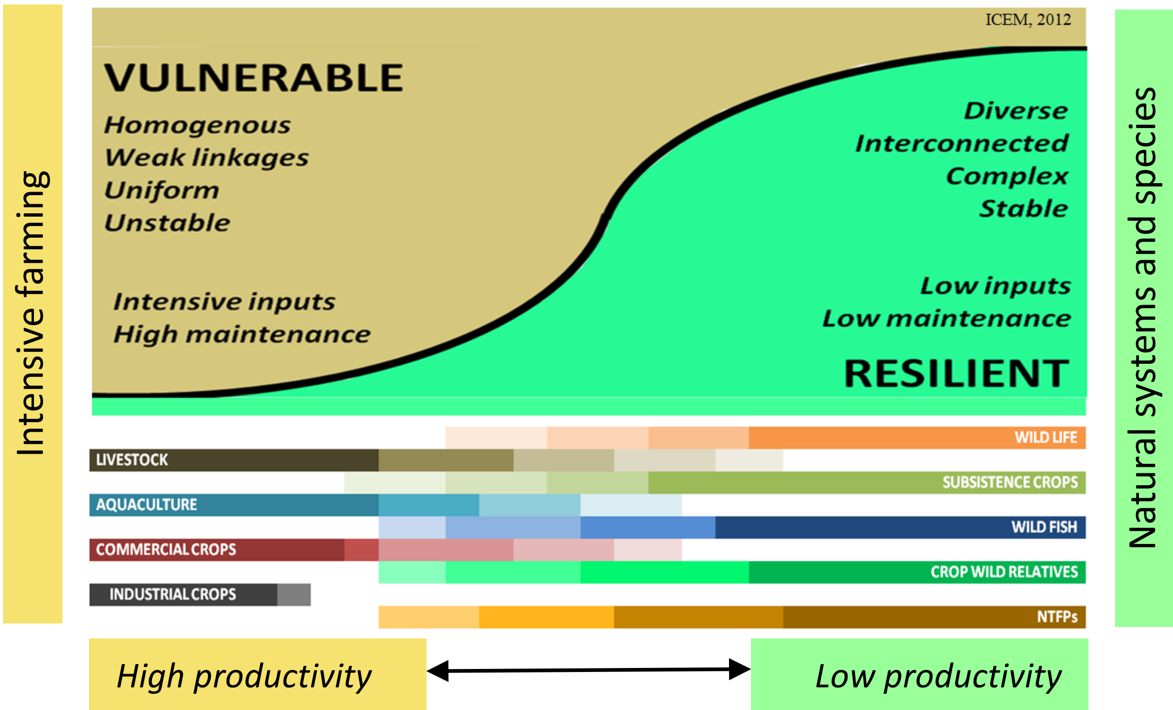
Diminished or changing ecological provisioning may reduce availability and access to NTFPs and water. Weakening regulatory and habitat services may reduce pollination and pest control, reduce soil organic carbon content and reduce soil micro fauna and flora. The culmination of these ecosystem shifts may mean that in any location farming systems require more intensive inputs and a greater dependence on specialised more resilient crops. Therefore, natural systems and ecological communities must be given the best possible chance to shift and adapt.

5.2 INTEGRATION OF FARMING AND NATURAL SYSTEMS FOR RESILIENCE

Farming systems have much to gain in terms of long-term productivity and resilience to climate change through greater harmonisation and integration with natural systems. However, that shift will require a change from a focus on short-term productivity increases and profits to a broader longer-term perspective on sustainability and multiple benefits.

During the past 50 years, the commercialization of farming systems brought about by technological advances and economic forces including large agricultural subsidies have increased food availability and decreased the real costs of agricultural commodities. Yet, the resulting agricultural practices have incurred costs related to losses in environmental quality and biodiversity, degraded or lost ecosystem services, emergence of pathogens, and the long-term instability of agricultural production (Tilman et al 2002). The shift from subsistence to commercial and industrial agriculture is gaining pace in the LMB and is contributing to the degradation of natural systems. Figure 6 illustrates the continuum between subsistence farming and industrial farming and the changes in the level of inputs, productivity and ecosystem stability with climate change.

Figure 6: The agro-ecological systems and climate change continuum



As farming systems move along the continuum they are becoming less diverse, more intensive, and less resilient to climate change without substantial maintenance and inputs to keep them stable. Subsistence based systems, while low in productivity, are inherently integrated with natural systems and benefit from their diversity and resilience to climate related shocks (ICEM 2014a).

