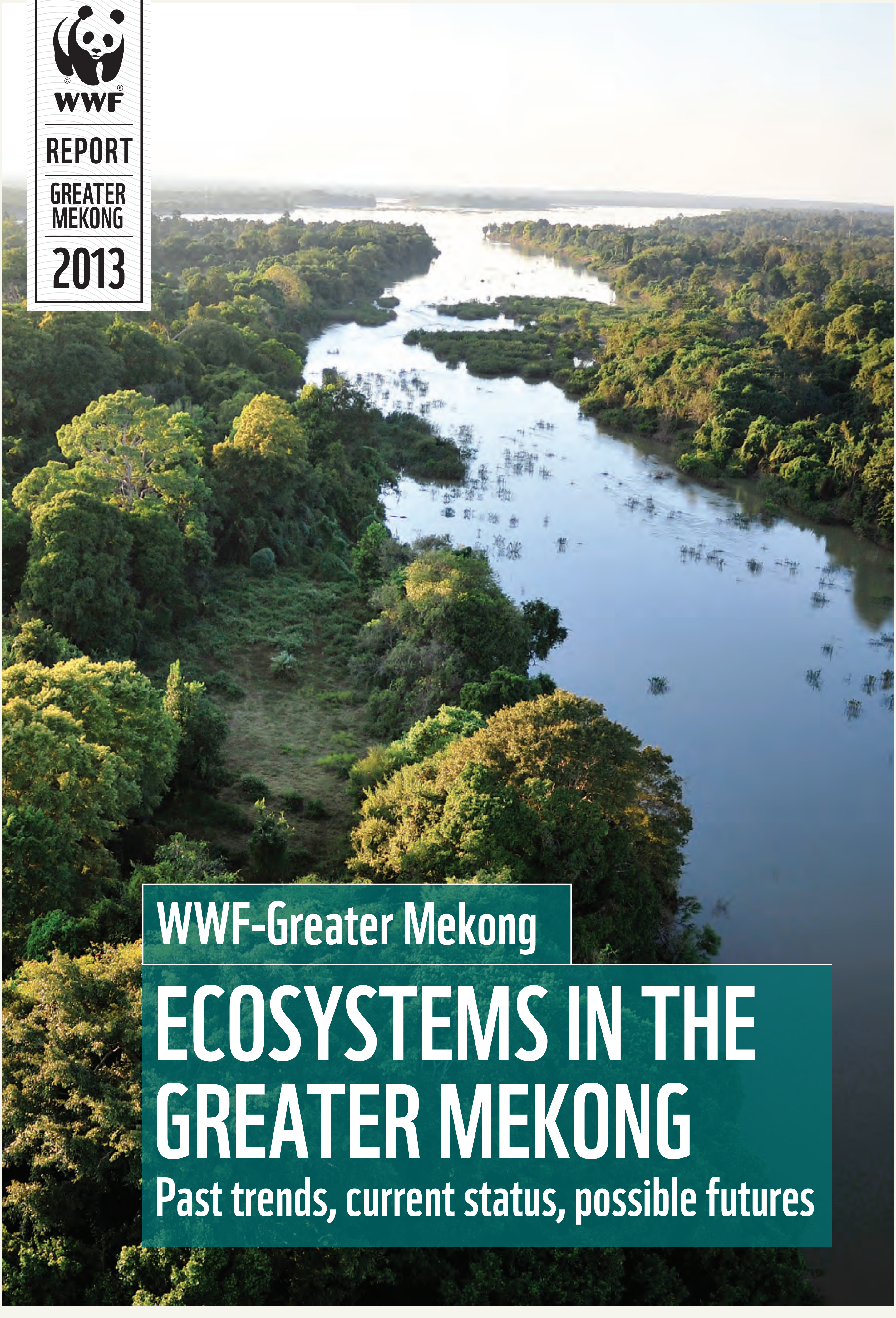


WWF

REPORT

GREATER MEKONG

2013

WWF-Greater Mekong

ECOSYSTEMS IN THE GREATER MEKONG

Past trends, current status, possible futures

Ecosystems in the Greater Mekong

Past trends, current status, possible futures

Design by Millerdesign.co.uk

Front cover photo: © Adam Oswell / WWF-Greater Mekong

Published in May 2013 by WWF-World Wide Fund For Nature (Formerly World Wildlife Fund), Greater Mekong.

WWF is one of the world's largest and most experienced independent conservation organizations, with over 5 million supporters and a global Network active in more than 100 countries.

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by: conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

When citing this report, please use the following citation: WWF. 2013. Ecosystems in the Greater Mekong: Past trends, current status, possible futures.

The report and details on methodology can be accessed at wwf.panda.org/greatermekong

CONTENTS

FOREWORD 5

SUMMARY 7

1. INTRODUCTION 10

2. FOREST ECOSYSTEMS 16

Introduction and changes over the past 50 years 16
Forest change analysis: methods, assumptions and limitations 18
Current status 20
Future projections 22
Forest cover and naturalness 23
Forest fragmentation 26
Forest futures 31
Future scenarios 32

3. FRESHWATER SYSTEMS 36

Introduction and changes over the past 50 years 36
Current status and pressures 37
Future scenarios 41

4. KEYSTONE / FLAGSHIP SPECIES 44

Changes over the last 100 years 44
Maps of historical and current distribution of WWF focal species 45
Current status 50
Protected areas 50
Future scenarios 53

5. DRIVERS OF ECOSYSTEM CHANGE 54

Human population density, poverty and increased wealth 54
Unsustainable resource use and increasing resource demands 54
Infrastructure 56
Government policy and lack of integrated planning 59

6. CONCLUSIONS: CHOOSING A FUTURE 60

Opportunities and remaining challenges 60
Recommendations 62

APPENDICES 66

Maps of the spatial distribution of forest cover change 1973-2009 66
References and sources for diagrams 70
Abbreviations 75
Acknowledgements 75

FIGURES

1.1. The Greater Mekong Subregion (GMS) with principal features
1.2. Global ecosystem services values
1.3. Forest carbon stored in the GMS
2.1. Forest cover change in the GMS 1973-2009
2.2a. Forest cover by area and naturalness in the countries of the GMS
2.2b. Change in forest area in GMS countries 1973-2009
2.3a. Fragmentation index for forests in the GMS, 1973
2.3b. Fragmentation index for forests in the GMS, 1985
2.3c. Fragmentation index for forests in the GMS, 2002
2.3d. Fragmentation index for forests in the GMS, 2009
2.4. Risk map of likelihood of conversion from forest to no-forest in the GMS
2.5 Predicted forest cover in the GMS in 2030 under an unsustainable growth scenario and green economy scenario
2.6a. Potential fragmentation index for forests in the GMS, 2030 in an unsustainable growth scenario
2.6b. Potential fragmentation index for forests in the GMS, 2030 in a green economy scenario
3.1. Freshwater ecosystems of the Mekong river system in a connectivity tree
3.2. Impact of existing dams and the planned Xayaburi dam on ecosystem connectivity
3.3. Classification of the free-flowing systems of the Mekong River with 50 existing dams
4.1. Historical, confirmed or compelling reports between 2002-2010 and confirmed in 2011 and/or 2012 distribution of tiger in and around the GMS
4.2. Historical and confirmed current distribution of elephant in and around the GMS
4.3. Historical and current distribution of the Irrawaddy dolphin, Mekong River subpopulation
4.4. Approximate historical distribution of Javan rhino
4.5. Potential current distribution of saola
4.6. Protected areas in the GMS
5.1. Current and planned mineral and coal mines in the GMS
5.2. Locations of principal national roads, planned major roads and major cities in the GMS
5.3. Map of current and planned dams in the GMS
A.1. Forest cover change from 1973 to 1985
A.2. Forest cover change from 1985 to 1992
A.3. Forest cover change from 1985 to 2002 in Vietnam
A.4. Forest cover change from 2002-2009

BOXES

1. Limitations of the forest change analysis
2. Use and limitations of FAO data for the purposes of this report
3. Levels of forest naturalness
4. Fragmentation analysis
5. Assumptions used to apply the scenarios to the forest change analysis
6. Ecosystem services in the GMS

FOREWORD

This report gives an overview of the current status and potential future of the principal ecosystems of the Greater Mekong Subregion (GMS) and, by association, the well-being of millions of people who are dependent on the region's ecosystem services.

It highlights forest and freshwater ecosystems, and some of the most endangered species these ecosystems support. It explores some of the main drivers of ecosystem change and how these have impacted and will likely continue to impact the region's valuable natural capital if current practices and policies prevail. To highlight some of the options facing the region, an "Unsustainable Growth" scenario based on some current trends is contrasted with an alternative future scenario based on a "Green Economy", based on systematic planning, strong conservation policies and sustainable development. The scenarios and accompanying maps are based on best available information at the present time. The scenarios will be refined as more complete data becomes available and used as the basis for strategic planning.

Purpose of this report
The GMS is one of the most biologically diverse places on earth. About 70 million people depend directly on its ecosystems for food, water, livelihoods and other vital services. In addition, natural resources and ecosystems have been fuelling the region's rapid economic development. Despite the vital importance of natural ecosystems in providing food, water and energy security, and the central role they play in the region's development, a comprehensive and up-to-date assessment of the status of key ecosystems is lacking. Available evidence suggests that pressures from development and other human activities are seriously degrading these ecosystems. Climate change is exacerbating this situation.

This report is based on recognition of the strong interaction between ecosystem integrity, sustainable economic development and human well being. These linkages are articulated in a series of influential global studies (e.g., MEA, 2005; ten Brink, 2011) and are accepted intuitively by GMS countries (see GMS Strategic Framework), but continued degradation of natural ecosystems and the services they provide suggests that they are not well appreciated or appropriately valued. Thus, the first aim of the report is to take stock of some key ecosystems of the GMS to highlight what is at stake for the subregion's economy and heritage. We hope it will inform policy and decision-makers, as well as the private sector, donors, development and conservation organizations, and the general public.

The need for a stock taking is especially important because of major changes taking place in land use and investments in infrastructure. Most of these changes are inconsistent with the stated goals of the GMS countries to green their economies, strengthen resilience to climate change impacts and achieve sustainable development. For example, the current 10-year GMS Strategic Framework (approved in December 2011) stipulates as high-level outcomes reduced biodiversity loss, reduced greenhouse-gas emissions and reduced poverty. Thus, another purpose of the report is to show that these goals will be more feasible to achieve under an economy that emphasizes investments in maintaining natural capital than one that depletes natural capital. WWF hopes that the report will help to catalyse a high-level dialogue on how better to manage and conserve the region's shared ecosystems. This is facilitated by reference to two alternative scenarios, representing possible futures along a spectrum between unsustainable and sustainable use.

The analyses in this report were completed using an ecosystems lens. This approach has limitations (see Chapter 2 for details) because, for example, data on forest or freshwater ecosystem conditions is not readily available at the scale of the entire GMS. Much of the data available for forests, for example, does not allow for discerning differences between relatively intact and degraded forests or even distinguishing natural forests from plantations, most of which are single-species. These distinctions, however, are crucial because biologically diverse natural forests, which are well connected at landscape scales, are the main storehouses of the region's globally important biodiversity and provide many ecosystem services beyond those provided by single-species plantations. WWF has drawn on multiple data sources to provide the best available information but we recognize that serious gaps in our knowledge still remain.

FORESTS SUPPLY ECOSYSTEM SERVICES, INCLUDING: CARBON SEQUESTRATION; PROTECTION AGAINST FLOODS, LANDSLIDES, AVALANCHES, OCEAN SURGES AND DESERTIFICATION; PROVISION OF CLEAN WATER, MEDICINES, TIMBER, NON-TIMBER FOREST PRODUCTS, CROPS AND FISH; POLLINATION SERVICES; SOIL STABILIZATION; SOURCES OF CLEAN WATER; SPACE FOR RECREATION; AND PLACES SACRED TO THE WORLD'S VARIOUS FAITHS

(MEA, 2005; ten Brink, 2011).

EXECUTIVE SUMMARY

The Greater Mekong Subregion (GMS: Myanmar, Thailand, Cambodia, Laos, Vietnam, and Yunnan and Guangxi in China) is undergoing unprecedented changes.

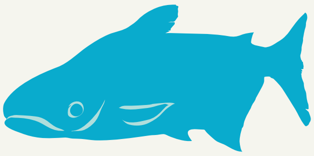
Many of these are positive, reflecting political stabilization and economic growth following decades of poverty and conflict. But the rate and type of development is also threatening critical natural resources, particularly native forests, the Mekong River and its tributaries, and many wild plant and animal species. The GMS faces a critical choice: it can either continue with unsustainable development and see many of its unique natural resources disappear forever or switch policies and choose a more sustainable path into the future. This report gives an overview of what is happening, and provides key recommendations for how natural resource management can be made more sustainable.

THE GREATER MEKONG SUBREGION RISKS LOSING MORE THAN A THIRD OF ITS REMAINING FOREST COVER WITHIN THE NEXT TWO DECADES.
(WWF, 2013)

The core of the report is a series of maps, developed by WWF, describing the historical trends, current status and future projections of forests in the GMS excluding China. Future projections for the period 2009 to 2030 contrast two scenarios; an *unsustainable growth scenario*, which assumes deforestation rates between 2002 and 2009 continue, and a *green economy scenario*, which assumes a 50 per cent reduction in the annual deforestation rate relative to the unsustainable growth scenario, and no further losses in key biodiversity areas.

Forests
Recent changes: between 1973 and 2009, the GMS (excluding China) lost just under a third of its forest cover (22 per cent in Cambodia, 24 per cent in Laos and Myanmar, and 43 per cent in Thailand and Vietnam) according to WWF's analysis. In official statistics for tree cover across the whole of the GMS, these losses are partially masked by large-scale plantation establishment in Vietnam and China, where there has been a gradual replacement of natural forests by monoculture plantations. Myanmar accounted for over 30 per cent of total forest loss in the GMS over this period. At the same time, forests became far more fragmented: large areas of intact forest (core areas) declined from over 70 per cent of the total in 1973 to only about 20 per cent in 2009.

Projections: by 2030, under the unsustainable growth scenario, another 34 per cent of GMS forests outside China would be lost and increasingly fragmented, with only 14 per cent of remaining forest consisting of core areas capable of sustaining viable populations of wildlife requiring contiguous forest habitat. Conversely, under the green economy scenario, core forest patches extant in 2009 would remain intact, although 17 per cent of GMS forests would still be converted to other uses. Regardless of scenario, deforestation "hotspots" include the margins of large forest blocks remaining in Cambodia, Laos and Myanmar. The model suggests that deforestation in Vietnam will be distributed in small pockets across the country, although the greatest losses are anticipated in parts of the Central Highlands and northern provinces. This report also contains a map, constructed from historical patterns, of likelihood of conversion of any particular forest block, based on the distances from roads, non-forest areas, water, cities, and new and planned mines, along with elevation and slope.



THE MEKONG RIVER SUPPORTS THE WORLD'S LARGEST AND MOST PRODUCTIVE INLAND FISHERY, AT LEAST 35 PER CENT OF WHICH DEPENDS ON MIGRATORY SPECIES

Freshwater

The Mekong river basin contains one of the most productive and diverse river systems on Earth. Its connectivity and natural variability of flows support exceptional productivity, while sediments and nutrients sustain the landforms, agriculture, and marine fisheries of the Mekong Delta. The Mekong river system supports the world's largest and most productive inland fishery at least 35 per cent of which depends on migratory species. Thirteen unique, yet connected, ecosystems exist. Despite long-term intensive human use, the freshwater system has maintained connectivity between 11 of the 13 ecosystems in about 60 per cent of the system by area. The growing need for energy in the GMS has led to an unprecedented rate of dam building, impacting on freshwater ecosystems, the river's connectivity and flow, and the people that rely on these. Eleven dams are planned on the Mekong main stem. Main stem dams:

- Cause ecosystem collapse and biodiversity loss;
- Hinder movements of fish up and down the river system to grow or spawn;
- Harm wild fisheries in Laos, Thailand and Cambodia;
- Reduce sediments and nutrients that build and feed the delta's productivity;
- Degrade the functionality of the whole interconnected ecosystem.

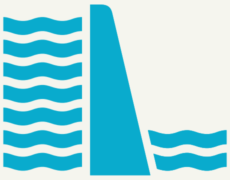
Other major river systems in the region face similar challenges, but there are opportunities to benefit from lessons learned from experience in the Mekong basin.

Wild species

The report maps the enormous decline in range of several important and iconic species of the region: the tiger, elephant, Irrawaddy dolphin and endemic saola, along with the historical range of the Javan rhino, now extinct in mainland SE Asia since April 2010. All the species described face the same fate as the rhino unless conservation becomes more effective.

© ELIZABETH KEMF / WWF-CANON

The Mekong Delta is one of the most fertile and productive deltas in the world.



FISH SUPPLY FROM THE MEKONG RIVER COULD BE CUT BY CLOSE TO 40% IF ALL PLANNED HYDROPOWER PROJECTS ARE BUILT

(Orr et al. 2012)

Drivers of change

WWF identifies four key drivers of change of the region's ecosystems:

1. Human population growth and increasing population density, along with worsening income inequality;

2. Unsustainable levels of resource use throughout the region, increasingly driven by the demands of export-led growth rather than subsistence use;

3. Unplanned and frequently unsustainable forms of infrastructure development (dams, roads and others);

4. Government policies, along with lack of integrated planning, poor governance, corruption and wildlife crime on a massive scale.

Recommendations

The report outlines ten recommendations, which WWF believes will enable GMS countries to achieve their aspirations of building greener economies:

1. Halt impacts to ecological patterns and processes that are at their breaking point. Key actions in this regard include:
    - Preventing further conversion of primary forest in the GMS;
    - Preventing the construction of dams on the main stems of major rivers, and supporting only sustainable hydropower projects on select tributaries;
    - Implementing species-specific conservation and recovery actions for endemic species; and
    - Ceasing the illegal wildlife trade.