Generally, this shift in farming ecosystems has taken place on a localized, gradual and incremental basis as individual farmers seek more productive and profitable crops and methods. Now, it is occurring rapidly and over large areas. Clear-felling of forests to make way for large industrial plantations and expansion of concession areas to cover large proportions of Cambodia and Laos are accelerating the shift along the continuum. These abrupt changes, or system leaps, greatly intensify the vulnerability of affected communities.

The transition from subsistence to more intensive forms of agriculture can bring significant benefits in terms of lifting people out of poverty, improving food security and taking pressure off natural areas through increasing incomes. Commercialisation and industrialisation of farming – i.e. growing highly marketable and improved cultivars or varieties, together with an expansion of farm holdings, increased capital investment and additional hired labour – often increases farm incomes. However in the process large numbers of people may lose their land, livelihoods and food sources with increasing modification of natural systems.

The intensification of agriculture systems also faces sustainability issues, with erosion and loss of fertility due to the use of monoculture. A changing climate and higher climate variability will increase the vulnerability of this dynamic sector. Building more resilient and sustainable cropping systems will be necessary to allow the agriculture sector to grow (ICEM 2014f).

Local farming practices can sustain and enable poor families to adapt in a variable and challenging environment through manipulation of genetic diversity using indigenous knowledge and at low cost. Commercialisation may exclude or reduce the role of local agro-diversity, for example, through dependence on commercial seed supplies – which in turn may have longer term implications for poverty with local resilience to climate change. This transition must therefore balance economic efficiency and profits with local livelihoods, sustainability in agricultural systems and the conservation of natural systems.

6 ADAPTATION OF NATURAL SYSTEMS IN THE LMB

The key strategy for coping with climate change in the Mekong region is to recognise that healthy natural systems are a foundation for the development and wellbeing of farming systems and for building resilience in communities, economic sectors and areas (ICEM 2014a). Adaptation actions should contribute to ecological sustainability and social equity as well as reducing climate change vulnerability - the corollary to that axiom is to ensure that adaptations do not contribute to environmental and biodiversity degradation.

Human actions reduce the resilience of natural systems where they degrade biodiversity, pollute ecosystems or disrupt natural disturbance regimes (Folke *et al.* 2004). Healthy connected ecosystems are best placed to respond and adapt to a changing climate (Luck *et al.* 2003). Given that natural systems in the LMB are subject to ongoing degradation and fragmentation, there is a need to address the existing management deficiencies when planning for climate adaptation. Determinants of the adaptive capacity of natural systems include (ICEM 2014a):

- Species diversity and integrity;
- Species and habitat tolerance levels;
- Availability of alternative habitat;
- Ability to regenerate or spatially shift;
- For individual species - dispersal range and life strategy.

6.1 PROTECTED AREAS

Protected areas are effective tools for optimizing the contribution of natural ecosystems in climate change response strategies (Dudley et al 2010). Protected areas enable adaptation through the maintenance of ecosystem integrity, buffering of local climate and the reduction of risks and impacts from extreme events. They provide the backbone for adaptation in LMB agriculture, fisheries, livestock and linked natural systems – and consequently for rural livelihoods. Yet, large and rapid transformations and simplification of biodiversity in the LMB is likely within and outside protected areas due to the impacts of climate change along with other threats. That transformation will tend to reduce overall productivity in linked farming ecosystems with the poorest communities most affected.

Changes are inevitable. Some species and habitats will be lost from local areas, ecozones or from the basin. Others will shift from current locations to another. The structure and composition of ecosystems in some areas will change over time and require adaptation responses from protected area managers and farmers. Management should aim for the enhancement and maintenance of functions and values of the LMB protected area system as a whole. Basin wide priorities for adaptation through protected areas and biodiversity conservation are set out here (ICEM 2014a).

6.1.1 *Expand and strengthen the protected area system*

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 habitat is one of the most effective ways to maintain viable populations of a wide range of species. Building a diverse protected area system of habitats is critical in the face of climate change. The size of an ecosystem is known to influence its resilience with larger, less fragmented systems being more resilient (Zhou *et al.* 2013). The role that forests play in supporting livelihoods and adaptation in agriculture (e.g. through NTFPs and CWRs) should be recognised and maintained wherever possible.