2. Significantly increase the level of integration, the spatial scale, and the timeframe of planning.

3. Commit sufficient and sustainable financing for conservation.

4. Incorporate the values of ecosystems and the services they provide into decision-making.

5. Insist on greater responsibility of companies operating in or purchasing from the GMS.

6. Improve regional and international consultation and cooperation.

7. Empower communities and civil society to more significantly and effectively participate in decision-making.

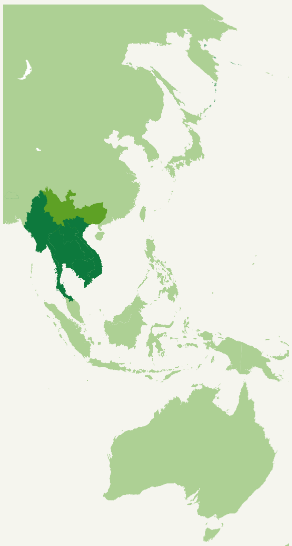
8. Enforce existing laws, policies, and regulations.

9. Ensure effective and representative protection of the region's natural heritage.

10. Restore natural capital in strategic areas.

1. INTRODUCTION

The Greater Mekong Subregion is one of the most biologically and culturally diverse places on the planet, yet one facing tremendous pressures to utilize its vast natural resources quickly and sometimes without adequate planning or safeguards.



The Greater Mekong Subregion (GMS) (***Figure 1.1***) consists of Myanmar, Thailand, Cambodia, Laos, Vietnam, and Yunnan and Guangxi in China. It is one of the most biologically and culturally diverse places on the planet, yet one facing tremendous pressures to utilize its vast natural resources quickly and sometimes without adequate planning or safeguards. Most ecosystems have already been greatly reduced in extent and their condition severely degraded by centuries of human exploitation – exploitation that has increased rapidly in the past two decades and shows little sign of slowing (Asia Pacific Forestry Commission, 2011). Diverse forest and freshwater systems provide food, livelihoods and other ecosystem services to tens of millions of people[1] (***Figure 1.2***), yet they have become precariously fragmented and are further threatened by plans for massive infrastructure development. Iconic species, including tiger and elephant, and species unique to the region, such as the saola *(Pseudoryx nghetinhensis)*, a forest-dwelling bovine, occur in only a small portion of their former ranges. Many challenges including the legacy of recent wars (Loucks et al, 2009) and ongoing conflicts, poor governance (PROFOR, 2011) and high incidence of wildlife crime and timber poaching (Lawson and MacFaul, 2010) all increase the pressures on natural systems. Recently problems of protected area downgrading, downsizing, and degazettement (PADDD; Mascia and Pailler, 2011) and land-grabbing (Human Rights Watch, 2011; Vrieze and Naren, 2012) of various sorts have become more significant.

The region's dependence on its natural ecosystems means that governments, communities, development banks and the private sector are increasingly recognizing the importance of collaborating to maintain the functions these ecosystems provide. This is already happening, in the form of the Mekong River Commission (MRC), albeit still imperfectly (Ratner, 2003). Other critical cooperative initiatives include official joint agreements by environment ministers from the six GMS countries to develop a "green, inclusive, and balanced economy" that values and conserves the productivity of natural systems and incorporates environmental aspects into national development planning (Greater Mekong Subregion Economic Cooperation Program, 2011). Awareness of the importance of natural resource management is increasing across the region. At the same time, standards of living are rising, freeing more people from the poverty trap and allowing them space to think about sustainability and natural resource management. A new air of optimism is growing in the region after decades in which many countries have suffered serious political conflicts and human rights abuses.

However, the current rapid rate of damage requires equally fast reaction if permanent environmental degradation is to be avoided. Cooperative action needs to increase fast enough to halt and reverse the current levels of conversion and degradation. The majority of the region's globally important biological heritage and supporting ecosystems occur in landscapes that cross political boundaries,

1 wwf.panda.org/what_we_do/where_we_work/greatermekong/discovering_the_greater_mekong/people_of_the_greater_mekong

© ZEB HOGAN / WWF-CANON

Few places on Earth demonstrate so dramatically the fundamental link between people and nature.

necessitating regional collaboration that reaches all levels and is long term. Cooperation, together with political will and financial investment, is needed both to conserve the remaining ecological systems and to restore formerly diverse terrestrial and freshwater ecosystems as a risk management strategy in the face of climate change and other environmental pressures. The differing histories, economies, political systems and regional tensions present challenges to such cooperation (Ratner, 2003). At this crossroads moment, regional decision-makers must invest in protecting remaining natural capital as a building block for a diverse, stable and sustainable green economy that maintains the region's productivity and diversity for the long-term well-being of its citizens.

Fortunately, building greener economies in the GMS is well within reach because the subregion is still rich in natural capital. In fact, the GMS boasts some of the highest ecosystem services values in the world (***Figure 1.2***). These high values are attributable to the many services provided by the region's diverse natural ecosystems and the fact that these services continue to benefit millions of people (***Figure 1.2***). The GMS's relative wealth in terms of natural capital provides it with many advantages compared especially with its mainland Asian neighbours (***Figure 1.2 inset***). For example, the GMS's high forest carbon stocks (***Figure 1.3***) and high biodiversity should help secure forest carbon financing through programmes to reduce emissions from deforestation and degradation (REDD+). Commitment and cooperation of many actors and institutions from local to subregional levels will be required to realize such investments.

Scenarios

The region is already undergoing severe losses of natural resources and ecosystem function, and these losses are likely to continue unless significant threats from planned infrastructure and demand for resources are addressed and decisions are taken to invest in maintaining the region's natural capital. As part of its analysis, WWF developed two contrasting scenarios, one looking at what will likely happen if things develop without due attention to managing natural resources responsibly (*unsustainable growth*) and the other looking at options for a more sustainable future (*green economy*). These scenarios represent examples of many possible futures. They are used here to help policy-makers consider the implications of decisions they make now on the subregion's natural capital and in particular its natural ecosystems. Such scenarios mirror the approach used in the WWF *Living Planet Report*, published every two years as a major state-of-the-planet report (WWF, 2012). In the current study, WWF modelled the forest change analysis. The assumptions used in building the scenarios for this purpose are explained in Chapter 2 (see Box 5). Further descriptions of these scenarios are included in other sections as a basis for discussion. Thus, the scenario descriptions below and in other chapters should be read as contrasting storylines intended to catalyse dialogue about the region's future development. The green economy scenario constitutes an outline of WWF's vision for the region.

Unsustainable growth

This scenario assumes a sustained high demand for land and agricultural products, coupled with weak institutions and governance, together leading to continued region-wide forest loss and degradation, which is assumed to continue at a constant rate. Forces of greater industrialization and urbanization, as well as agricultural intensification and rural out-migration, which might be expected to slow the rate of forest loss, are balanced by higher demand for forest products. Illegal logging and forest clearing continues, particularly near existing agricultural areas, but also even in protected areas.

For a region with its natural capital already under severe stress, an unsustainable growth strategy is likely to effect a sharp deterioration of ecosystem viability and ecosystem services. Accelerating subsistence and market demand from within and outside the subregion for land, cash crops and wood products leads to further loss and degradation of remaining forests in all countries (FAO, 2011b), including increasing encroachment in protected areas. Conversion of forest to agriculture remains high, particularly in lower-income Cambodia, Laos and Myanmar (FAO, 2011b). Poor governance and weak rule of law facilitates illegal timber harvesting on a large scale. Other drivers, such as land grabbing by foreign governments and large corporations, and badly managed and poorly planned economic land concessions, hamper implementation of sustainable forest management.

Loss of forest cover from important montane and coastal areas puts resident communities at increased risk from natural disasters. In middle- and upper-income GMS countries such as Thailand and Vietnam, greater industrialization, urbanization and agricultural intensification slow or reverse the rate of forest loss in some areas, though the demands of a large population for energy and fluctuations in food prices continue to drive forest degradation and loss.

Forest loss increasingly degrades natural capital and associated environmental services (FAO, 2011a; Achard et al., 2002), which, in turn, can promote further degradation. In the near future, government policies tend to prioritize rapid economic growth at the expense of protecting environmental services or longer-term returns. Implementation of green economy polices is hindered by a lack of enabling conditions or other factors, and is too weak to offset the drivers of degradation. Within government, there is poor understanding and/or implementation of forest management, poor coordination among forestry and other sectors (e.g. energy, agriculture, mining), and inadequate funding for and coordination of adaptation activities. This continues to undermine the capacity of forests in the GMS to adapt to climatic changes and provide ecosystem services to help human communities adapt to expected climate change. Low wages, a system of patronage and widespread corruption further weaken efforts at sustainable management. Focus on technological fixes rather than maintenance and restoration of natural capital fails to mitigate impacts of climate change or rehabilitate degraded ecosystem services.

Green economy

A green economy scenario incorporates systematic land-use planning, as well as institutional and market mechanisms designed to reduce human impacts and allow degraded ecosystems and their associated natural capital to recover while generating sustainable financial flows. Consequently, this scenario assumes deforestation throughout the subregion will be 50 per cent less than under the unsustainable growth scenario, and virtually zero in protected areas and other key biodiversity areas (see Box 5 for details).

Applying enhanced knowledge, revenue and political stability, countries across the GMS adopt strategies to reduce human impacts and allow degraded ecosystems and the natural capital and environmental services they provide to recover:

1. "Climate-smart" planning (Kareiva et al., 2008) is implemented for sustainable low-carbon growth throughout the region.
2. Newly developed financing mechanisms are applied to support restoration of diverse forest cover by replanting native species, alongside ongoing mono-specific plantation establishment.
3. Institutional and formal market mechanisms, such as ecotourism and payments for environmental services (PES), develop and advance to protect forests while providing livelihoods (Chaudhury, 2009)
4. Illegal logging and forest clearance are addressed through processes such as the European Union's FLEGT Action Plan and Timber Regulation, the amended Lacey Act in the United States and similar initiatives being developed in other consumer countries
5. Ecologically representative protected area systems are completed throughout the GMS, with regulations enforced, poaching controlled and the system effectively managed.
6. Reducing emissions from deforestation and degradation (REDD+) projects (Chenery et al., 2009) are employed to enhance forest carbon stocks, including in protected areas, and to stabilize and reconnect remaining forest patches.

These efforts, in turn, help reduce regional impacts of climate change and generate financing for sustainable rural development. With improved governance and associated management of forests and protected areas, natural ecosystems and their endangered species are expected to recover.

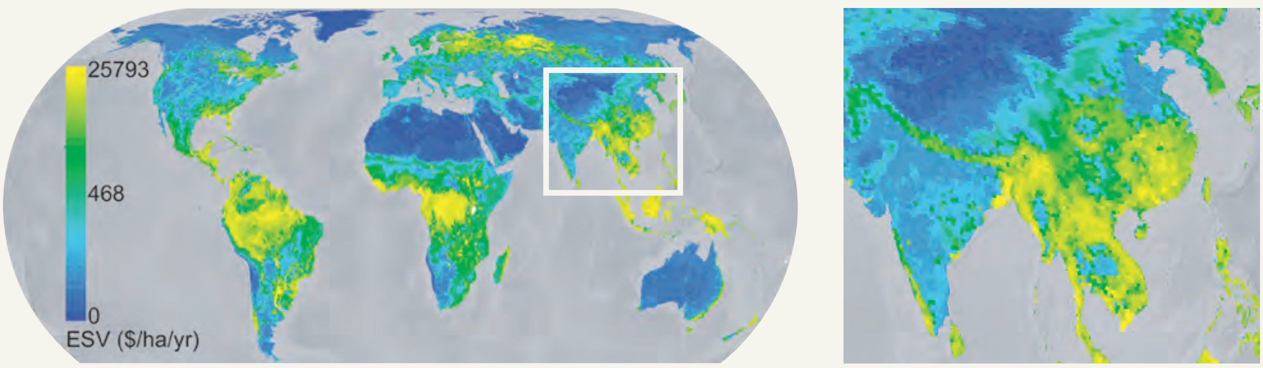
Figure 1.1.
The Greater Mekong Subregion (GMS)
with principal features (topography, Mekong River and delta, major cities).
Credit: WWF.
Data Source: elevation data: NASA Shuttle Radar Topography Mission (SRTM)

Elevation (m)

300

0

Figure 1.2. (below) Estimated values (US$/ha/year) of ecosystem services (including food, water, fibre, climate regulation, water protection and erosion control) realized by individuals across the planet, and the GMS (inset).
Areas with brighter yellow have higher ecosystem service values because they provide many services and many people are benefiting from them. The GMS stands out in mainland Asia for its high ecosystem service values. These high values are attributable to the fact that the subregion's natural capital, although degraded over the past several decades, is still relatively intact. (Source: Turner et al., 2012).



FORESTS IN THE GREATER MEKONG SUBREGION STORE MORE THAN 320 MILLION TONNES OF CARBON

(Saatchi et al. 2011)

Forest carbon

High

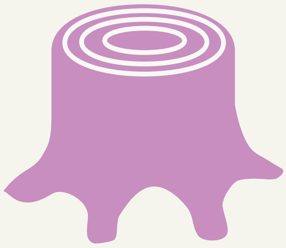
Low

Figure 1.3.
Forest carbon stored in forests of the GMS.
Across the GMS, forests store an estimated 320 million tonnes of carbon. Source: Saatchi et al., 2011.

2. FOREST ECOSYSTEMS

Introduction and changes over the past 50 years

Before the 1970s, the GMS was a highly forested region. Wet evergreen forests covered the Cardamom and Elephant Mountains of Cambodia and the Annamites in Vietnam, while evergreen, semi-evergreen and dry dipterocarp forests dominated the landscapes of northern and central Thailand, Laos and Cambodia (MRC, 2003) (***Figure 2.1***). In contrast to the Lower Mekong region, natural forests in Yunnan and Guangxi were heavily exploited after the People's Republic of China was founded in 1949, and by the 1970s large areas of primary forest had been degraded to post-extraction secondary forests (Zaizhi, 2001). These included a significant proportion of China's tropical rainforests and subtropical evergreen broadleaved forests, originally distributed across Yunnan, Guangxi and other parts of the country's southern subtropical zone (Dai et al., 2011).



THE GREATER MEKONG HAS RETAINED ABOUT 98 MILLION HECTARES OF NATURAL FOREST, JUST OVER HALF OF THE REGION'S LAND AREA.

(WWF, 2013)

Most of the natural forest ecosystems of the GMS are now reduced, severely fragmented or degraded (Chaudhury, 2009; Stibig et al., 2007). Large areas of lowland forest have been cleared, primarily for rice and other agricultural production, increasingly by industrial actors rather than individual farmers. State restrictions on industrial logging and growing demand for timber in China, Thailand and Vietnam have resulted in indirect land-use change in other countries of the GMS and further afield through increased timber harvesting for export (Global Witness, 2009; Meyfroidt and Lambin, 2009; WWF, 2009). In addition to logging concessions and illegal forest conversion, some forests are in effect bartered by being exchanged as in-kind payment during infrastructure development projects; this system tends to be particularly wasteful of forest resources.

Among the other drivers of forest conversion is the production of export commodities such as rubber, sugar, rice (Baumüller, 2008) and, increasingly, biofuels (Yang et al., 2009). Some natural forests are also being replaced by tree plantations (Moeliono et al., 2010). Mangrove forests have been cleared for several alternative land uses including rice production and shrimp farms throughout the region. Large expanses of mangroves were destroyed with defoliants in the Mekong Delta in the 1960s and 1970s during the war (Quy, 2005). Between 1980 and 2005, Lower Mekong countries (Cambodia, Myanmar, Thailand and Vietnam) lost an estimated 222,650ha of mangroves (see Table 2.1).

The clearing of forests along major rivers threatens hydrologic and ecological processes (Chapter 3) and the well-being of human cultures that have adapted to the high productivity of floodplain ecosystems. Forest clearing on steeper terrain has been more recent, reflecting the increasing demand for wood products, agricultural land and accompanying infrastructure. Natural forest habitats, along with their resident wildlife (e.g., Baltzer et al, 2001; Tsechalicha and Gilmour, 2000 – see Chapter 4), face virtual elimination outside of protected areas if current development trends toward intensive agro-industry continue.

Forest loss and degradation in the GMS is a major source of greenhouse gases (ADB, 2009). Individual country statistics give a picture of what is happening. FAO data indicates that between 1990 and 2005 average annual emissions from deforestation in Cambodia totalled 84 million tonnes and in Myanmar 158 million tonnes (Table A2, World Bank, 2010). In 2010, emissions from deforestation and degradation were estimated at 60 million tonnes in Laos (Climate Investment Funds)[1]. More recent estimates of emissions based on remote sensing data and spatially explicit analyses are more conservative. Based on a global, spatially explicit analysis of forest extent and loss, between 2000 and 2005, median annual emissions from deforestation in the GMS (except China) totalled 76 million metric tonnes (calculated from Table S2 in Harris et al., 2012).

Table 2.1
Mangrove loss (ha) in Lower Mekong countries between 1980 and 2005.
Source: The World's Mangroves 1980-2005 (FAO Forestry Paper 153, Chapter 5)
Note: China is excluded from this analysis because of a lack of data. However, recent assessments indicate that mangrove forests in Guangxi have been similarly converted and degraded over time. According to Chen et al. (2009), in 2002 Guangxi's remaining mangroves covered only 8,375ha.

	1980	1990	2000	2005
Cambodia	91,200	82,400	73,600	69,200
Myanmar	555,500	536,100	516,700	507,000
Thailand	280,000	250,200	244,100	240,000
Vietnam	269,150	213,500	157,500	157,000

Natural forest loss needs to be distinguished from changes in overall land area under tree cover. Concurrent with the loss of native forests in the GMS, the overall area under trees in Yunnan and Guangxi in China, and in Vietnam, has increased dramatically owing to large-scale reforestation and afforestation efforts. In Vietnam, reforestation has been mainly with monoculture plantations of exotic species (MRC, 2003), particularly acacia and eucalyptus. Similarly, in China, most of the increase in forest cover has come from plantations, including shelterbelts, economic tree crops and orchards (Rozelle et al., 2003; Song and Zhang, 2010).