6.1.2 *Strengthen the authority and capacity of protected area managers*

The highest priority for PA adaptation in the LMB is the strengthening of capacities and processes for management planning – and for the effective implementation of a plan. Many PAs throughout the basin do not have management plans.

There are two basic principles which need to be embraced in PA legislation and strongly enforced at national and provincial levels – first the principle of "one area one plan" 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" which ensures that the protected area managers are the recognized authority within their tenured territory and that they have a mandate respected across government. Realizing the second principle will require significant institutional reform in all Mekong countries to raise the status of protected area managers within government. Stand alone protected area legislation and statutory authorities need to be considered.

Some adjustments, and new emphasis and approaches will be needed. These will include high level political commitment and pro-active interventions.

6.1.3 *Management Zones*

Management zones are necessary to the effective management of activities within PAs of the LMB (ICEM 2014c). Zoning defines what can and cannot occur in different areas of a PA in terms of human uses and benefits and PA development, maintenance, and operations. While widely recognized and applied as a basic ingredient in PA management plans in the region, in practice they are not well defined on the ground or enforced.

Climate-induced shifts of ecosystems may require adjustments to PA zones to balance conservation and development around PAs. An important consequence of climate change is shifting habitat. That shift may force the migration of species to become more frequent and necessary for genetic exchange. Facilitating this migration requires long term planning of buffer zones and corridors, including extensive scientific research to shape management actions.

Key actions for zoning management include:

Establishment of a core zone of significant ecosystems or habitat – this zone is the central area of the PA and is the focus of strong protection measures. Defining the core zones' resources, as well as agreed control and safeguards therein are important activities. In the context of climate change, this zone may need to be expanded or relocated to provide appropriate protection for significant habitat or species;

Buffer zone – this zone is an extension of a PA that surrounds the core zone. The intensity of human activities is greater than that allowed in the core zone. This zone creates a buffer wherein NTFP collection, tourism, and other uses may occur; the existence of this area provides communities with an alternative to exploiting forest resources in the core zone and thereby protects the latter. Once again, it may be necessary to expand or relocate the buffer zone to increase resilience of the core zone to climate change.

Transition area – this zone is similar to the buffer zone, except that even more intense development is permitted, such as agriculture.

Community participation and a flexible approach to management zones are crucial to their success as a policy tool (ICEM 2003). Climate change represents a major regime change and, therefore, must be integrated into ongoing planning of management zones with PAs.

6.1.4 Building functional connectivity across the landscape

Climate adaptation capacity is generally increased through improving landscape scale connections between core habitat patches. 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 need to 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.

Corridors to link protected areas require extensive and long term commitment to rehabilitation work. The local expressions of rehabilitation vary between ecosystems and habitats. Typically, rehabilitation brings back or creates benefits provided by PAs and increases their resistance to climate change impacts. Options for delivering corridors and rehabilitation are:

Rehabilitation of degraded areas – Seeding and plantation activities on cleared land or critically degraded ecosystems may provide the basis of ecosystem rehabilitation. Ongoing monitoring of a range of biological processes is necessary to success.

Enrichment planting – where valuable species are introduced or re-introduced to degraded forests or wetlands that complement existing species. In some cases, this may involve plantations of mixed native species for commercial purposes.

Breeding programs – For some threatened or critical species breeding programs, including those in captivity may assist the re-establishment of breeding populations.

6.1.5 Build on and strengthen existing conservation management approaches

Build on and strengthen existing conservation management approaches which are likely to continue to be important under climate change. Much of what is required is better and more proactive conservation management to meet adaptation requirements. After much support in the 1990's, protected areas and biodiversity conservation have been neglected by most donors who could not see substantial community development and poverty reduction benefits from their investments. Now there is a fresh and pressing need for increased and well coordinated support to LMB protected areas as an essential adaptation and development strategy.

6.1.6 Integrated adaptation in protected area management planning

Climate change adaptation planning and strategies need to be a fundamental part of overall PA management planning. The priority for PA adaptation strategies is the reinforcement of conservation measures currently being planned and implemented in the LMB, and additional resources and attention to new measures. A lack of management plans and inadequate implementation of existing plans is a major constraint to climate change response. PA management planning requires support and strengthening with a precise and clear primary goal of biodiversity conservation. A lack of precision in the primary PA management goal and confusion between competing goals – for example, poverty reduction, community development and biodiversity conservation – has lead to confusion and failure to sustain effective responses to any of them. Meeting that primary goal will enable protected areas to meet their subsidiary functions, including underpinning adaptation in farming systems.