According to national reports, the establishment of new forest cover in China and Vietnam has driven a regional forest "transition" in the GMS, with overall forest cover increasing by about 8.1 million hectares between 1990 and 2010. WWF welcomes the substantial efforts that the countries of the GMS have made to provide a secure supply of timber and other products by establishing plantations, particularly in China and Vietnam. Well-managed plantations (ideally certified to Forest Stewardship Council standards or equivalent) can provide a range of goods and services for industries and local communities. However, plantations cannot be viewed as equivalent to natural forests in every respect. Most plantations, and in particular fast-growing plantations, support only a small range of wild species, and do not supply a full range of ecosystem services. For local communities, tree plantations do not supply non-timber forest products such as fodder, medicines and foods, although they can provide fuelwood and housing timber. Plantations can also reduce erosion and protect against extreme weather, thus helping to stabilize local farming systems. They therefore have an important role in the landscape, but only as one part of a sustainable forest mosaic that combines natural forests, plantations, agricultural land, infrastructure and settlements to meet the needs of multiple stakeholders (Chenery et al., 2009; The Center for People and Forests, 2012).

1 See https://www.climateinvestmentfunds.org/cifnet/?q=country/lao-peoples-democratic-republic

IN 2000, LAND-USE CHANGE AND THE FORESTRY SECTOR CONTRIBUTED 75 PER CENT OF SOUTHEAST ASIA'S EMISSIONS.

(ADB, 2009)

Forest change analysis: methods, assumptions and limitations

The forest change analysis presented in the next sections of this chapter was motivated by the need to understand where the change in forest cover is happening, not just what form it takes. Conservation planners use the kind of spatially explicit analysis presented below to plan and prioritize conservation actions. Likewise, to allocate land uses effectively and efficiently, and achieve as many of the benefits from land and especially forests as possible, decision-makers need to understand forest trends across the landscape. Without such information, it is difficult to direct resources and actions appropriately toward hotspots of deforestation or degradation, or to develop and implement policies that enable actions to reduce deforestation and enhance the supply of forest goods and services.

Assessing forest change in a spatially explicit way is increasingly possible due to the greater availability of remote sensing imagery, tools and approaches for interpreting this imagery in robust ways. The maps presented below are based on the best available interpreted data. As such, they represent a state-of-the-art, spatially explicit assessment of forest change over the period 1973-2009.

The WWF analysis marks a step forward in our understanding of the dynamics of forest cover in the GMS. However, it remains approximate. Box 1 explains some of the constraints faced by the WWF analysts, how these were addressed, and what limitations remain. The WWF analysis also differs in methodological approach from the FAO Global Forest Resource Assessments, which we also draw on in this report. Box 2 explains how and why the FAO data are different and thus why WWF undertook a separate, spatially explicit analysis of forest cover.

MITIGATION ACTIONS SHOULD PUT PRIORITY ON EFFORTS TO AVOID DEFORESTATION, ENCOURAGE REFORESTATION AND AFFORESTATION, AND PROMOTE SUSTAINABLE FOREST MANAGEMENT IN THE FORESTRY SECTOR

(ADB, 2009)

Box 1. Limitations of the forest change analysis

WWF had to confront various challenges to produce the maps shown in Figures 2.1, 2.3, 2.4, 2.5 and the corresponding maps in Appendix I. Major challenges and our solutions are described below.

Challenge: Processing and interpreting primary remote sensing data is very time consuming and cost prohibitive.

Solution: WWF used secondary (i.e., processed) datasets (see Online Methodology and Appendix II for source information).

Challenge: Remote sensing data at appropriate and similar resolution was not necessarily available for all countries for the same time periods of the change analysis.

Solution: WWF compiled comparable data for the GMS countries for five years over the past 50 years – 1973, 1985, 1992, 2002 and 2009 – from different datasets (see Online Methodology and Appendix X.X for source information). Unfortunately, data for Yunnan and Guangxi was not available for these years, so we excluded China from the analysis. Data for Vietnam was also unavailable for 1992, but was available for all other time steps so we were able to include Vietnam in the analysis.

Challenge: The lack of data for Vietnam in 1992 and also cloud cover obscuring some land areas in all the countries posed a substantial problem.

Solution: We assumed that any area (pixel) classified as forest in the most recent point in time should be classified as forest in previous time steps. For Vietnam, this assumption meant that any area classified as forest in 2002 would also be classified as forest in 1992. For areas obscured by clouds (anywhere in the region) in 1973, 1985 and 1992, but classified as forest in 2002, we also classified them as forest for the previous years. We recognize that this approach may, in some cases, misclassify non-forest areas that were afforested or reforested between earlier years and 2002, particularly in Vietnam.

Challenge: Due to seasonal flooding especially in coastal areas, but also in some low-lying areas, as well as wetland drainage and dam construction, we found that areas classified as forest in one year became water in a subsequent year or vice versa.

Solution: WWF did not attempt to modify the results because we did not have the resources to ground-truth the imagery and because the proportion of areas where we encountered this challenge was relatively small and mostly near the coasts. We point out this challenge here because there are slight inaccuracies in the change statistics (among the three classes: water, non-forest and forest).

Challenge: Available remote sensing datasets do not distinguish between plantations and natural forest, or relatively undisturbed and degraded forests.

Solution: WWF could not overcome this challenge; thus, all maps and statistics reported from the analysis include plantations and natural forests. One of the key messages of this report is that investments in monitoring must be made to overcome this challenge in the near future.

Box 2. The FAO Forest Resource Assessment

All six countries in the GMS provide periodic forest inventory data to the FAO, which is aggregated in FAO's Global Forest Resource Assessments; this data is useful primarily for assessing overall trends at the national level. The data is used by most organizations and in public documents because it constitutes the official statistics of each country. However, the countries reporting to FAO do not necessarily use the same definition of forest. Plantations (including oil palm, rubber, and other single-species tree crops) are often considered to be forests. Other challenges include a lack of completeness and comparability in national data, stemming from wide variations in measurement and estimation techniques (Grainger, 2008). Most importantly for the purposes of this report, the FAO data is in many cases not based on spatially explicit trend analyses, making it difficult for decision-makers to take action in specific locations where changes in forest cover or condition are most worrisome. By using spatially explicit data WWF has been able to track where forests still exist, where they have only recently disappeared and, through a trends analysis, where they are most highly at risk.

Current status and trends

WWF's forest cover change analysis indicates that the GMS, minus Yunnan and Guangxi, still retains about 98 million hectares of forest (***Figure 2.1***), just over half of its land area. By contrast, the most recent Global Forest Resources Assessment (FAO, 2010) provides an equivalent figure of about 90 million hectares, of which only 13 per cent is primary forest, about 10 per cent is in tree plantations, and the remainder (about 75 per cent) is mostly degraded natural forest that, where permitted, is naturally regenerating (***Figure 2.2b***, Corlett, 1994; FAO, 2010; FAO, 2011c) (see ***Box 3*** for definitions of these categories). According to FAO (2010), primary forest has virtually disappeared in Vietnam, is extremely low in Cambodia, and is scarce in Laos, Myanmar and Thailand (***Figure 2.2b***).

The WWF analysis allows us to draw a detailed picture of changing forest resources in the region. Between 1973 and 2009, natural forest cover fell dramatically. The GMS outside China lost just under a third of its forest cover. During this period, the proportion of forests lost in each country was 22 per cent for Cambodia, 24 per cent for Laos and Myanmar, and 43 per cent for Thailand and Vietnam (***Figure 2.2a***). However, the different sizes of the various countries mean that their proportional contributions to total forest loss vary. Forest loss in Myanmar accounted for about 31 per cent of total forest loss for the GMS, followed by Thailand (27 per cent), Vietnam (24 per cent), Laos (12 per cent) and Cambodia (7 per cent, all figures rounded). At the same time, forests became far more fragmented: intact core forest areas declined from over 70 per cent of the total in 1973 to only about 20 per cent in 2009. (see Figures 2.3a to 2.3d and Box 4 for an explanation)

WWF's spatial analysis detected some forest gain during this period, mostly in Vietnam as a result of national afforestation and reforestation programmes. This forest increase occurred in the most fragmented areas – small patches, transition forests and forest edges – and appears to have taken place in close proximity to areas of forest loss. Not all of the gains in forest cover have been captured for Vietnam, because of the missing data for 1992 and the potential misclassification of non-forest areas as forest areas (see Box 1 above). These constraints may have led to an under-estimation of the increase in forest cover in Vietnam and other countries.

© GERALD S. CUBITT / WWF-CANON

Mixed deciduous forest in Huai Kha Khaeng Sanctuary, a UNESCO World Heritage Site in West Thailand.

WWF's analysis draws entirely on satellite imagery, whereas the data used by FAO in its periodic Global Forest Resource Assessments is drawn primarily from country reporting, some but not all of which uses remote sensing methods. Comparison of the two datasets highlights some key differences:

- WWF data describes a faster rate of annual decline for each country in terms of percentage lost per year.
- The trends in WWF and FAO estimates were similar for Cambodia, Laos, and Myanmar but differed for Thailand and Vietnam. The FAO estimates show very little forest cover loss since 1990 for Thailand and a gain in forest cover for Vietnam in contrast to WWF's estimates of steady forest loss in both countries.
- In 2010, FAO reported an overall reduction in forest loss during the past decade, whereas WWF has found a continuing increase (***Figure 2.2a***), with the greatest rate of loss between 2002 and 2009. WWF attributes this difference to the significant increase in forest cover in China (and in Vietnam according to FRA, 2010), which masked ongoing loss of forests in Laos, Cambodia and Myanmar.

LOSSES OF NATURAL FOREST ARE LIKELY TO REMAIN HIGHEST IN CAMBODIA, LAOS AND MYANMAR, WHERE DEFORESTATION FROM 2010 TO 2020 IS PROJECTED AT 4.8 MILLION HECTARES (FAO, 2009).

Future projections

WWF's *Living Forests Report* (Chapter 5, publication pending) identifies part of the GMS as one of 10 "deforestation fronts", where natural forest loss of several million hectares is projected over the next 20 years. Projections for the future suggest that the region will continue to suffer from elevated rates of natural forest loss over the coming few decades, particularly in Cambodia, Myanmar and Laos, unless major shifts of policy occur and are implemented on the ground, including application of REDD+ and consumer-driven attempts to reduce the illegal timber trade, such as FLEGT.

Forest cover and naturalness

Types of change

- Forest to non-forest
- No change in forest
- Non-forest

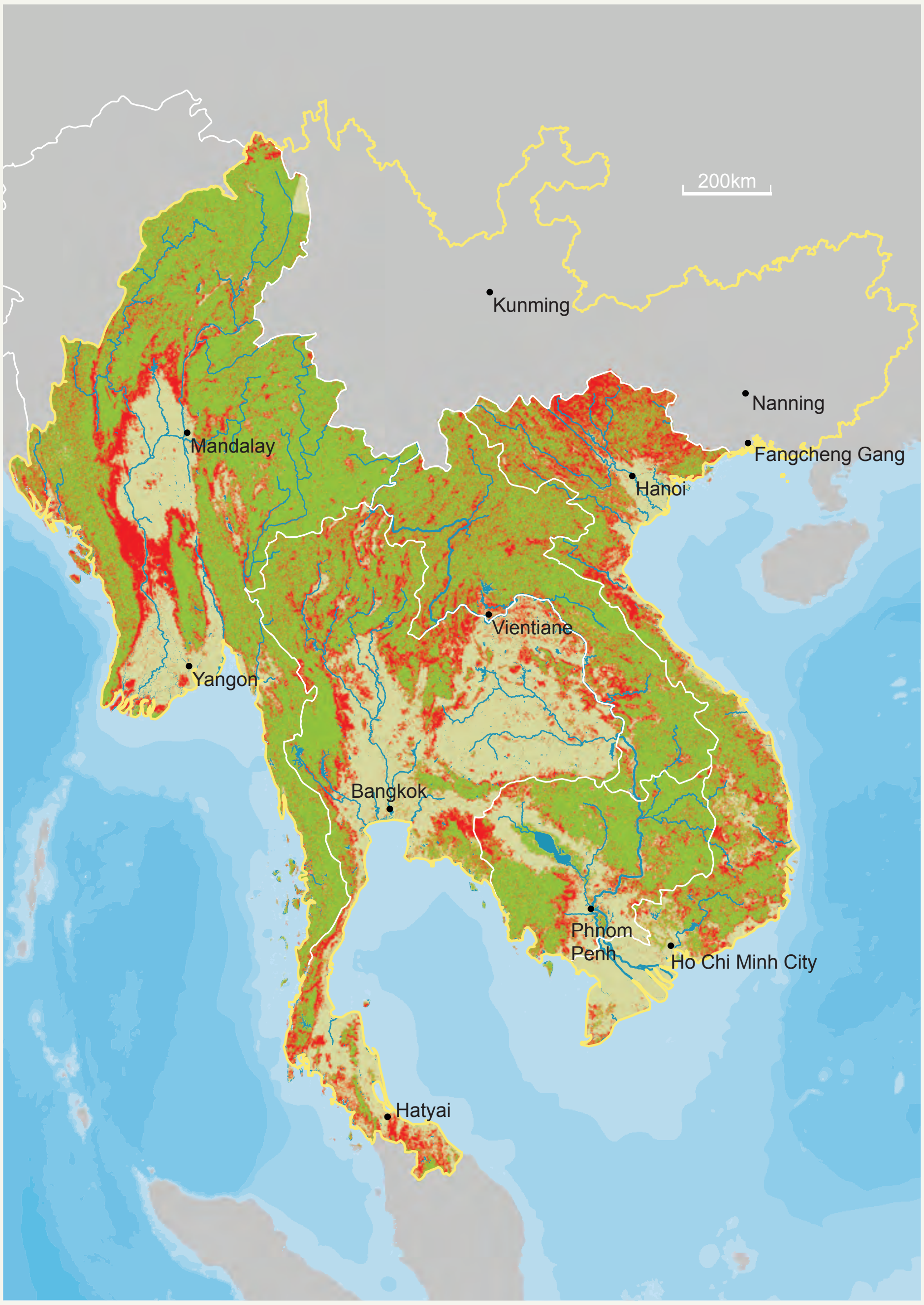


Figure 2.1.
Forest cover change in the GMS 1973-2009.
Forest area has been reduced from approximately 140 million hectares (73% of land area) in 1973 to under 100 million hectares (51%) in 2009 (green colour), a 31% decrease (in red).
Source: WWF-Greater Mekong Programme based on multiple datasets, see appendix.

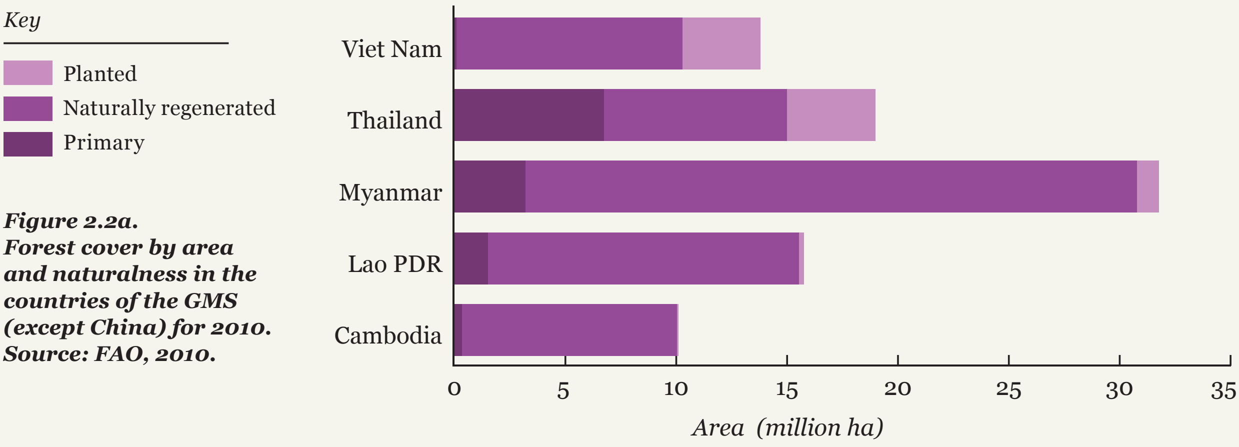


Figure 2.2a.
Forest cover by area and naturalness in the countries of the GMS (except China) for 2010.
Source: FAO, 2010.

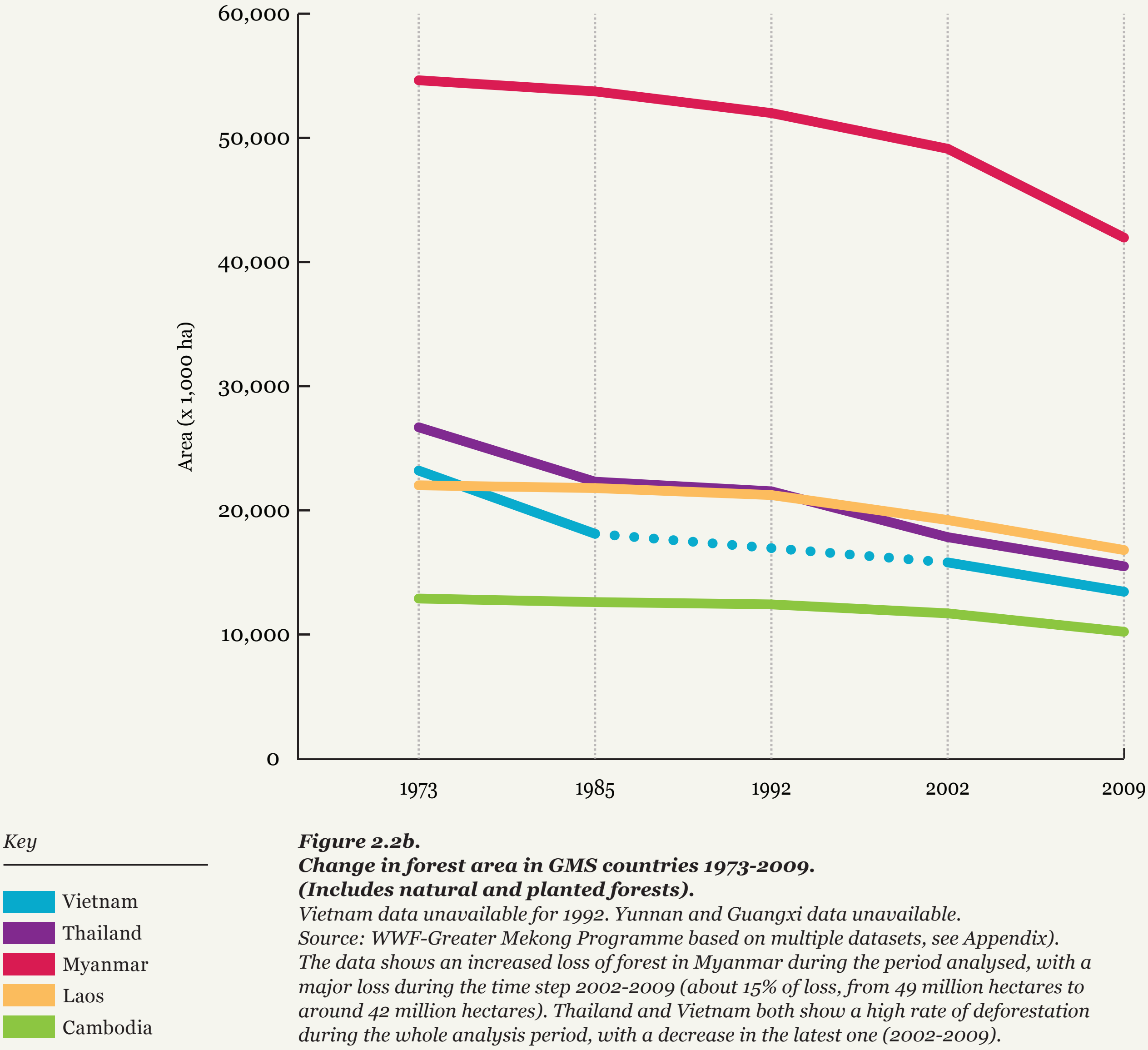


Figure 2.2b.
Change in forest area in GMS countries 1973-2009.
(Includes natural and planted forests).
Vietnam data unavailable for 1992. Yunnan and Guangxi data unavailable.
Source: WWF-Greater Mekong Programme based on multiple datasets, see Appendix).
The data shows an increased loss of forest in Myanmar during the period analysed, with a major loss during the time step 2002-2009 (about 15% of loss, from 49 million hectares to around 42 million hectares). Thailand and Vietnam both show a high rate of deforestation during the whole analysis period, with a decrease in the latest one (2002-2009).

Box 3. Levels of forest naturalness

Primary forest: largely undisturbed (directly) by humans and composed of native plant species that have regenerated naturally. Primary forest over rich soils in the GMS is complex in terms of structure (e.g. often having a tall, multi-layered tree canopy with natural breaks caused by tree falls) and species composition, with original suites of native plants, animals and fungi intact. In areas where soils are shallower and more poorly developed, the primary dry forest is simpler in terms of structure and composition but with a very productive understory, usually supporting a diverse faunal assemblage.

Modified, disturbed (or degraded) forest: forest that has been substantially logged, cleared or otherwise damaged but is still composed of native species and will regenerate naturally.

Secondary forest: forest that has regenerated, usually naturally, on land previously cleared or seriously disturbed by humans or by some extreme natural causes, such as fire. Initially dominated by fast-growing trees, vines and shrubs that form a short, single-layer canopy and provide shade needed for the climax canopy to regrow.

Planted forests: composed of trees established through planting or seeding by human intervention. Plantation forests are planted forests that comprise primarily non-native tree species and are managed to produce commercial forest products or provide an environmental service. In the GMS plantation forests primarily consist of eucalyptus and acacia species.

Forest fragmentation

In parallel to forest loss, once-intact blocks of natural forest are gradually being fragmented. Fragmented forest comprises patches of natural habitat separated by roads or other land uses. Fragmentation not only decreases total forest area: it also isolates remaining patches and their resident species; increases the proportion of edge habitat; dries soil; increases risks of fire; obstructs movements of wide-ranging and migratory species; and facilitates entry of invasive species. Fragmentation also often facilitates access by humans, including illegal access for bushmeat hunting and poaching, leading to the “empty forests” syndrome. Increased fragmentation reflects both loss of habitat and alteration of remaining habitat (Laurance, 1991; Corlett, 1994; Laurance et al., 2009).

Box 4: Fragmentation analysis

Forests were categorized into five levels of historical fragmentation for the years 1973, 1985, 2002 and 2009 (***Figures 2.3a - 2.3d***) and potential fragmentation, under two future scenarios, for 2030 (***Figures 2.6a - 2.6b***). The levels, based on a neighbourhood analysis of each pixel in the map surface (see Ritters et al., 2000), can be described as follows:

Core: Interior zones within a continuous forest. The neighbourhood (a 7-pixel x 7-pixel window) is 100 per cent “forest”, and so are all neighbours of a pixel.

Patch: The neighbourhood is 40 per cent or less forest. Represents primarily small patches of less connected forest dispersed from a core area.

Transition: Between core and patch typology, these represent areas with approximately 40-60 per cent forest that are at the limits of connectivity. Lower ends of the range (lower percentage of forest cover) will be more fragmented, while higher ends (higher percentage forest) are more connected to core areas.

Edge: Represents forested pixels bordering “non-forest”.

Perforation: Represents an area of non-forest inside forest (like a doughnut hole).

Forest in five levels of predicted fragmentation are presented for the year 2030, under an unsustainable growth scenario (***2.6a***) and a green economy scenario (***2.6b***), using the same levels of fragmentation (core, patch, transition, edge, perforation) and methods of fragmentation analysis as above. For both scenarios, the value of each pixel was generated using a combination of values for the following parameters: distance to roads, distance to non-forest, distance to water (coasts and rivers), elevation, distance to cities. The green economy scenario differs by assuming a 50 per cent reduced deforestation rate (overall); no deforestation inside protected areas, key biodiversity areas or “core areas”; and a 1km “no deforestation” buffer on either side of rivers.

Source: WWF-Germany using the software created by DLR-Deutsches Zentrum für Luft und Raumfahrt, and methodology from Riitters et al., 2000.

Forest fragmentation type

- Core
- Perforation
- Transition
- Edge
- Patch

Figure 2.3a. Fragmentation index for forests in the GMS, 1973

Forest fragmentation type

- Core
- Perforation
- Transition
- Edge
- Patch

Figure 2.3b. Fragmentation index for forests in the GMS, 1985.

Forest fragmentation type

- Core
- Perforation
- Transition
- Edge
- Patch

Figure 2.3c. Fragmentation index for forests in the GMS, 2002.

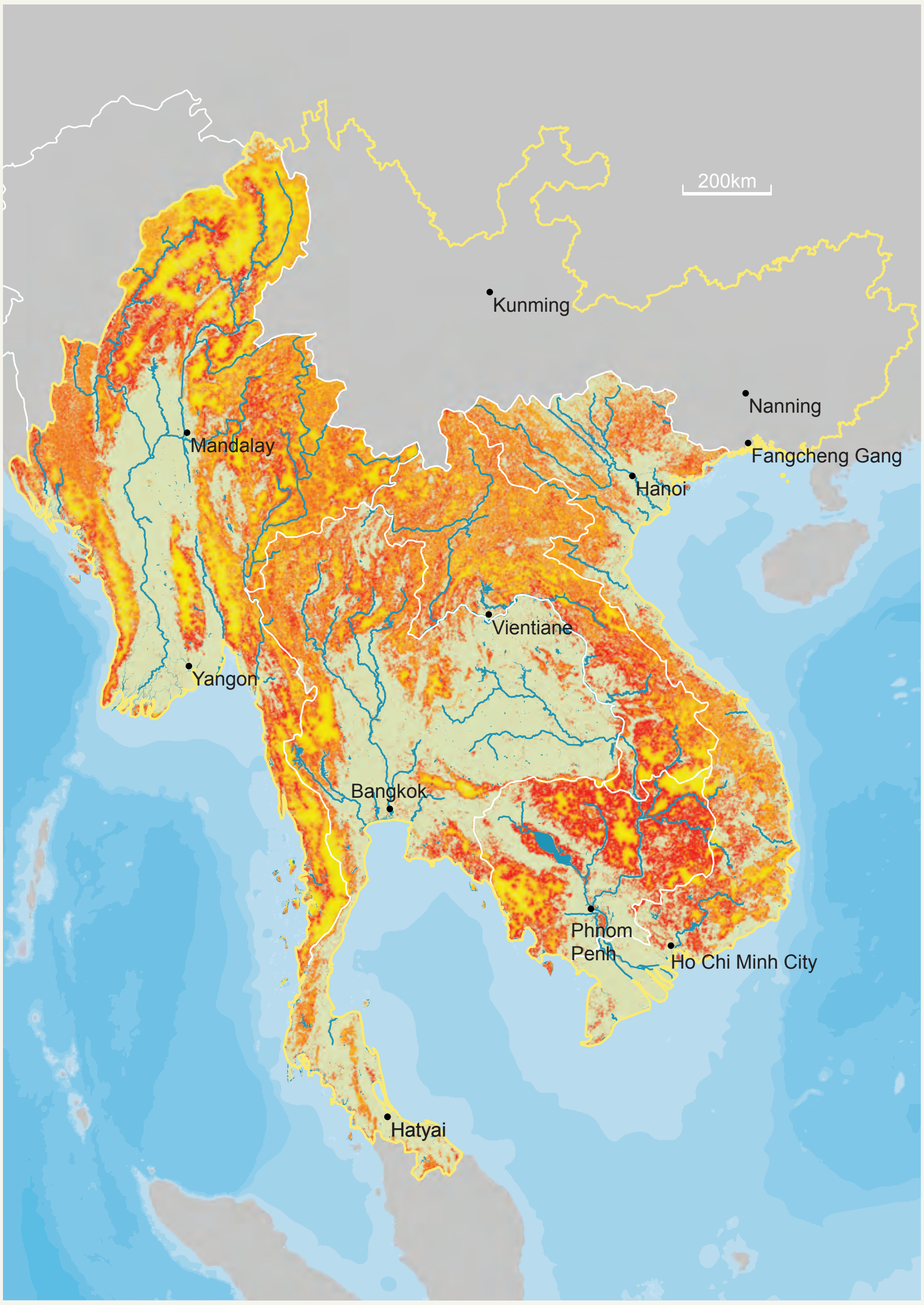
Forest fragmentation type

- Core
- Perforation
- Transition
- Edge
- Patch

Figure 2.3d. Fragmentation index for forests in the GMS, 2009.

Forest futures

Many development pressures and trends indicate that natural forests will continue to be converted in the GMS. WWF used a computer model to predict the likelihood of any particular forest block being cleared based on its distance from roads, non-forest areas, water, cities and mines (new and planned), along with its elevation and slope (see Box 5). This was combined with information on the location of historical deforestation in relation to each variable, giving a rank of areas by likelihood of conversion. The resulting map shows major areas of threat in Cambodia, western Myanmar and southeast Thailand (***Figure 2.4***).



Likelihood of deforestation

High

Low

Figure 2.4.
Risk map of likelihood of conversion from forest to no forest in the GMS *based on changes from 2002 to 2009 and on statistical correlation with driver variables (distance to roads, rivers, cleared areas, and mines, as well as elevation and slope). Source: WWF-Germany using Idrisi Taiga Land Change Modeller (Clark University, 2009).*

Future scenarios

The future scenarios summarized in the introduction were applied to forests of the GMS excluding China (due to data limitations). It is important to emphasize that we did not model climate change or otherwise explicitly include climate change impacts in the land-use change model we used to compare the scenarios. Nor did we include other potential drivers of change. The key technical assumptions relating to the scenarios are described below in Box 5. Modelling these scenarios indicates that by 2030, under the unsustainable growth scenario, 34 per cent of GMS forests would be cleared (***Figure 2.5***) and become increasingly fragmented (***Figure 2.6a***), with only 14 per cent of remaining forest consisting of core areas capable of sustaining viable populations of wildlife requiring contiguous forest habitat. Conversely, under the green economy scenario, core forest patches extant in 2009 would remain intact (***Figure 2.6b***), although 17 per cent of GMS forests would still be converted to other uses (***Figure 2.5***). Deforestation "hotspots" regardless of scenario include the margins of large forest blocks remaining in Cambodia, Laos and Myanmar (***Figure 2.5***). The model suggests that deforestation in Vietnam will be distributed in small pockets across the country, although parts of the Central Highlands and Northern provinces appear to suffer the greatest losses (***Figure 2.5***).

Box 5: Assumptions about the scenarios

The unsustainable growth model assumes a constant rate of deforestation, which is based on the observed 2002-2009 change from forest to agriculture. The green economy scenario includes a 50 per cent overall reduction in deforestation rate. Both models use "distance to agriculture" as a dynamic variable, which is recalculated at yearly intervals. For every time step a new distance to agriculture area is determined and used for the next time step.

The modelling of the variables related to past change (2002-2009) is done by machine learning neural networks using Idrisi Land Change Modeller (Eastman, 2009). It takes samples of points that have changed, and samples of points that have not changed, and adjusts a multivariate function in a series of iterations (n=10,000) until criteria of accuracy are met, using a separate sample of random points as validation. In each case, the models achieved an accuracy of 70-75 per cent.

Once these multivariate models have been created, the prediction is then completed with transition probabilities from the known data sets, and uses Markov chains to determine exactly how much land is expected to change and predict these changes into the future.

Software: Eastman, J.R., 2009. IDRISI Taiga (Worcester, MA: Clark University).

Scenario 1: unsustainable growth *Figure 2.5*

The unsustainable growth scenario was produced using material from scenarios developed according to different levels of willingness and ability to protect forest services by 2020 based on the socioeconomic condition of the country (Chaudhury, 2009).

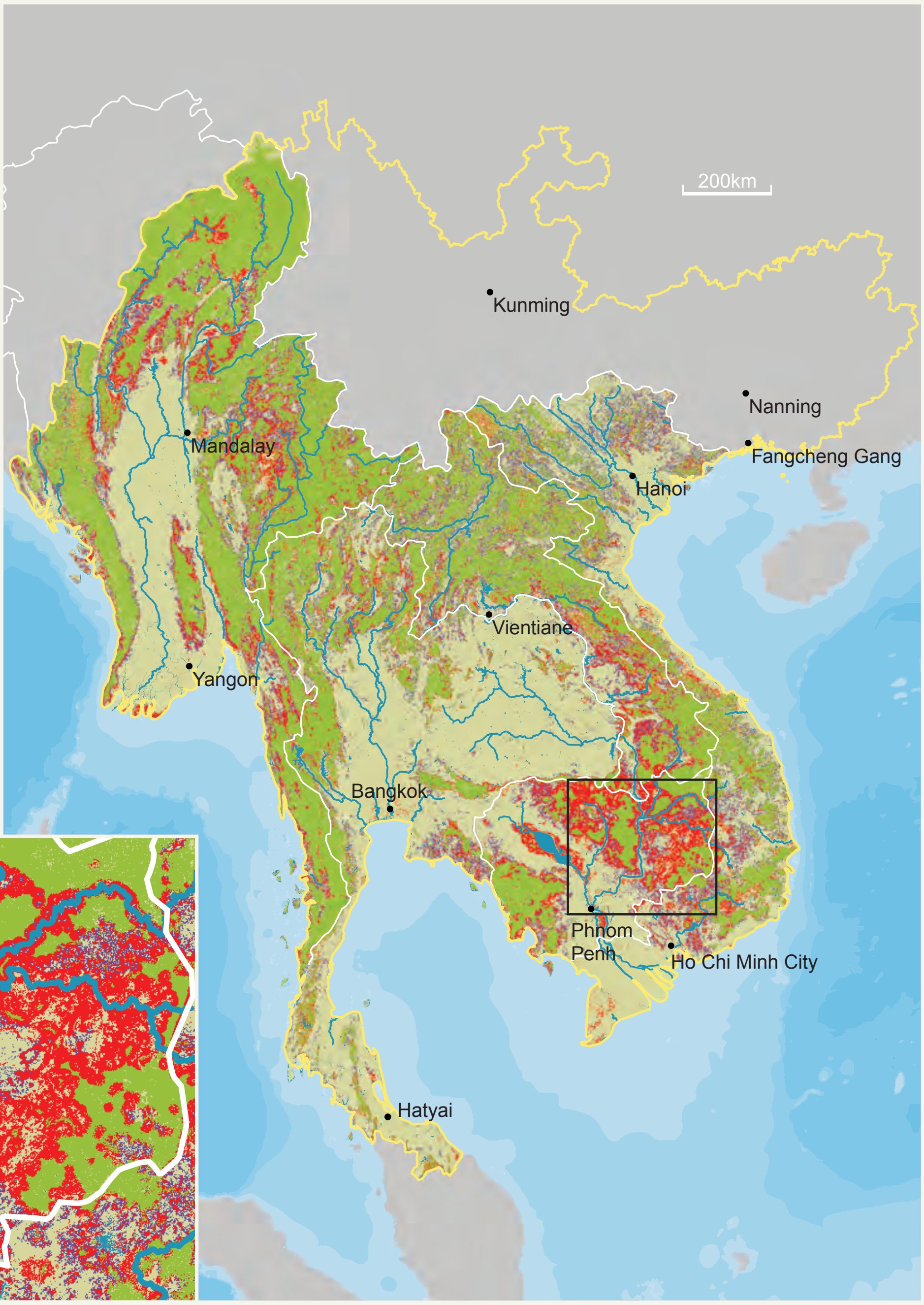
Scenario 2: green economy: systematic planning and sustainable development *Figure 2.5*

The green economy scenario is generated using the same variables as the unsustainable growth scenario but assumes a 50 per cent reduction in deforestation rate, and zero deforestation in important conservation areas (key biodiversity areas, protected areas and riparian buffers).

For four **alternative scenarios** that consider macroeconomic trends and levels of aggregate demand and institutional effectiveness, please consult FAO, 2011.

Projected forest cover

- Forest lost under both scenarios
- Forest lost in unsustainable growth, conserved in green economy scenario
- Forest remaining in 2030 under both scenarios



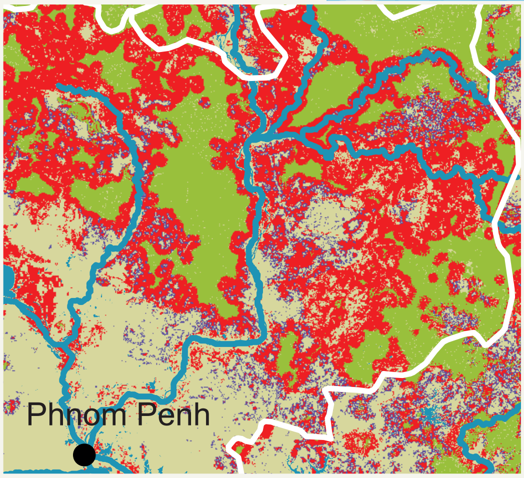


Figure 2.5. Projected forest cover in the GMS in 2030 under an unsustainable growth scenario and green economy scenario. *Inset shows details for eastern Cambodia, which our analysis shows is a deforestation front. Source: WWF-Germany, based on multiple datasets, see Appendix.*

Forest fragmentation type

- Core
- Perforation
- Transition
- Edge
- Patch

Figure 2.6a. Potential fragmentation index for forests in the GMS in an unsustainable growth scenario, 2030.