6.1.7 Improve understanding of climate change impacts on biodiversity

Greater attention and resources to improving scientific understanding of climate change impacts on species and ecosystems is required. Effective adaptation strategies need to be informed by 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 of ecological change, including early warnings of key changes in ecological processes;
- types of ecological change, such as in situ changes in species abundance, changes in interactions; between species and distributional shifts;
- patterns of geographic range shifts over elevational and latitudinal gradients;
- changes in other threats to biodiversity and their interactions with climate change;

- detection of new invasive species at sites and changes in abundance and dynamics of species that may become problematic in the future, and;
- the effectiveness of management actions (NSW 2010).

6.1.8 *Building ecosystem resilience*

There are clear links between ecosystem health and climate change. Higher levels of biodiversity provide more options for ecosystems to adapt and therefore, greater climate change resilience. Actions that maintain or expand biodiversity are conservation priorities in their own right but have become more important for their role in responding to climate change. These include three priorities (NSW 2010):

Keystone species: Understanding the maintenance requirements of key biological processes giving priority to 'keystone' species that play an important role in maintaining ecological processes, such as dispersal. 'Keystone' species have a disproportionately large influence on community and ecosystem function relative to their numbers or biomass.

Refugia: Identification, maintenance, and proactive management of refugia and pockets of resilience. Two examples of dry season refugia that need to be maintained are deep pools in the Mekong River and its tributaries which provide microhabitats for many fish species, and deep valleys in mountainous terrain which are moister and cooler than the surrounding environment with surface water that persists during severe droughts.

Invasive species: Mitigation of threats from invasive species and pests. Monitoring of habitats supported by satellite imagery and ground survey is needed to keep track of the spread of invasive species. It is a serious problem gaining momentum as more areas are disturbed and the number of aggressive invasive species increases.

6.2 WETLANDS

All of the PA adaptation measures apply to wetlands. However, as most wetland areas are outside the protected area estate and are heavily utilised they warrant special attention. Key adaptation responses in the conservation and management of wetlands include maintaining connectivity of wetland sites with wider rivers and floodplains ensuring that the wetland habitats, flora and fauna have space to move and disperse, and protecting and rehabilitating habitats of species important for conservation and livelihoods (ICEM 2012). Many natural wetland ecosystems and their component habitats have a high adaptive capacity. The best adaptation strategy will be to try to maintain the wetlands in their natural conditions and allow them to adapt naturally to changing climatic conditions.

6.2.1 *Enhancing resilience of wetland species*

One of the big challenges in enhancing resilience of wetland species is the very limited data on the species tolerances of environmental factors. There is the need for more research and development of baseline data on key species of concern. In terms of building resilience in species, important measures include (ICEM 2012) targeted habitat protection and rehabilitation for key species, and the identification of needs for species at different stages of their lifecycles, especially breeding and nursery grounds, and provide protection and rehabilitation as necessary. That requires research into ecosystem rehabilitation and regeneration requirements, for example, the tall trees which are keystone species in large parts of the basin and research into food sources for key species, with targeted protection of those food sources. Improved wetland management for fisheries covers a very wide range of adaptation activities including habitat protection, fishing regulations, artificial seeding and stocking, and removal of man-made structures to ensure connectivity for fish migration.

6.2.2 *Physical infrastructure, engineering options*

Built infrastructure options for adaptation are widely used by most sectors to protect and enhance physical assets. However, their use in supporting natural systems to adapt to climate change should be done with caution and only after thorough assessment. For sector adaptation, built infrastructure is typically used to *isolate* individual components from threatening hydrological processes which may lead to damage, failure or reduced performance of assets. However, for natural systems, reduced connectivity, isolation and compartmentalization of components increase vulnerability (IUCN, 2009; UNFCC, 2006). Connected, diverse natural systems spread vulnerability over a range of species and habitats allowing some to cope and even thrive in the new climate conditions even while others suffer. The cumulative effect may be a shift in the composition of the natural system but it is protected or buffered against total collapse – except in the most extreme threats.