Forest fragmentation type

- Core
- Perforation
- Transition
- Edge
- Patch

Figure 2.6b. Potential fragmentation index for forests in the GMS in a green economy scenario, 2030.

3. FRESHWATER SYSTEMS

Introduction and changes over the past 50 years

The Mekong river basin is one of the most productive and diverse river systems on Earth and is particularly rich in migratory fish species. Its connectivity and natural variability of flows drive both its exceptional productivity and basin-wide fish migrations (Coates et al., 2003). Sediments and nutrients from upriver sustain the productive Mekong Delta which in turn supports 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[1] (ICEM, 2010; WWF, 2011).

While not at quite the same scale, much of the Mekong's uniqueness and significance to livelihoods, agriculture and industry is also reflected in other major river systems in the region. Indeed, for several large rivers, including the Salween and Irrawaddy, there is still an opportunity to retain ecological connectivity that has already been lost on the upper Mekong. In this chapter we focus on the situation of the Mekong basin in hope that patterns and lessons learned can positively inform decisions that relate to all complex river basins in the region.

THE MEKONG RIVER SYSTEM SUPPORTS AROUND 850 FRESHWATER FISH SPECIES INCLUDING THE MEKONG GIANT CATFISH, ONE OF THE WORLD'S LARGEST FRESHWATER FISH.

Thirteen unique, yet connected, ecosystems have been identified in the basin (Sindorf and Wickel, 2011; Sverdrup-Jensen, 2002) (***Figure 3.1***). Each of these ecosystems represents a unique combination of hydrologic conditions, nutrient profiles and temperature regimes, producing unique environmental conditions and associated natural communities. The strong connection among these ecosystems and the linkages between riparian and forest systems (Sheil and Murdiyarso, 2009) (e.g., through microclimates and regulation of the flow of water and sediment) both contribute to the system's high biological diversity.

The linked character of a river system presents its own responses to and challenges for human management activity: the system depends on unimpeded flow and on the maintenance of and connectivity among a variety of ecosystems – from cold highland streams to brackish channels of the delta. Power sector projections of increasing electricity demand in the GMS (ICEM, 2010) have led to an unprecedented rate of dam building, in which many projects are poorly planned from a social and environmental perspective and implemented with little consideration of the impacts on the freshwater ecosystems, the river's connectivity and flow, and the people that rely on these (Amornsakchai et al., 2000; MRC, 2009; Dugan et al., 2010; ICEM, 2010; MRC, 2010). Such disturbances affect sections both far upstream and downstream, yet environmental impact assessments, when they are performed, have focused on discrete project sites without considering the cumulative impacts on connectivity at the sub-basin to basin levels (Dugan et al., 2010; ICEM, 2010; Sindorf and Wickel, 2011).

1 wwf.panda.org/what_we_do/footprint/water/dams_initiative/examples/mekong

Freshwater Ecosystems

- Highlands with snow influence
- Tributary on highlands
- Upland slopes
- Tributary on upland slopes
- Tributary on upland slopes
- Upper plateau
- Tributary on upper plateau
- Lower plateau
- Tributary on lower plateau
- Main stem plateau to delta
- Karstic formations
- Tributary through karstic formations
- Main stem along karstic formations

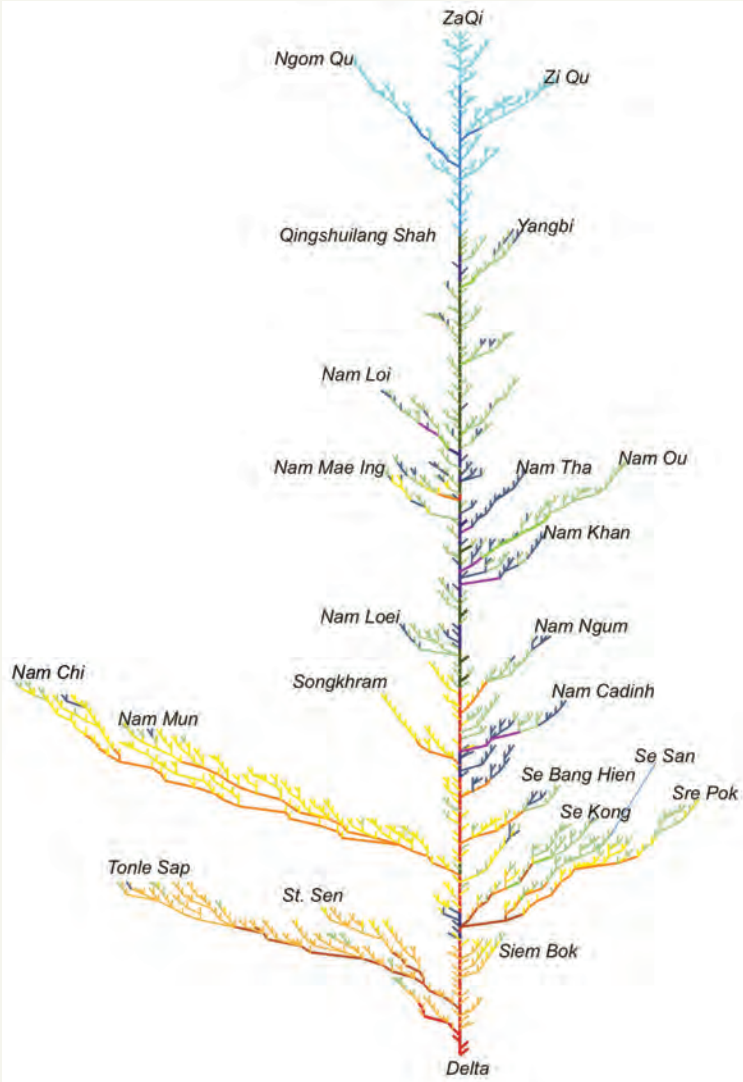


Figure 3.1. Freshwater ecosystems of the Mekong river system in a connectivity tree with the ecosystem characteristics of the main stem and main tributaries.
Source: Sindorf and Wickel, 2011.

Current status and pressures

Despite long-term intensive human use of freshwater resources in the Mekong basin, the system has maintained connectivity between 11 of the 13 ecosystems in ~60 per cent of the system by area, as well as much of its original ecological patterns and processes (Sindorf and Wickel, 2011; WWF-Germany, 2011) (***Figure 3.2a***). Nevertheless, the main threat to the persistence of the Mekong river system is the construction of dams, particularly on the main stem, such as the disputed Xayaburi dam in Laos, which will disrupt linkages among sub-basins. Of key concern is the lack of appropriately coordinated planning among decision-makers for the different portions of the basin (ICEM, 2010). Xayaburi is not the largest dam planned on the main stem, but its go-ahead would set a precedent for countries and marginalize the Mekong River Commission's Procedures for Notification, Prior Consultation and Agreement (PNPCA) and could herald even more disruptive developments, with up to 10 additional dams planned (Grumbine et al, 2012) (One non-dam hydropower project, Thako, is also planned; WWF supports this). Models indicate that although the loss of connectivity from existing dams has already negatively affected fisheries production in various Mekong sub-basins, declines in productivity to date have not substantially affected overall fisheries output (Amornsakchai et al., 2000; Coates et al., 2003). This is likely to change if planned developments go ahead (Friend et al., 2009, Cochrane et al., 2010), with major impacts downstream and on major freshwater resources such as Tonle Sap (Arias et al., 2012). Additional models also indicate that some 60 per cent of the basin is no longer free-flowing: many smaller systems are effectively “locked” behind dams (Sindorf and Wickel, 2011; WWF-Germany, 2011) (***Figure 3.3***).

Decision-makers in the Mekong river basin face a difficult dilemma: how can countries that share the freshwater resources of the Mekong River profit from a renewable energy source such as hydroelectric power without at the same time degrading the fisheries and ecological services that support at least 60 million people? To produce energy through hydropower, up to 11 new dams are planned for the main stem of the Lower Mekong River alone. Their construction will negatively impact both wild fish populations (Amornsakchai et al., 2000; ICEM, 2010) and the many people who rely on wild fish as their major source of protein. For example, once built, a main stem dam would:

- Hinder movements of eggs and young fish downstream to the Lower Mekong floodplains to grow and those of adult fish upstream to spawn;
- Harm wild fisheries in Laos, Thailand and Cambodia by flooding upstream spawning grounds and altering nutrient input and replenishment of downstream habitats (Dugan et al., 2010; ICEM, 2010; Sindorf and Wickel, 2011);
- Reduce sediments and nutrients that build and feed the Mekong Delta’s productivity;
- Degrade the functionality of the whole, interconnected ecosystem and risk exceeding thresholds that could lead to very large and rapid negative impacts (WWF, 2011).

Number of ecosystems

1
2
3
4
6
9
11

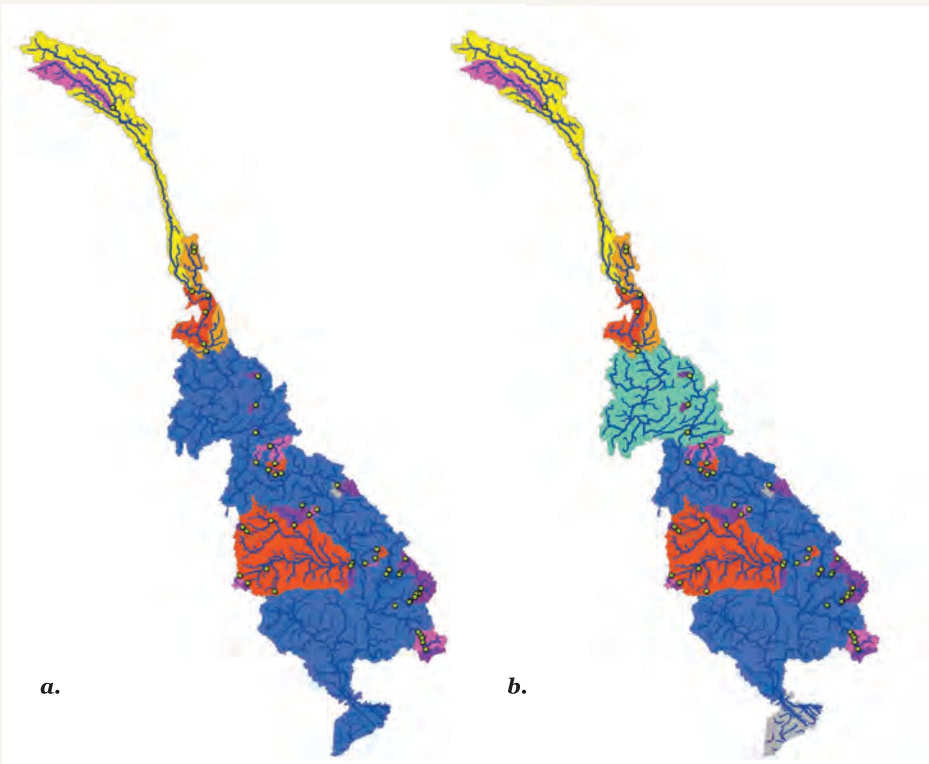


Figure 3.2. Impact of existing dams and the planned Xayaburi dam on ecosystem connectivity, expressed as number of connected ecosystems: (a) in 2011 and (b) if the Xayaburi dam is built. *If the dam is built, the number of connected ecosystems will decrease from 11 to 9 (see legend) and the proportion of the basin’s total system length that is still connected will decrease from 60% to 40%. Note that connectivity as of 2011 was already reduced due to historic dam development. Source: Sindorf and Wickel, 2011.*

Free flowing

- FF Type 1
- FF Type 2

Compromised

- C Type 1
- C Type 1b
- C Type 2
- C Type 2b

Figure 3.3. Classification of the free-flowing systems of the Mekong River with 50 large existing dams. *While 60% of the basin retains the functionality of free-flowing rivers, the flow in the main stem and some sub-basins, particularly in Thailand, China and Vietnam, has been impeded by dams. The flows of types 1b and 2 rivers with both upstream and downstream dams are most compromised. Source: Sindorf and Wickel, 2011, more details in reference section.*

The hydropower potential in the basin has been subject to a series of evaluations (King, Bird and Haas, 2007; MRC, 2009; ICEM, 2010). Results suggest that although dams would bring substantial additional income to the region, they would negatively impact fisheries, increase inequality and net poverty, and have long-term and detrimental environmental impacts. Some key aspects of river ecosystems and their functions – such as flow dynamics and the capacity of rivers to reshape ecosystem features (Coates et al., 2003) – are difficult to identify and measure and thus have been excluded from main stem hydropower cost-benefit analyses.

© ELIZABETH KEMF / WWF-CANON

Fishing and aquaculture in the Mekong Delta employ over 2.8 million apeople – 10 per cent of Vietnam's labour force.

OVER 75 PER CENT OF RURAL HOUSEHOLDS IN THE LOWER MEKONG BASIN ARE INVOLVED IN FISHERIES, BOTH FOR THEIR OWN CONSUMPTION AND FOR SALE

(MRC, 2003).

Future scenarios

Unsustainable growth

Demand for electricity in the GMS grows 6-7 per cent per year (cf. Rowcroft, 2005), and planned dams are built on the main stem (***Figure 3.3***) and numerous tributaries of the Mekong River. Connectivity among ecosystems declines markedly (***Figure 3.2***). Economic valuation of dams, especially on the main stem, continues to exclude their substantial costs to human and wildlife communities and, in the face of potential climatic effects, to the system as a whole. Multiple main stem and major tributary dams trap the sediment that rebuilds the Mekong Delta, identified as one of the three most vulnerable deltas to climate change by the Intergovernmental Panel for Climate Change (IPCC) (IPCC, 2007; WWF, 2009a), and carries nutrients that feed the delta's outstanding productivity. Reduction in sediment flow decreases the capacity of the delta to replenish itself, making it more vulnerable to threats of climate change, including sea level rise, saline intrusion into fresh and brackish water, and severe storms and subsequent coastal erosion. Serious social and economic challenges arise from the subsequent deterioration of the delta's productivity and continued decline of migratory fish populations and associated fisheries (ICEM, 2010).

35-40 PER CENT OF FISH CATCH IN THE MEKONG DEPENDS ON SPECIES THAT MIGRATE LONG DISTANCES ALONG THE MEKONG MAIN STEM AND INTO ITS TRIBUTARIES

(Baran et al., 2013);

Green economy

Consistent with the results of the MRC-commissioned strategic environmental assessment (ICEM, 2010), GMS countries agree to a 10-year delay in the approval of the main stem dams to fully consider the costs and benefits of their construction and operation (ICEM, 2010). Conservation and development plans incorporate the maintenance of the natural processes related to connectivity along rivers, across rivers and through the water column required to ensure persistence of freshwater systems and their biodiversity. Natural connectivity, together with better fishing practices – including improved processing, reducing waste and curtailment of illegal fishing – enable wild fish populations, including those of migratory species and top predators, to remain sufficiently intact to both fulfil their biological roles and sustain the region's immense fishery. GMS countries develop a comprehensive energy vision for the region, which considers the need for additional power generation capacity to meet projected increases in electricity demand. In addition to energy conservation through policy, individual behaviour change and technology, this vision includes a hydropower generation plan, which:

- Emphasizes only sustainable hydropower on tributaries, and avoids main stem dams;
- Employs rapid basin-wide hydropower sustainability assessment tool (RSAT) methodology to determine the most sustainable hydropower options in key river sub-basins;
- Includes provisions to maintain ecosystem connectivity and to mitigate any loss of flow; and
- Protects watersheds by avoiding deforestation of steep slopes.

Deciduous mixed species forest at the Thi Lo Su waterfall in Umphang Wildlife Sanctuary, West Thailand.

ECOSYSTEM SERVICES IN THE GMS

Natural habitats provide distinct services to society. The Millennium Ecosystem Assessment (MEA, 2003) divides these into four main categories:

- **Supporting services**: soil formation, nutrient cycling, primary production
- **Provisioning services**: food security, water, fuelwood, fibre, genetic resources
- **Regulating services**: climate, water flow and quality, control of disease vectors, disaster mitigation, pollination
- **Cultural services**: spiritual, recreational and tourism, aesthetic, cultural heritage, sense of place.

Ecosystem services play a huge and frequently under-reported role in the GMS, and their significance could be further capitalized on by better natural resource management and, where necessary, targeted restoration. Critical services include protein from inland fisheries, coastal protection from natural vegetation, soil stabilization and a host of freely available natural resources, many now at risk.

Inland fisheries in the Mekong watershed yield an estimated 2 million tonnes of fish per year (Wellcome et al., 2010). Freshwater fish contributes almost 80 per cent of animal protein for people in Cambodia (Hortle, 2007). Protected areas have helped regulate off-take: 60 per cent of fish come from Tonle Sap Lake, a UNESCO Man and Biosphere reserve (ICEM, 2003) and the Ream National Park in Cambodia generates an estimated US$1.2 million a year for local residents, particularly from fishing (Emerton, 2005). In Laos, fish conservation zones are co-managed as a conservation tool for fisheries, in areas selected using indigenous knowledge. Since their establishment, villagers have reported significant increases in stocks of over 50 fish species (Baird, 2000). Marine fisheries are also important: the gross value of fisheries supplied by the Hon Mun Marine Protected Area in Vietnam is estimated at US$15,538 per km2 per year through reef-related aquaculture and near-shore fishing, supporting over 5,000 people (Dudley et al., 2008).

Low-lying land and frequent storms open the Mekong Delta to serious coastal damage and natural barriers, particularly mangroves and corals, are increasingly valued. In Thailand, mangrove species such as *Rhizophora apiculata* and *R. mucronata* and *Pandanus odoratissimus*, a tree that grows in beach sand, were found to be effective barriers in part because of their complex aerial root structure (Tanaka et al., 2007). The coastal storm protection value of mangroves in Thailand has been estimated at between US$27,264 and US$35,921 per hectare (Sathirathai and Barbier, 2001). Restoring mangroves can be a cost-effective option for improving coastal protection. For example, a US$1.1 million mangrove restoration scheme in northern Vietnam saved an estimated US$7.3 million a year in sea dyke maintenance, and provided effective protection during typhoons (Brown et al., 2006).