Structural innovations have been successful in expanding and recreating natural systems through protection and mimicking, for example, constructed wetlands and lagoons for natural water treatment. Engineering teams have re-created hydraulic characteristics of natural wetlands typical of a geographical region, drawing on the same biological species and hydro-geochemical processes to maintain system productivity with mutual benefit for the wetland biota and the treated effluents. In the Mekong Basin, rural communities of Cambodia have used natural flooding process of the Mekong River to maintain small community ponds during the dry season by replicating in miniature the natural hydraulic processes which sustain the Tonle Sap system. River waters are directed by a series of small gravity canals (*colmatages*) to community ponds which fill up during the annual flooding of the Mekong. As the water levels in the Mekong drop with the onset of the dry season, small volumes of water remain trapped in the floodplain and are used as community fish ponds and water supply sources.

6.2.3 *Wetland livelihoods adaptation*

Substantial adaptation measures undertaken by local communities are related to adapting wetland related livelihoods to negative climate change impacts and threats. These adaptation measures include autonomous adaptation pursued by local stakeholders to maximise their welfare. Sometimes this comes at the expense of wetland ecosystems health and integrity, e.g. when water is abstracted from the wetland for maintaining irrigation of crops during droughts. When livelihood adaptation measures are being planned, negative impacts on wetlands must be avoided.

6.2.4 *The role of economic instruments in wetland adaptation*

The efficacy of economic instruments in adaptation strategies lies in their ability to align private incentives with the wider public goals, in this case with the goal of preserving the integrity of wetland ecosystems. Economic instruments include both those that seek to exploit characteristics of markets to align public and private incentives, and more rigid rule-based and discretionary approaches such as the use of fines and discretionary funds.[23] Perhaps the most common example is the establishment of property rights, usufruct rights or other entitlement systems to natural resources such as in payment for ecosystem services schemes.

However, the experience of these schemes has been mixed. What appears to be effective from the perspective of economic theory turns out to be difficult to implement on the ground. The institutional framework for administering a system of rights can be difficult, especially for common-pool resources.[24] Monitoring and enforcement are particularly problematic. The nature of many of the services offered by natural systems as common-pool resources can be inappropriate targets for the application of market based economic instruments. This is especially so in a context where the requisite institutional and management capacity is low.

Other types of economic instrument are perhaps more practical. A system of more limited fines, fees and discretionary funding maybe more appropriate. While these instruments do not offer the ever-present private/community incentive to maintain the value of the asset, they can still offer a strong incentive but with a lower regulatory burden. Capacity is still likely to be an issue with planning, monitoring and enforcement all requiring a significant investment of resources.

6.2.5 *Land use planning*

One of the most significant threats to all wetlands in the LMB is conversion of land use and encroachment. Land use planning and Integrated Water Resource Management (IWRM) are tools that may be applied for achieving more ecological and equitable use of the land, water and natural resources. To work effectively for wetlands, national and provincial agencies involved in land use

[23] In practice, there is no clear boundary between market based and non-market based instruments. Frequently instruments include elements of both. Indeed most instruments that do have market-based elements often rely on regulatory approaches to set their scope.

[24] Even in the case of land rights, the creation of an effective land administration is a significant task, including the development of a land cadaster, supporting legislation, dispute resolution systems and a monitoring system. For common-pool resources, which are much more difficult to monitor, the difficulties are much more acute.

planning and IWRM need to recognise wetlands as a form of land use tenure, with their own specific management needs and water requirements. Most wetlands fall outside protected areas and are not given legal status as an appropriate and productive form of land use. For example, many wetlands have a critical role in flood management. That function needs to be recognised and actively maintained including delineation of boundaries and protection from encroachment and degrading exploitation.

6.3 CAPTURE FISHERIES

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 (ICEM 2014e). 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.

Identifying adaptive measures that can reverse declines and protect resources and stocks faces four challenges:

- The development of dams for hydropower – blocking fish passage so upstream adaptation measures are not effective.
- Capture fisheries are open systems and their productivity depends more on natural variations than on planned controlled management.
- The sheer size of the capture fisheries areas means that adaptation actions would need to be large scale and therefore expensive.
- Given the extensive 'noise in the system', which affects year-on-year production from the capture fisheries, measuring the impact of any adaptation effort is likely to be complex.