Other natural resources remain highly important. In Nam Et National Biodiversity Conservation Area in Laos, 81 village communities depend on the area for non-timber forest products with a value estimated at US$1.88 million/year (30 per cent cash income and the rest subsistence), providing villagers in the region with a higher than average per capita income (ICEM, 2003a).

Natural ecosystems also provide an increasingly important facet of tourism, ranging from coral reef diving through to forest and mountain trekking, nature viewing, and homestays with local and indigenous people. Vietnam, Thailand and Cambodia in particular have experienced rapid growth of tourism, in part connected with nature-based tourism (Mastny, 2001).

To date there has been no comprehensive overview of the value of ecosystem benefits in the region, leading to a serious undervaluing by both politicians and even many local communities. A full review of Mekong ecosystem services is urgently overdue.

4. FLAGSHIP SPECIES

The GMS is home to approximately 5 per cent of globally threatened wildlife species (UNEP, 2006).

WITH THE RECENT EXTINCTION OF A UNIQUE SUB-SPECIES OF JAVAN RHINO, THE GMS HAS EXPERIENCED ONE OF THE MOST SPECTACULAR WILDLIFE LOSSES OF THE PAST HALF-CENTURY

(Brook et al., 2011).

Changes over the last 100 years

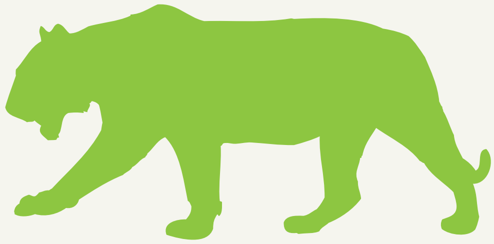
The GMS has exceptionally rich wildlife, including many species endemic to the region. But the expanding human footprint has increasingly threatened the region's globally important biodiversity, to the point of pushing many species to the verge of extinction, including some of the largest and most iconic. The dry forest savannahs of the GMS were once called the Serengeti of Southeast Asia: 100 years ago, elephants, wild cattle and other large mammals were plentiful (Bennett et al., 2002; Corlett et al., 2007; FAO, 2011b). Their movements and foraging helped to shape the ecosystems we still see today and created unique ecological features (such as isolated ephemeral ponds).

Intensive hunting and extensive deforestation together have caused virtually all larger species – including Asian elephants (*Elephas maximus*), tigers (*Panthera tigris*), banteng (*Bos javanicus*) and gaur (*Bos gaurus*) – to suffer serious declines in number and range (***Figures 4.1 - 4.4***); endemic species such as the saola (*Pseudoryx nghetinhensis*) (***Figure 4.5***), kouprey (*Bos sauveli*), and giant (*Thaumatibis gigantea*) and white-shouldered (*Pseudibis davisoni)* ibises are among the most endangered species in the world; the kouprey has not been seen for many years and is likely to be extinct. The region lost its last Javan rhinoceros (*Rhinoceros sondaicus*) to poaching in 2010 (Brook et al., 2011). Populations of primates, elephants and other dispersers of large seeds now depend almost exclusively on protected areas (Corlett, 1998), and even there they continue to be hunted and face possible extirpation. Vast areas of forest across the Lower Mekong are empty of megafauna. Loss of these large animals has altered disturbance and regeneration regimes, which have, in turn, degraded the structure and function of the ecosystems and, hence, the services they provide. Among aquatic species, the migratory Mekong giant catfish (*Pangasianodon gigas*) has declined more than 80 per cent over the last 21 years (since 1990), due primarily to overfishing (Hogan, 2011; MRC, 2009a).

© WWF GREATER MEKONG

In 2010, poachers killed the last rhino in mainland SE Asia, in Cat Tien National Park, Vietnam

95 PER CENT OF THE WORLD'S TIGERS HAVE DISAPPEARED IN THE LAST CENTURY, DUE TO DECIMATION OF THEIR HABITATS AND PREY, AND DELIBERATE HUNTING TO MEET DEMAND FOR SKINS AND IN TRADITIONAL MEDICINES (Thompson, 2010).

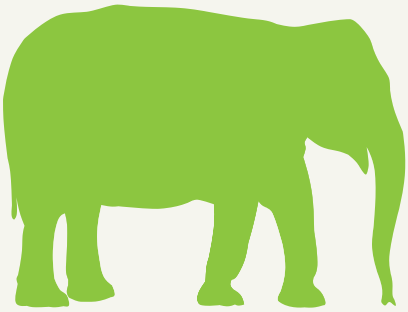


Tigers

Species presence

- Confirmed during 2011-2012
- Confirmed or compelling reports between 2002-2010
- Tiger historical distribution

Figure 4.1. Historical, confirmed or compelling reports between 2002-2010 and confirmed in 2011 and/or 2012 distribution of tiger in and around the GMS. *Source: WWF-Greater Mekong Programme based on multiple datasets, see Appendix.*



Elephant

Species presence

Historical distribution

Current distribution

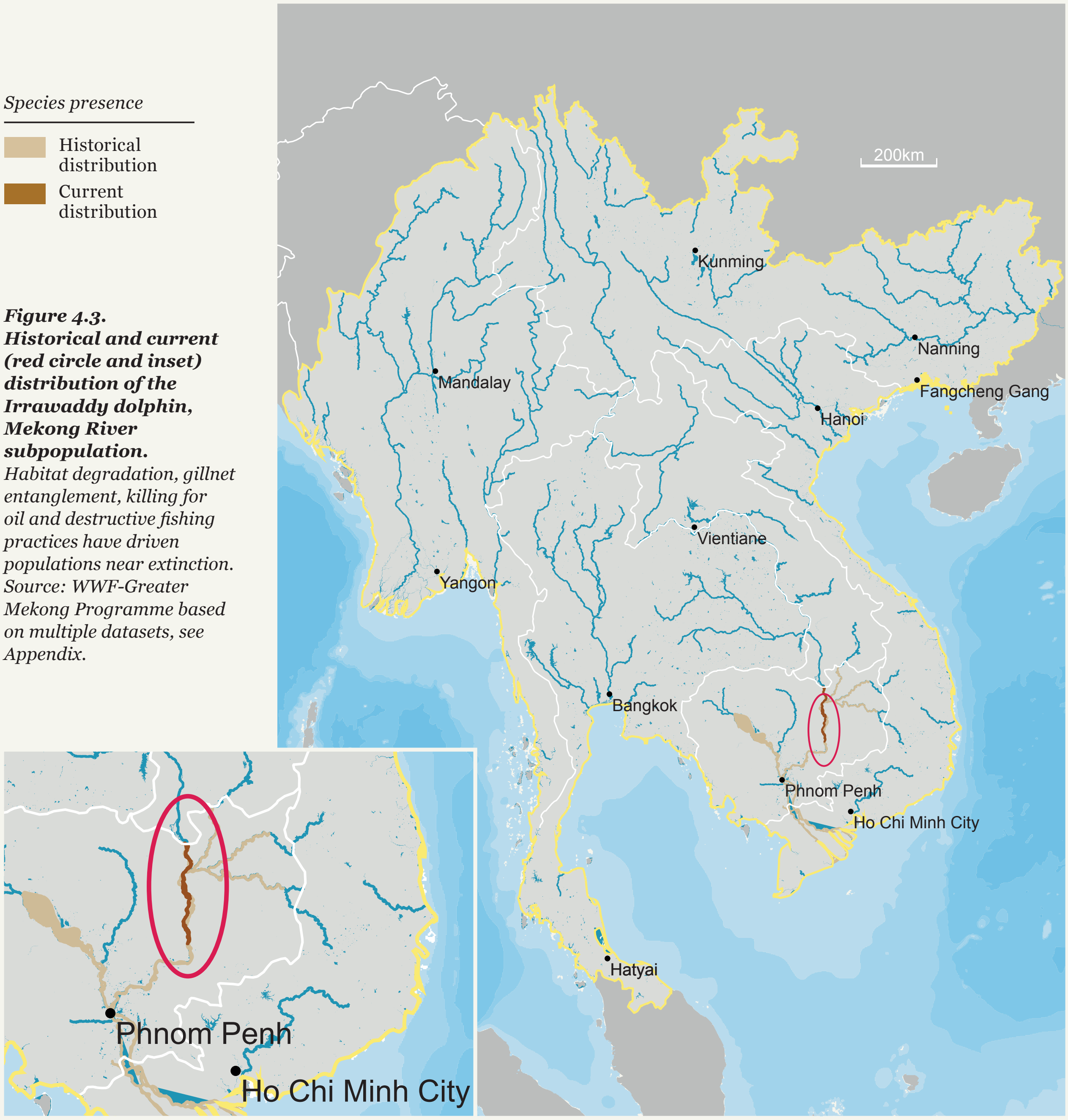
Figure 4.2. Historical and confirmed current distribution of elephant in and around the GMS.
Source: WWF-Greater Mekong Programme based on multiple datasets, see Appendix.

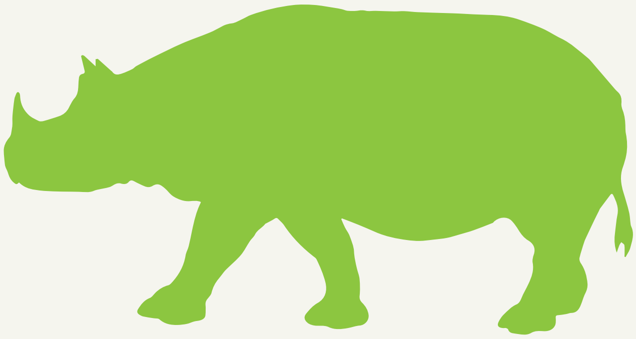
Irrawaddy Dolphins

Species presence

- Historical distribution
- Current distribution

Figure 4.3.
Historical and current (red circle and inset) distribution of the Irrawaddy dolphin, Mekong River subpopulation.
Habitat degradation, gillnet entanglement, killing for oil and destructive fishing practices have driven populations near extinction. Source: WWF-Greater Mekong Programme based on multiple datasets, see Appendix.



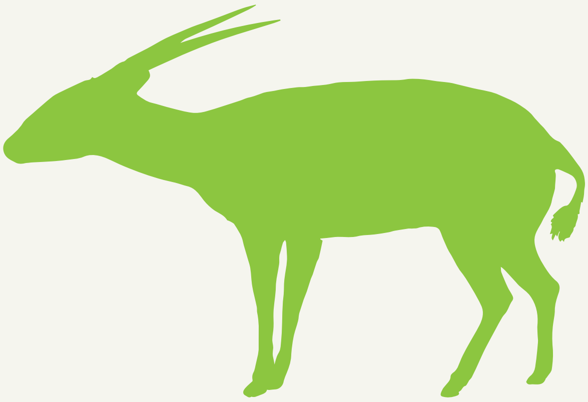


Javan Rhino

Species presence

- Historical distribution
- Last known location

Figure 4.4. Approximate historical distribution of Javan rhino.
In 2010, poachers killed the last rhino in mainland SE Asia, in Cat Tien National Park, Vietnam (red circle). Source: WWF-Greater Mekong Programme based on multiple datasets, see Appendix.



Saolas

Species presence

Historical distribution

Current distribution

Figure 4.5
Potential current distribution of saola, which is endemic to wet evergreen forest in the northern and central Annamites on the Laos-Vietnam border.
The saola was discovered by a joint government-WWF survey in 1992. There are few records of the critically endangered species, which is threatened with extinction from hunting (snares) and habitat loss throughout its narrow range.
Source: WWF-Greater Mekong Programme based on multiple datasets, see Appendix

THE RECENT LARGE-SCALE DEFORESTATION IN THE GMS MEANS THAT MANY NATIVE SPECIES, SUCH AS RARE LONG-LIVED TREES, WHILE NOT EXTINCT, MIGHT PERSIST AS "LIVING DEAD" - UNABLE TO REPRODUCE DUE TO ISOLATION CAUSED BY HABITAT FRAGMENTATION

(Sodhi et al., 2004).

NEW SPECIES ARE STILL BEING DISCOVERED IN THE GMS! BETWEEN 1997 AND 2011, SCIENTISTS DISCOVERED 1,710 NEW SPECIES. IN 2011 ALONE, ANOTHER 82 PLANTS, 21 REPTILES, 13 FISH, 5 AMPHIBIANS AND 5 MAMMALS - ALL NEW TO SCIENCE - WERE ADDED TO THE REGION'S INCREDIBLE BIODIVERSITY. THAT'S OVER 2 SPECIES PER WEEK

(Thompson, 2012).

Current status

The GMS still supports extraordinary numbers of species: over 430 mammal species, over 800 reptile and amphibian species, some 1,200 bird species and at least 20,000 species of plants. However, the subregion's unsustainably high rates of hunting, exploitation of other natural resources and habitat loss have left only about 5 per cent of its natural habitats in relatively pristine condition (Conservation International, 2007), rendering the region among the world's most threatened biodiversity hotspots. Given the high endemism and rapid rate of new species discoveries in the GMS over recent decades, the drastic loss of habitat suggests that many additional species may disappear before scientists can find and identify them.

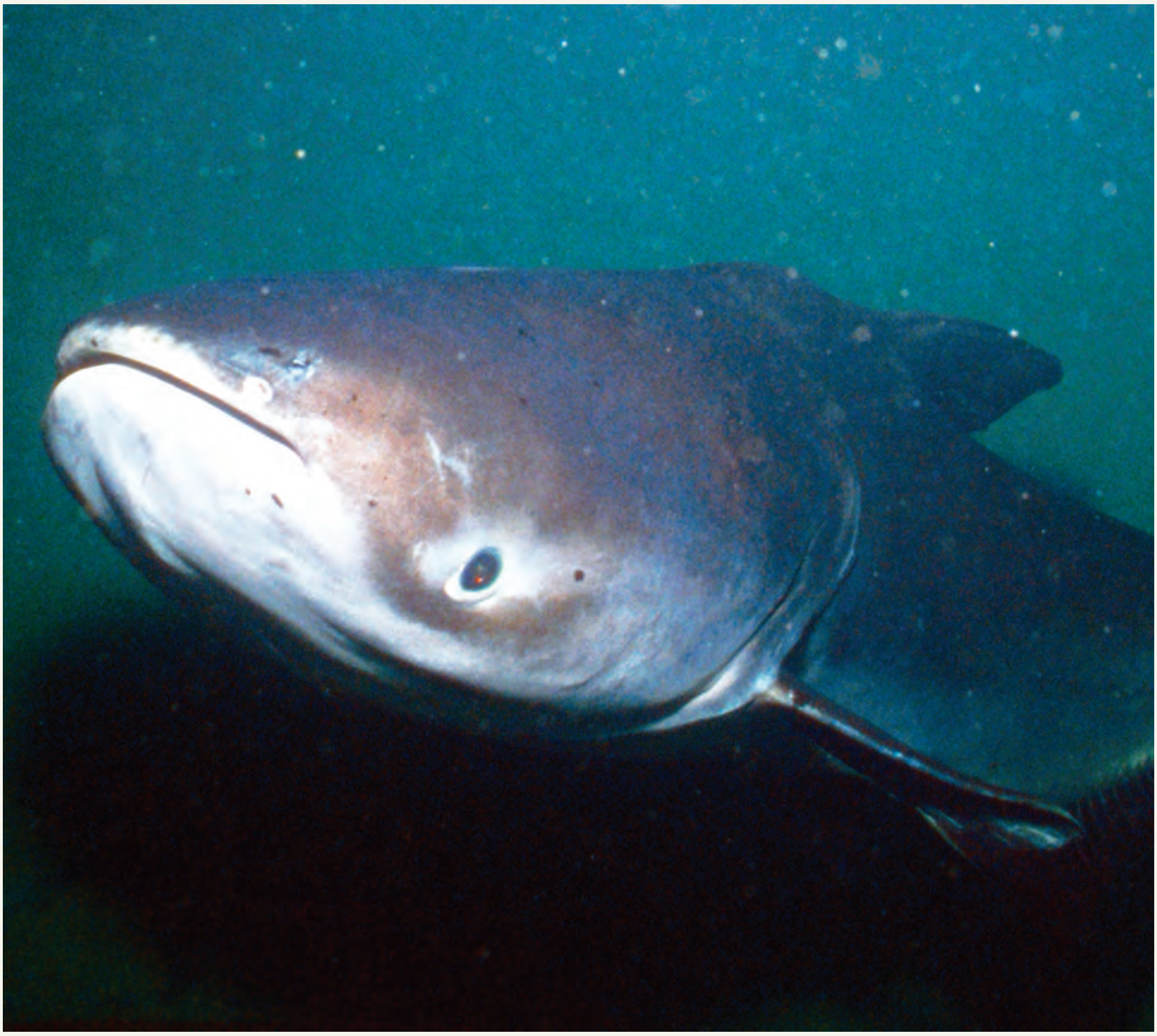
Protected areas

The survival of many species in the GMS depends on the existence of effectively managed protected area systems. Protected area systems have expanded dramatically in the GMS since 1970, to levels close to 20 per cent of total area in Cambodia, Laos and Thailand, though still less than 10 per cent in Myanmar and Vietnam (***Figure 4.6***). Countries in the region have agreed protected area systems, and agencies and staff to carry out management. Ecotourism, while still small scale when compared with the most popular tourist destinations for wildlife holidays, is increasing fast.

However, the system remains fragile. Even today 11 per cent of the land area and only 19 per cent of remaining forest is under protection, and encroachment into protected areas seriously threatens the stability of many species (Conservation International, 2007; Stibig et al,. 2007; MRC, 2010; FAO, 2011a). Many species and critically threatened habitat types largely occur outside the protected area network (e.g. Wright et al., 2012; Packman et al., 2013). Governments have also frequently reduced the size of protected areas throughout the region, for example in Thailand (Dearden et al., 1998) and Vietnam, while Cambodia has made major degazettements, converting large parts of protected areas to economic land concessions (ELCs)[1] (Vrieze and Naren, 2012); the network is still far from secure. Many protected areas exist in name only; even those that have secure boundaries often face continual degradation through poaching and timber theft. Despite long-term capacity-building exercises in the region, including by WWF, many protected area managers and rangers feel faced with an impossible task and morale in many protected areas remains low.

Nonetheless, protected areas now conserve much of the remaining primary forest and some important secondary forests. Importantly, they have been the site for restoration programmes, particularly in mangrove forests (Hong, 2004; Nguyen et al., 2008), and for some threatened species such as sarus crane (*Grus antigone sharpii*) (Buckton and Safford, 2004). The Cambodian government is committed to restoring tigers within the protected area complex of the Eastern Plains Landscape. Consolidating and building capacity within the protected area system is one of the key priorities for the GMS. Countries like Thailand, where the protected area system is now well established, can help in this process.

1 See Open Development Cambodia for details of granted ELCs at www.opendevelopmentcambodia.net



Believed capable of reaching an almost mythical three metres in length and 350kg, the Giant Mekong catfish is one of the fastest growing in the world; newly hatched fry measure half a centimetre, by day 11 they measure 2.5cm, and at only six years of age they can weigh nearly 200kg.

Protected Areas System

Protected area

Remaining forest 2009

Figure 4.6. System of protected areas across the GMS. Source: WWF-Greater Mekong Programme based on multiple datasets

THE GMS CONTAINS THE LARGEST COMBINED AREA OF TIGER HABITAT IN THE WORLD, AS WELL AS 5 OF THE 11 COUNTRIES WHERE TIGERS STILL EXIST, SO PRESERVATION OF INTACT TIGER HABITAT AND POPULATIONS HERE IS BOTH ESSENTIAL AND POSSIBLE

(Thompson, 2010).

Future scenarios

Unsustainable growth:
Trends of forest degradation and loss continue, while poaching for local consumption and global trafficking continues to lower the densities of iconic, endangered species and their prey to near or complete regional extinction. The prognosis for much of the biodiversity of the GMS, and particularly that of focal species, is poor. Of the 13–42 per cent of species expected to be lost in Southeast Asia by 2100, at least half could represent global extinctions (Sodhi et al., 2004). Continued forest fragmentation devastates populations of larger animals, particularly tigers, which require large, intact landscapes (Wikramanayake et al., 2001; Thompson, 2010); forest interior specialist species, such as the saola; and those requiring large hunting areas, such as dhole (*Cuon alpinus*). Protected areas are largely “empty forests” devoid of charismatic and endemic megafauna.

As the impacts of climate change become more pronounced, animals are less able to move across habitat gradients which have become discontinuous due to forest fragmentation (Campbell et al., 2009; Millien et al., 2006). The ensuing increase in hotter, drier edge habitat relative to forest interior, combined with the general warming due to global climate change, facilitates the spread of pests, pathogens and invasive species, thereby directly and indirectly affecting native biodiversity. The warming and drying of certain habitats, particularly highland forests and streams and seasonal ponds, limits the survival and dispersal capacity of species limited to those areas and may hasten their regional, and perhaps global, extinction. Lack of climate change resilience within the protected area network prevents species movements and colonization in response to climate change.

Green economy:
With efforts made to improve governance and to make planning and development more sustainable, natural capital is protected and enhanced. The implementation of REDD+ and payments for ecosystem services projects improve community livelihoods and reduce unsustainable use of the forests, particularly in areas surrounding protected areas. Local land-lease property rights have helped to stabilize communities. Improved conservation awareness reduces demand for wildlife products along with strategic engagement to reduce opportunistic or poverty-based hunting, and more effective enforcement has also reduced level of trade. Through these mechanisms, forest regenerates and connectivity across ecosystems is enhanced, allowing species threatened by habitat loss and fragmentation to recover (Thompson et al., 2009). With better governance, forest-associated stakeholders are engaged and become defenders of forests and their biodiversity. Protected areas are valued for both ecosystem services and potential for poverty alleviation and are therefore effectively managed. Wildlife premium mechanisms help provide special incentives to governments and external funders to support conservation in areas that allow tigers and other large mammals to recover (Dinerstein et al., 2013). Adaptation for climate change becomes part of regional planning processes, encouraging forest restoration to reduce threats from fire and to give species more opportunity to adjust to conditions caused by climate change.

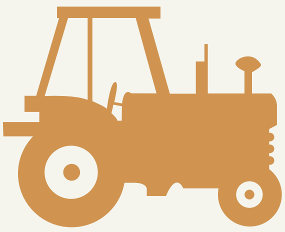
5. DRIVERS OF ECOSYSTEM CHANGE

Human population density, poverty and increased wealth

The high and ever-increasing human population density in Southeast Asia underpins the expansion of the major environmentally destructive human activities in the GMS, including deforestation, dam construction and overexploitation of natural resources (Rowcroft, 2005). Forest cover tends to be lower in countries with dense human populations (Laurance, 2007). High population levels are also associated with increased demand for fish protein, agricultural land, timber and other forest products. The GMS is also experiencing increases in both poverty, which exacerbates forest loss for slash-and-burn cultivation and fuelwood collection, and wealth, which improves off-farm opportunities but boosts demand for electricity, as well as timber and other cash crops and wildlife products. Direct foreign investment is helping a proportion of people in the region to build their wealth but does not always take account of the impacts of development on natural resources. All these additional pressures further intensify pressure on all natural resources (Rowcroft, 2005; Laurance, 2007).

Unsustainable resource use and increasing resource demands

The GMS now includes and is surrounded by the fastest-growing economies on Earth (United Nations, 2010). Agriculture is expanding not only to feed the burgeoning regional population but also to meet demands from wealthier portions of the population and a global market. Across the GMS, croplands, pastures and plantations are expected to expand for the next 30–50 years, replacing natural forest (Chaudhury, 2009). China, a major trading partner with other GMS countries, is sourcing timber, palm oil, rubber, wood pulp, minerals and other natural resources from the region (Rowcroft, 2005; Laurance, 2007; ADB, 2007) as well as heavily investing financially in other GMS countries. Demand by other countries in Asia and beyond for sugar, rice, coffee, rubber, cassava and tropical fruits from the Lower Mekong region are transforming the GMS from subsistence to a commercial, export-orientated agriculture. In today's globalized world, even sparsely populated countries can be intensively exploited: heavy demands by Chinese and other markets over the past 15 years for forest and plantation products have had a major impact on many tropical Asian forests (Katsigris et al., 2004; Rowcroft, 2005). Thailand and Vietnam have also become major importers of timber, which they obtain from Myanmar, Laos and Cambodia, exacerbating large-scale illegal logging activities in these forested countries (Chaudhury, 2009). The dominance of dipterocarp trees, which produce a large volume of marketable timber, has encouraged high-intensity industrial logging and thus exacerbated the severity of resulting ecological impacts. The explosion in industrial logging, oil-palm and rubber plantations, and mineral exploitation (***Figure 5.1***) in recent decades (Stibig et al., 2007; Lazarus, 2009) has built financial wealth for a minority of individuals while destroying or degrading forests both directly and by building new roads into forested areas.



POPULATION DENSITY IS STRONGLY CORRELATED WITH NET FOREST LOSS, AND ASIAN TROPICAL NATIONS HAVE POPULATION DENSITIES THAT ARE 3-5 TIMES HIGHER THAN THOSE IN EQUATORIAL AFRICA AND THE TROPICAL AMERICAS

(Laurance, 2007)

Mineral and coal mines

- Existing mines
- Planned mines

Figure 5.1. Current and planned mineral and coal mines in the GMS
Source: WWF-Germany based on multiple datasets, see Appendix.

Infrastructure

The expansion of roads and urban areas results in the conversion of forest to other land uses to meet the needs of the subregion's growing and rapidly urbanizing population. Access roads also facilitate further immigration to, and thus degradation and conversion of, formerly intact forest areas (Laurance et al., 2009. Stibig et al., 2007) (***Figure 5.2***). Deforestation occurs in hotspots near cities and roads and international borders where illegal timber trade flourishes (Rowcroft, 2005; FAO, 2011b). The demand for electric power is expected to continue to grow at approximately 7 per cent per year. In addition to providing power to towns and cities, growth is in part to support expansion of mining and industrial sectors (Rowcroft, 2005; ADB, 2011) (***Figure 5.1***). For example, Cambodian, Lao and Vietnamese governments are promoting bauxite mining to produce aluminium. Exploitation – delayed by conflict, low investment and bureaucratic inefficiency – is now supported both in-country and by foreign investment in mines and infrastructure. Aluminium smelting requires immense amounts of cheap energy, encouraging more hydropower development (***Figure 5.3***). However, to be cost effective, Laos must sell electricity at half its current selling price, and the lack of regulatory compliance or public disclosure of information masks potential costs to fisheries and water quality from contamination by toxic bauxite mining discharge (Lazarus, 2009).

NEW ROADS FACILITATE ACCESS, HELP DEVELOP MARKETS AND MAKE LIFE EASIER FOR LOCAL COMMUNITIES. BUT BADLY DESIGNED ROADS IN TROPICAL FORESTS ALSO HELP TO FRAGMENT FOREST, BLOCK WATER FLOW AND ANIMAL MOVEMENTS, POLLUTE SOIL AND WATERWAYS, AND FACILITATE ENTRY BY POACHERS, INVASIVE SPECIES AND FIRE

(Laurance et al., 2009).

Road Network

- Cities
- Existing Roads
- Planned roads

Figure 5.2.
Locations of principal national roads, planned major roads (red) and major cities in the GMS.
Source: WWF-Germany based on multiple datasets, see Appendix.

Dams

◆ Existing dams

▲ Planned dams

Figure 5.3.
Map of current (brown) and planned (red) dams in the GMS.
Eleven of the planned dams are located on the main stem of the Mekong River.
WWF-Germany based on multiple datasets, see Appendix.

Government policy and lack of integrated planning

The recent concurrent economic trends in the GMS of: (1) conversion from subsistence to export-orientated commercial agriculture; and (2) transfer from command-driven to market-driven economies, have been made possible by greater political stability in the subregion (Rowcroft, 2005). This has caused some of the rapid changes described and mapped earlier, but at the same time there has been a welcome increase in recognition of environmental values and, for instance, a rapid growth in protected area coverage. Government policies have nonetheless generally undervalued forest and water services, for example favouring conversion of native forests to other land uses, and they have not encouraged maintenance of forest health through sustainable forest management (The Center for People and Forests, 2012). Poor understanding and/or implementation of sustainable forest management, poor coordination among forestry and other sectors (e.g., energy, agriculture, mining, tourism), and inadequate funding for adaptation activities continue to undermine the capacity of forests in the region to adapt to climatic changes and, in turn, provide adaptation services to humans. Continuing disagreements among governments have similarly hampered efforts to develop integrated plans for freshwater management.

These problems of understanding are heightened by serious shortfalls in quality of governance in some of the countries of the GMS, resulting in lack of transparency, high levels of corruption, absence of local-level tenure and failure to implement existing laws for ecosystem management or species protection, seen most visibly in the booming illegal wildlife trade (e.g., Duckworth et al., 2012). Ministries responsible for forests are unable to halt deforestation, particularly when it originates in other sectors such as mining or agriculture (PROFOR, 2011). The high level of timber (e.g., EIA, 2008) and wildlife smuggling (e.g., Nguyen, 2008) is well known.

© WWF-CANON / JAMES MORGAN

Customs officials in Suvarnabhumi airport, Bangkok, discover an illegal shipment of African elephant tusks from Mozambique. Thailand is the world's largest unregulated ivory market.

6. CONCLUSIONS: CHOOSING A FUTURE

The opportunity: the Greater Mekong Subregion is at a crossroads. Despite thousands of years of human habitation and accompanying environmental change, it still contains globally important natural ecosystems, unique species and valuable ecosystem services, set amongst some of the most spectacular scenery on the planet. Many things are getting better: after decades of conflict and poverty, countries generally have greater political stability and a rising standard of living and the region as a whole has a new air of optimism. After decades when many countries were virtually isolated from most of the world, contact is increasing and tourism is becoming an important part of the economy. WWF's research shows that there are still serious problems to be faced in terms of natural resources, but the GMS is probably for the first time in many decades in a position to address these within a sustainable development strategy. In fact, GMS countries have agreed to a 10-year strategic framework for economic development in which the top-level outcomes are reductions in poverty, biodiversity losses and greenhouse-gas emissions. Achieving these outcomes would put the GMS squarely on a path toward greener economies.

The challenge: unfortunately, one side-effect of rapid growth is that future projections for the region's natural ecosystems are potentially catastrophic. WWF's research shows that, unless things change radically, the region could lose more than one-third of its remaining natural forests and associated species and ecosystem services within the next two decades. Coastal developments alone, with consequent destruction of protective mangrove forests, are exposing people to dramatically increased risks from typhoons and ocean surge. The Mekong river complex is one of the most significant freshwater systems in the world in terms of what it provides to local and downstream communities; yet huge dam-building programmes (Hirsch, 2010), promoted without sufficient environmental and social assessment or discussion of trade-offs, could radically alter water flow, freshwater and agricultural productivity, and human livelihoods. These issues are already causing tension between countries. A rapid escalation of poaching is stripping even protected areas of any species that can be sold; the extinction of the Javan rhino on mainland Asia (Brook et al., 2012) is one of the most serious wildlife losses of the last hundred years, yet has received little attention within the region or beyond. Further losses of unique and irreplaceable species endemic to the GMP, including saola, are likely. Climate change, recognized but not yet effectively integrated into development planning, is likely to exacerbate all these problems (see e.g., Pilgrim, 2007; Eastham et al., 2008), further upsetting water flows and stressing agriculture.

Meanwhile, pressures continue to increase and projections suggest that the region will experience further rapid development. Population is growing, with Vietnam, Laos and Cambodia all expected to experience net increase well beyond 2050 (Pech and Sunanda, 2008). The massive markets in China are among those fuelling a rapid increase in resource exploitation to meet export demands as well as rising domestic needs (Rowcroft, 2008). Coal and other mineral mining, expansion of agriculture (Mainuddin and Kirby, 2009) and widespread legal and illegal forest clearance continue to eat away at natural ecosystems.

Although there is widespread official recognition of the importance of natural ecosystems and ecosystem services and, at least in theory, a commitment to substantial protected area systems and sustainable management, these paper declarations are frequently not implemented effectively, leading to a veneer of conservation without corresponding results on the ground. So while cooperative efforts such as the Mekong River Commission are extremely welcome, and critically important, they have to date not always prevented national interests from overshadowing regional needs. Intra-regional discord is mirrored on a broader scale, where international bodies such as donor organizations simultaneously call for better environmental protection while other arms of their institutions fund unsustainable developments.

At the heart of many of the problems is a mismatch between what is written in laws and policies and what happens in reality. Weakness in governance, in-fighting between government departments, and a reluctance or lack of capacity at local level to enforce natural resource protection laws mean that illegal resource use has gone unchecked, sometimes at a grand scale and on occasion involving people at the heart of government or the military. Timber and wildlife products have been stripped from natural ecosystems while their traditional owners or protected area managers look on, unable to stop the depredation. Restaurants offer poached animals on their menus and medicines based on endangered species are sold openly in many cities of the region. Widespread poverty, coupled by the opportunity to boost economic production, has led to rapid conversion of natural ecosystems for economic gain. It is difficult to criticize people for wanting to emerge from a period of conflict and desperate levels of poverty, but the uncontrolled nature of many developments means that long-term costs to the region are likely to be severe. The people who benefit most from unsustainable development are usually not those in the greatest need, nor are they most directly reliant on healthy natural ecosystems.

The crossroads: in the report, we outline two scenarios; one pessimistic and one optimistic. Under the unsustainable growth scenario, current trends continue, resulting in massive losses to forest cover and freshwater connectivity; and in a large decline in sediment flow to the delta, reducing productivity and thus increasing the need for polluting artificial fertilizers. Delta areas will be left vulnerable to sea level rise, salinization and coastal erosion. Many wildlife species will have been hunted to extinction or exterminated along with their habitat. Freshwater and marine fisheries will begin to collapse, impacting on food security that is already compromised by climate changes. Emphasis on hard infrastructure to adapt to climate change impacts may provide temporary relief from hazards (e.g., floods, droughts and storm surge) associated with more frequent and severe extreme events, but will do little to alleviate cumulative impacts (e.g., altered flows and lowered resistance to invasive species, pests and disease leading to reduced agricultural productivity). Uncoordinated responses to climate change will also lead to conflict due to unintended negative consequences of implemented adaptation measures.

The green economy scenario assumes that the countries of the GMS are successful in meeting the challenge of sustainable natural resource management: slowing and where necessary reversing loss of natural ecosystems; maintaining a healthy hydrological system; managing mining; and curbing illegal resource use. Government decisions are transparent and increasingly participatory, and follow the rule of law. Communities understand the link between environmental protection, ecosystem services and human well-being, and work in partnership with government to balance production with conservation, proud to coexist with unique wildlife species. Native forest loss is halted and restoration programmes rebuild some of what has been lost. Healthy mangroves fringe coastal areas, holding back ocean storms. Fishing communities thrive on the banks of rivers and coastlines, with fish spawning areas preserved and negotiated set-asides used to rebuild fish stocks whenever they decline. Responses to climate change emphasize or at a minimum include an ecosystem-based approach, taking advantage of the resilience intact, connected and biologically diverse ecosystems provide at a landscape scale. Regional collaboration and coordination (across sectors, agencies and jurisdictions) generates and implements integrated adaptation strategies that are flexible and least likely to fail, harm neighbours or cause other unintended negative consequences.

WWF therefore believes that the green economy approach is the choice for a viable future in the Mekong and, recognising the anticipated changes in the region, is both realistic and feasible. Conservation responses need to be both strategic, addressing the need for long-term development, and where necessary tactical, using temporary measures to secure species and ecosystems under imminent threat. Multiple actions will be needed, ranging from initiatives at international, regional and national policy level to many thousands of projects, negotiations and decisions at the level of sites and landscapes.

WWF believes that the green economy scenario is fully realizable in the current political and economic context of the countries of the GMS. Some important steps towards realizing this vision are already being taken. We look forward to working with governments, corporations and communities in the GMS to make sustainable natural resource management a reality.

Recommendations

Below we provide ten key recommendations that, if applied with care and commitment, will represent a major step in the direction of a sustainable future for the region.