In the Mekong region, there is a growing trend towards encouraging managers to adopt ecosystem based approaches to fisheries management i.e. that focuses on stocks *and* the environment; not just stocks. This approach looks likely to become all the more important as the climate warms and the weather patterns become more unpredictable**.**

Priorities for adaptation in capture fisheries include the following measures (ICEM 2014e):

For upland fish, forest cover needs to be retained or rehabilitated to protect stream environments. Protection of small valley catchments is needed to reduce the effects of flash flooding so that the specialist upland fish species can remain prolific. For migratory white fish, the focus should be on improving their access to spawning grounds, and the habitats in those areas. 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. Whilst the black fish species of the Basin do not look particularly vulnerable to the changing climatic conditions steps still need to be taken to 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.

For estuarine species, the replanting and management of mangrove forests in coastal areas can do much to protect against storms and erosion resulting from sea level rise, storm surge and increased rainfall, and thereby help maintain fish biodiversity and production. Non-interference with natural tides and current patterns is also required to ensure that mangrove areas remain healthy and able to support the estuarine fishery. The monitoring of invasive aquatic species should be done at a rage of levels to plot the spread of species considered harmful to the wider environment. Eradication drives may be necessary to keep some invasive populations in check.

In all areas, a number of key species, considered the most valuable and vulnerable to climate change, will need specific protection and enhancement measures. Finally, despite the threats and uncertainties, it should be remembered that fishing communities in Mekong basin are extremely resilient to the vagaries of the weather and seasons, which in the case of the Mekong River and floodplain are already extreme – it is the serious development threats, especially hydropower, which will continue to have the greatest impacts on capture fisheries.

6.4 NTFPs AND CWRs

In their natural environment, most species have clear seasonal patterns, especially in the climatic conditions of the Mekong where there is a marked distinction between wet and dry seasons. They are well adapted to the dry season, when many species go into relative hibernation, shed their leaves, store up food sources in tubers, or aestivate (earthworms) or migrate (honey bees), all against the extremes of the hot, dry season. They can often withstand the extremes of drought at the end of the dry season and lowering of soil moisture availability. In some species the seeds they produce can survive several years of dormancy and wait for the ideal conditions before they germinate. Fungi are excellent examples of this strategy - the species can survive these periods of extreme climate and take advantage of the climate variability to grow and reproduce when the conditions are less extreme. A number of species, especially the grasses and herbs, climbers and aquatic plants have vegetative reproduction and can grow from the rootstock and rhizomes as well as producing seeds. This means that they can also take advantage of different conditions to multiply and spread when seed production is limited.

Thus there is a residual resilience in intact forest and wetland ecosystems to climate change. As conditions change there would be a gradual shift towards species or sub-species and the assemblages that they rely on that can tolerate the changes better. The situation in stressed and modified natural environments will be different, and in these situations more rapid changes in the species and their ecology may be expected. Once a threshold is passed for the ecosystem as a whole then there would be a more dramatic change, loss of the key species, loss of forest cover and overall transformation of the ecosystem. Usually this threshold is not obvious until the loss has occurred.

Many of the NTFPs have several species or sub-species that are already distributed widely according to different existing conditions, and it is possible that these will “move” to take up new positions as the climate changes. Effective dispersal mechanisms are therefore an important aspect of species resilience.

Many NTFPs and CWRs are well adapted to climate extremes if undisturbed by other influences. Changes in rainfall patterns would appear to have a less significant impact on NTFPs and CWRs – for most species in the hot spot provinces, the increases in annual rainfall are well within the normal range. Wetland plant species appear to be the least vulnerable of the NTFP plants assessed by ICEM (ICEM 2014a). The increased temperature is moderated by the water habitat and may in fact induce growth of the aquatic plants. They are well adapted to flood, and most are also adapted to periods of drought, and will come back when the flood waters return.

The existing development threats to NTFP and CWR species are more immediate and significant than climate change. Habitat loss, changes in land use to agriculture, plantations, aquaculture, deforestation, over-harvesting are the most important stressors reducing the populations of many species. Climate change comes as an additional but not necessarily the most important stressor. Therefore, the most effective adaptation strategies for protecting certain species will be to reduce existing threats and at the same time enhance resilience to climate change. The options for enhancing NTFP and CWR resilience of species can be grouped under several broad adaptation strategies - habitat protection, rehabilitation and reforestation; management of sustainable NTFP harvesting, domestication and cultivation and implementation of species conservation plans including assisted movement of those at risk of habitat shift. So little is known about NTFPs - and even less about CWRs - that all adaptation measures will benefit from more extensive research and monitoring.

6.5 DIVERSITY FOR RESILIENCE IN AGRICULTURAL SYSTEMS

Biodiversity is a product or outcome of co-evolving human and ecological systems over a very long time. Diversity in genetics, species and ecosystems is critical for the productivity, sustainability and adaptability of LMB farming ecosystems.

6.5.1 *Genetic diversity*

The loss of genetic diversity in farming ecosystems diminishes resilience and agricultural sustainability. To date, breeders of the major food staples (maize, rice and wheat) have been successful at improving resistances to pathogens and diseases in order to maintain yield stability despite low crop diversity in continuous cereal systems. However, any improvement in crop resistance to a pathogen is likely to be transitory because of their evolutionary interaction, requiring continuous intervention. For example, the useful lifetime of maize hybrids in the US (about 4 years) is now half what it was 30 years ago (Tilman et al 2002). It is uncertain if such conventional breeding approaches can work indefinitely. Similarly, agrochemicals, such as pesticides and antibiotics, are major selective agents - herbicide-resistant weeds were observed within about one or two decades from the introduction of each of the seven major herbicides (Palumbi 2001).

Crop rotation and the use of spatial or temporal crop diversity can reduce the need to breed new disease resistance crops and to develop new pesticides (Tilman et al 2002). This practice would also reduce costs. Both integrated pest management and biotechnology will be important in establishing durable resistance through multiple gene sources (Ortiz 1998; DeVries & Toenniessen 2001). Plant genetic diversity is *the* factor that enables adaptation (FAO, 2010a, 2011b). For example, the likelihood of crop failure due to drought decreases when traditional landraces with a higher genetic diversity are adopted over modern crop varieties. One of the most effective ways of dealing with environmental changes is the ability to match crop genetics (i.e. variety) to a particular management system and region (Howden et al 2006). To retain this ability local biodiversity must be protected. The coefficient of on-farm crop genetic diversity has a strong positive effect on crop yields and a negative effect on the variance of crop yields - this result is robust against different production function specifications, different types of crops, different scales of data (regional vs. plot specific) and different measures of crop genetic diversity.[25]

In the Mekong Delta, there is a general trend toward the domination of cropping by a handful of high-yielding rice varieties (Hashimoto 2001). In the absence of ecological balance and natural controls, pest and disease outbreaks and fluctuations in environmental conditions will increasingly pose a threat to agricultural production (Hashimoto 2001). Many traditional varieties of crop plants and livestock (as well as their ancestral or related species occurring naturally within the Mekong Delta) have higher environmental tolerances than the more recently introduced varieties - these could hold the key to the future development of more robust varieties for the local environment (Hirata, 2000). The absence of such genetic resources within the region will establish a feedback loop of perpetual reliance on costly inputs of agro-chemicals and new imported varieties, and continuing environmental and ecological degradation (Hashimoto 2001).

6.5.2 *Species diversity*

A diversity of crop species can better adapt to environmental changes because the broader pool of different metabolic traits and metabolic pathways enables more effective resource use (such as water and soil nutrients) over a wide range of environmental conditions (Schlapfer et al 2002). Also, food insecurity is reduced when there is a diversity of plants, animals and micro-organisms in and around the farm – an important principle for all farmers in the LMB but particularly those that are poorer and more isolated (Araya & Edwards 2006; IFAD 2011).

6.5.3 *Ecosystem diversity*

A significant opportunity to support and improve agricultural livelihoods while reducing environmental degradation and vulnerability to climate change is through the adoption of sustainable agricultural[26] practices. Rather than transition to large scale commercialised high input systems, the aggregate benefits in terms of productivity, provision of ecosystem services and resilience to climate change impacts may be much greater by improving existing management and productivity through sustainable agricultural practices. Expanding the area of land under agricultural production is not necessarily the solution – especially with changing climate. Often the short-term benefits of land conversion are outweighed by losses in ecosystem services and adaptive capabilities that intact

[25] Just and Candler (1985); Smale et al (1998, 2008); Widawsky and Rozelle (1998); Di Falco and Perrings (2005); Di Falco and Chavas (2008b); and Heisey et al (1997).

[26] Agricultural sustainability means maintaining productivity while protecting the natural resource base. Possible actions include: improving low impact practices such as organic agriculture and providing incentives for the sustainable management of water, livestock, forests, and fisheries. Science and technology should focus on ensuring that agriculture not only provides food but also fulfills environmental, social and economic functions such as mitigating climate change and preserving biodiversity. Policy-makers could end subsidies encouraging unsustainable practices and provide incentives for sustainable natural resource management (IAASTD 2008).

natural systems provide. During the conversion period (say 3–5 years) sustainable agriculture can have lower productivity than high input systems, but in the longer term, it has comparable production levels with the added positive effects on soil and water quality and reduced costs.

Integrating agricultural systems with adjacent natural, semi-natural or restored ecosystems through landscape-scale management holds significant potential for maintaining the benefits to individual farms of ecosystem services and reducing the negative effects of the farms on their natural system foundations (ICEM 2014a). For example, surrounding cultivated fields with a diversity of trees and shrubs decreases soil erosion and can intercept nutrients that otherwise would enter surface or ground waters. Nutrient and silt loading from cultivated fields or pastures can be reduced with buffer zones along streams, rivers and lakeshores. Crop pollination can be provided by insects and other animals living in nearby habitats or buffer strips, and other organisms from these habitats, such as parasitoids, can provide effective control of many agricultural pests (Tilman et al 2002).

Introducing biodiversity into farming systems improves soil fertility and, in the process, reduces net GHG emissions through carbon fixation. Agro-forestry through composting for example and organic agriculture significantly reduces greenhouse emissions compared with conventional practices (Ajayi et al 2011; Muller 2009; Niggli et al 2009). Organic practices also contribute to reducing emissions through the use of organic fertilisers, crop rotations (including legumes, leys and cover crops) and through avoiding open biomass burning, synthetic fertilisers and the related production emissions from fossil fuels. In addition, systems that have and produce *soil* biodiversity also foster carbon sequestration, good soil tilth and high fertility (Sperow et al 2003).

In general, the more a cultivation system mimics natural ecosystem functions, the fewer resource inputs are required and negative environmental effects felt (Folke & Kautsky 1992). For example, the diversification of land use and the development of agro-forestry and silvofishery[27] systems in the Mekong Delta could significantly contribute to the creation of varied ecological habitats (Hashimoto 2001). Such integrated systems that work with ecosystems without degrading the resource base on which they depend will be more sustainable and have positive contributions to the surrounding ecosystems and socio-economy (FitzGerald 2002).

7 CONCLUSIONS

Despite the great diversity of livelihoods and ecosystems in the Lower Mekong Basin, the sectors of agriculture, livestock, fisheries, NTFPs and heath and rural infrastructure have one thing in common – their resilience to climate change is dependent on healthy, functioning natural ecosystems.

The foundation adaptation strategy for the Mekong region – i.e. the set of measures that underlie all other responses to climate change – can be summarised 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. The two foundation characteristics of a resilient farming ecosystem mean greater stability when confronted by climate change shocks. They also create more opportunities to recover be providing a broader range of adaptation options.

Farmers face many risks such as climatic factors, pests and diseases, price uncertainties and changing government policies. Farm diversification is a response to avoid and minimise those risks. 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 small holder farming in the LMB is extremely diverse and flexible. Yet, the trends are

[27] Silvofisheries are a form of low-input sustainable aquaculture where the cultivation of mangroves is integrated with brackish water aquaculture (FitzGerald 2002). Silvofisheries strive to mimic natural ecosystem functions in a culture system with reduced resource use; avoidance of chemicals and medicinal compounds; and the recycling of nutrients and materials to increase the efficiency of the system (FitzGerald 2002). This integrated approach to conservation and utilization of the mangrove resource allows for maintaining a relatively high level of integrity and biodiversity in the mangrove area while capitalizing on the economic benefits of brackish water aquaculture (FitzGerald 2002).

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 optimising 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 and their surrounding areas and catchments – i.e. viewing farms as ecosystems which are integrated and managed with linked natural systems. The aim is to steadily increase the number of living components within the farm ecosystem 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 micro fauna 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. A diverse and biodiversity rich farming system builds on traditional practices with improvements from modern technologies and approaches.

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 giving priority to building natural capital as a way of ensuring long term consistency in farm productivity and incomes in the face of climate change.

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