1. **Immediately halt impacts to, and where possible, restore patterns and processes that are at their breaking point.** While it is clear that a sustainable future for the region depends in part on developing infrastructure and the production landscape, society must acknowledge that some valued patterns and processes (such as endemic species and the delivery of clean water to households) will simply disappear if direct threats to their integrity are not curtailed. With this in mind, WWF recommends immediate action to:
    - Prevent further conversion of any additional primary forest in the GMS;
    - Prevent the construction of dams on the main stem of major rivers, and tributaries that contribute substantial flows to these systems;
    - Implement species-specific conservation and recovery actions for endemic species like the saola; and
    - Cease the illegal wildlife trade.
2. **Significantly increase the level of integration, the spatial scale, and the timeframe of planning.** A common pattern in development all over the world is that the aggregate effects of local impacts such as land conversion or a new infrastructure installation are rarely appreciated until after it is too late to optimize the amount, intensity, and configuration of such impacts. Some progress is already being made to better coordinate water management, forest management, protected area design, and measures to control wildlife trade. However, this coordination must be enhanced and greatly expanded to ensure that planning and development in energy, transportation, agriculture, industrial,

and other sectors are brought into the same framework so that the complex interactions and feedback loops that exist between them can be better anticipated and managed. Progress toward this level of integration and coordination is already taking place in the region. For example, the GMS economic cooperation program serves as a platform to achieve the necessary integration across sectors and jurisdictions for the entire region. At the national level, the government of Myanmar has recently convened a multi-sector land use planning committee to confront and manage an accelerated rate of land use change in the face of renewed international investment. The 2014 World Parks Congress would be an ideal venue to launch a regional protected area plan, while the CBD Conference of Parties (COP) and the CITES COP both provide opportunities to address issues related to curbing illegal wildlife trade.

3. **Commit sufficient and sustainable financing for conservation.** Securing sustained financing for conservation, at a level commensurate with the challenges at hand, remains a major challenge in the region. As the recent “year of the tiger” activities have highlighted, even funding for one of the world’s most beloved and iconic wildlife species is far too low to ensure the basic protections needed for protecting the last of the world’s tiger populations.

   Financing must also come from sustainable sources. The sources of funding that currently support everything from species conservation to ecosystem management are rarely linked to the users of the resource being conserved. There are now many signs that this unsustainable pattern is being addressed in the region. For example, Vietnam recently passed laws requiring that, in certain cases, require users to pay communities for their role in maintaining the natural capital that underpins the services provided.

4. **Incorporate the values of ecosystems and the services they provide into decision-making.** Knowing and appreciating the value of what might be lost or saved will not only lead to more informed decisions but also potentially different decisions that yield outcomes with the fewest tradeoffs. Mapping, quantifying, and assessing the economic value of the region’s natural capital are crucial steps in this regard. These assessments can also make a strong case at local level as well, and limited experience with Payment for Ecosystem Service (PES) schemes in the Mekong region suggests that communities can radically reduce forest loss if someone is paying them to do so. REDD+ initiatives also offer important opportunities for helping pay for good natural resource management. Processes like TEEB, The Economics of Ecosystems and Biodiversity (ten Brink, 2011), and a growing number of tools for assessing ecosystem services, can help to build a better understanding of economic values of ecosystem services that still remain largely theoretical in the minds of many policy makers today. Laos and Vietnam are beginning to pilot national accounting structures that explicitly account for the values of ecosystem services so that the financial association between these services and the activities that either enhance or degrade them can be better understood and managed.

5. **Insist on greater responsibility of companies operating in or purchasing from the GMS** so that the private sector uses and manages natural resources more efficiently and sustainably. Private sector actors must play a critical role in promoting greener economies. Opportunities include developing business models that emphasize legality and transparency (for example, subscribing to FLEGT or similar initiatives); adhering to best management

practices including those formalized through certification schemes such Forest Stewardship Council. Interest in concepts of corporate responsibility, while still relatively undeveloped in the GMS, is increasing; consumers from outside the region can assist by demanding assurances of best practice.

6. **Improve regional and international consultation and cooperation.** The interconnectedness of forests, mountains, coastlines, and river systems means that cooperation between governments is particularly important. The Mekong River Commission, while far from perfect, is a welcome indication that such cooperation is possible. The presence of transboundary protected areas between virtually all GMS countries is another sign that governments are looking beyond their borders. Such cooperative efforts need to be redoubled.

   Governments, international actors both inside and outside of the region, and local institutions as well as civil society also need to consult each other more carefully and work together more effectively than has sometimes been the case to ensure that projects supported through grants and loans fit into a framework of sustainable development. Ideally, such coordination should encompass the most senior national authorities to the largest donor organisations to the smallest NGOs. Large, transboundary infrastructure projects warrant special emphasis with regard to appropriate levels of consultation and cooperation.

7. **Empower communities and civil society to more significantly and effectively participate in decision-making.** There are not always clear opportunities for communities to take part in decisions that relate directly to their lives, creating instead a culture that has tended to ignore rules and regulations. Experience shows that although participatory approaches to natural resource management are often more difficult, and more time consuming, if done correctly the decisions reached are more likely to persist over the long term. Empowerment of communities, in terms of voice, rights and tenure, helps build long-term interest in sustainable management. There are signs of communities working together in natural resource use, but the lessons learned from these experiences need to be more widely disseminated.

8. **Enforce existing laws, policies, and regulations.** There is a global trend towards larger, more ruthless, and better organised wildlife crime, relating to both illegal logging and wildlife poaching. In these cases local communities may themselves feel threatened by poaching gangs or be losing natural resources to outsiders. Here the need is less for new legal structures than for the implementation of existing laws, both in terms of catching criminals and, crucially, following through with stipulated penalties through the judicial process. However, there is also the need to strengthen available penalties to ensure that the law does offer a significant deterrent. The current disheartening situation, where many wildlife criminals have cases dismissed even if they are captured, needs to be radically overhauled. Such a change requires both capacity building and training – of community and protected area guards, of policy makers and of lawyers, but even more importantly the building of pride and commitment to conservation within these institutions. In some countries it also means addressing long-standing enmity between particular ministries, government departments and civil service groups to unblock obstacles to putting necessary laws into practice.

9. **Ensure effective and representative protection of the region's natural heritage.** Effective management of an ecologically representative protected area network is emphasized in the Convention on Biological Diversity, to which all GMS countries have committed. Nevertheless, several countries in the region have undergone a process of PADDD, Protected Area Downgrading, Downsizing, and Degazettement (Mascia and Pailler, 2011). While some rationalisation of protection may be needed in line with systematic conservation planning, the unplanned and frequently illegal destruction of protected areas and their resources is causing enormous damage to biodiversity. Many protected areas are ineffective at protecting wildlife even in conditions where they maintain native vegetation, creating so-called "cemetery forests" with few if any of the species they were set aside to protect. Building an effective, representative, and climate smart protected area system should continue to be a cornerstone of biodiversity conservation in the region.

10. **Restore natural capital in strategic areas.** Restoration is always more difficult and costly than protecting original habitat and key ecological processes, and most restoration efforts do not bring back the full diversity of original ecosystems. Nonetheless, restoration is possible and in some cases already implemented (e.g., Hong, 1996; Lamb, 2011). Rebuilding the value of secondary and degraded natural forests is an important and achievable priority for restoring ecosystem services. Techniques and knowledge are improving but most attempts are still tentative and small scale in approach, in contrast with the massive scale of establishment of exotic plantations.

Mekong river, a vital lifeline for 60 million people living in the Greater Mekong.

APPENDIX I

The following series of maps presents the spatial distribution of forest cover change during four successive time periods: 1973-1985, 1985-1992, 1992-2002 and 2002-2009. (*Source: WWF-Greater Mekong Programme based on multiple datasets*).

Types of change

- Forest to non-forest
- Non-forest to forest
- No change in forest
- Non-forest

Figure A.1.
Forest cover change from 1973 to 1985
Between 1973 and 1985, the GMS overall lost about 6% of its forest cover. The greatest national decreases occurred in Thailand (13% lost) and Vietnam (9.9% lost). Data for Yunnan and Guangxi in China and parts of northern Vietnam were unavailable.

Types of change

- Forest to non-forest
- Non-forest to forest
- No change in forest
- Non-forest

Figure A.2.
Forest cover change from 1985 to 1992
Forest cover loss between 1985 and 1992 was greatest in Laos and Myanmar, though still significant for Thailand (7%). Forest cover in Cambodia declined by just 1%. Data for 1992 for Vietnam, Yunnan and Guangxi were unavailable.

Types of change

- Forest to non-forest
- Non-forest to forest
- No change in forest
- Non-forest

Figure A.3.
Forest cover change from 1985 to 2002 for Vietnam.
This longer time step is shown here because 1992 data were missing for Vietnam.

Types of change

- Forest to non-forest
- Non-forest to forest
- No change in forest
- Non-forest

Figure A.4. Forest cover change from 2002 to 2009. *During this period, Myanmar continued to experience heavy forest loss (about 15% of forest loss at an annual rate of about 2%), while implementation of logging bans in Thailand and Vietnam may have shifted some deforestation to Laos (about 13% of forest loss) and Myanmar.*

REFERENCES

Achard, F., Hugh, D., Eva, H.D., Stibig, H.J., Mayaux, P., Gallego, J., Richards, T. and J.P. Malingreau. 2002. Determination of Deforestation Rates of the World's Humid Tropical Forests. *Science* **297**: 999-1002.

ADB. 2009. *The economics of climate change in Southeast Asia: a regional review*. Asian Development Bank. Available at www.adb.org/publications/economics-climate-change-southeast-asia-regional-review

Amornsakchai, S., Annez, P., Vongvisessomjai, S., Choowaew, S., Thailand Development Research Institute (TDRI), Kunurat, P., Nippanon, J., Schouten, R., Sripapatrprasite, P., Vaddhanaphuti, C., Vidthayanon, C., Wirojanagud, W. and E. Watana. 2000. *Pak Mun Dam: Mekong River Basin, Thailand*. World Commission on Dams, Cape Town, South Africa.

Arias, M.E., Cochrane, T.A., Piman, T., Kummu, M., Caruso, B.S. and T.J. Killeen. 2012. Quantifying changes in flooding and habitats in the Tonle Sap Lake (Cambodia) caused by water infrastructure development and climate change in the Mekong Basin. *Journal of Environmental Management* **112:** 53–66.

Asian Development Bank. 2007. Development effectiveness brief: Greater Mekong Subregion. ADB, Philippines. 16 pages.

Asian Development Bank. 2011. Asian development outlook 2011. South-south economic links. ADB, Philippines.

Asia Pacific Forestry Commission. 2011. *Forests and Forestry in the Greater Mekong Subregion to 2020: Subregional Report of the Second Asia-Pacific Forestry Sector Outlook Study*. FAO, Bangkok, Thailand.

Atkinson, P.M. et al. 1997. Neural networks in remote sensing. *International Journal of Remote Sensing* **18**(4): 699-709.

Baird, I. 2000. *Integrating Community-Based Fisheries Co-Management and Protected Areas Management in Laos: Opportunities for Advancement and Obstacles to Implementation*. Evaluating Eden Series, Discussion Paper No.14, IIED, London, UK.

Balzer, N.C., Nguyen, D. and R. Shore (eds.). 2001. Towards a Vision for Biodiversity Conservation in the Forests of the Lower Mekong Ecoregion Complex. WWF and partners. Hanoi, Vietnam.

Baran, E., Chheng, P. and T. Nao. 2013. Food security in the Mekong: the contribution of fisheries. Presented at the SIWI / UNDP / IWMI workshop, *Food Security in the Mekong*, Chiang Rai, Thailand, 12-13 March 2013. Available at: www.watergovernance.org/documents/WGF/events/2013-Mekong/Baran-et-al-Fish-and-food-security-in-the-Mekong.pdf

Baumüller, H. 2008. *Prospects and Drivers for Agricultural Change in the Mekong Region: The case of sugar, rice and rubber*. WWF-Greater Mekong Programme, Vientiane, Laos.

Bennett, E., Eves, H., Robinson, J. and D. Wilkie. 2002. Why is eating bushmeat a biodiversity crisis? *Conservation Biology in Practice* **3**: 28–29.

BMA, GLF and UNEP. 2009. Bangkok Assessment Report on Climate Change 2009. Bangkok Metropolitan Administration, Green Leaf Foundation and United Nations Environment Programme, Bangkok, Thailand.

Brook, S.M., van Coeverden de Groot, P., Mahood, S. and B. Long. 2011. *Extinction of the Javan Rhinoceros (Rhinoceros sondaicus) from Vietnam*. WWF, Washington DC, USA.

Brook, S.M., van Coeverden de Groot, P., Scott, C., Boag, P., Long, B., Ley, R.E., Reischer, G.H., Williams, A.C., Mahood, S.P., Tran Minh Hien, Polet, G., Cox, N. and Bach Thanh Hai. 2012. Integrated and novel survey methods for rhinoceros populations confirm the extinction of rhinoceros *Sondaicus annamiticus* from Vietnam. *Biological Conservation* **155:** 59–67.

Brown, O., Crawford, A. and A. Hammill. 2006. *Natural Disasters and Resource Rights: Building resilience, rebuilding lives*. International Institute for Sustainable Development, Manitoba, Canada.

Buckton, S.T. and Safford, R.J. 2004. The avifauna of the Vietnamese Mekong delta. *Bird Conservation International* **14**: 279-322.

Campbell, A., Kapos, V., Scharlemann, J.P.W., Bubb, P., Chenery, A., Coad, L., Dickson, B., Doswald, N., Khan, M.S.I., Kershaw, F. and M. Rashid. 2009. *Review of the Literature on the Links between Biodiversity and Climate Change: Impacts, Adaptation and Mitigation*. Technical Series No. 42. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Campbell, I.C. 2009. *The Mekong: biophysical environment of an international river basin*. Academic Press. New York, USA.

Chaudhury, M. 2009. APFSOS II: Assessing the protection of forest-based environmental services in the GMS. FAO.

Chen, L., Wang, W., Zhang, Y. and G. Lin. 2009. Recent progresses in mangrove conservation, restoration and research in China. *Journal of Plant Ecology* **2** (2): 45-54.

Chenery, A., Coad, L., Dickson, B., Doswald, N., Khan, M.S.I., Kershaw, F. and M. Rashid. 2009. *Review of the Literature on the Links between Biodiversity and Climate Change: Impacts, Adaptation and Mitigation*. Technical Series No. 42. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Civco, D.L. 1993. Artificial neural networks for land cover classification and mapping. *International Journal of Geographic Information Systems* **7**(2): 173-186.

Coates D., Poeu, O., Suntornratana, U., Thanh Tung, N. and S. Viravong. 2003. *Biodiversity and fisheries in the Lower Mekong Basin*. Mekong Development Series No. 2. Mekong River Commission, Phnom Penh, Cambodia.

Cochrane, T.A., Arias, M.E., Teasley, R.L. and T. Killeen. 2010. Simulated changes in water flows of the Mekong River from potential dam development and operations on the Se San and Sre Pok tributaries. IWA World Water Congress and Exhibition (IWA 2010), 19-24 Sep 2010, Montreal, Canada.

Corlett, R.T. 1994. What is secondary forest? *Journal of Tropical Ecology* **10**: 445-447.

Conservation International. 2007. *Biodiversity hotspots*. Arlington, USA.

Corlett, R.T. 1998. Frugivory and seed dispersal by vertebrates in the Oriental (Indomalayan) Region. *Biological Reviews* **73**: 413–448.

Corlett, R. T. 2007. The Impact of Hunting on the Mammalian Fauna of Tropical Asian Forests. *Biotropica* **39**: 292–303.

Dearden, P., Chettamart, S., Emphandu, D. and N. Tanakanjana. 1998. Protected areas and property rights in Thailand. *Environmental Conservation* **25**: 195-197.

Duckworth, J.W., Batters, G., Belant, J.L., Bennett, E.L., Brunner, J., Burton, J., Challender, D.W.S., Cowling, V., Duplaix, N., Harris, J.D., Hedges, S., Long, B., Mahood, S.P., McGowan, P.J.K., McShea, W.J., Oliver, W.L.R., Perkin, S., Rawson, B.M., Shepherd, C.R., Stuart, S.N., Talukdar, B.K., van Dijk, P.P., Vié, J-C., Walston, J.L., Whitten, T. and R. Wirth. Why South-East Asia should be the World's Priority for Averting Imminent Species Extinctions, and a Call to Join a Developing Cross-Institutional Programme to Tackle this Urgent Issue. *Sapiens* **5** (2): 77-95.

Dudley, N., Mansourian, S., Stolton, S. and S. Suksuwan. 2008 *Safety Net: Protected areas and poverty reduction*, WWF, Gland, Switzerland.

Dugan, P., Barlow, C., Agostinho, A., Baran, E., Cada, G., Chen, D., Cowx, I., Ferguson, J., Jutagate, T., Mallen-Cooper, M., Marmulla, G., Nestler, J., Petrere, M., Welcomme, R. and K. Winemiller. 2010. Fish Migration, Dams, and Loss of Ecosystem Services in the Mekong Basin. *Ambio* **39**:344-348.

Eastham, J., Mpelasoka, F., Mainuddin, M., Ticehurst, C., Dyce, P., Hodgson, G., Ali, R.

and M. Kirby. 2008. *Mekong River Basin Water Resources Assessment: Impacts of Climate*

Change. CSIRO: Water for a Healthy Country National Research Flagship, Australia.

EIA. 2008. *Borderlines: Vietnam's Booming Furniture Industry and Timber Smuggling in the Mekong Region*. Environmental Investigation Agency, London, UK.

Emerton, L (ed.) 2005. *Values and Rewards: Counting and Capturing Ecosystem Water Services for Sustainable Development*. Water, Nature and Economics Technical Paper No. 1, IUCN, Ecosystems and Livelihoods Group Asia.

FAO. 2009. *Assessing The Protection Of Forest- Based Environmental Services In The Greater Mekong Sub-Region*. Asia-Pacific Forestry

Sector Outlook Study II Working Paper Series, Working Paper No. APFSOS II/WP/2009/14, FAO, Bangkok, Thailand.
FAO 2010. *Global forest resources assessment 2010.* Rome, Italy.
FAO. 2011a. Asia-Pacific forests and forestry to 2020: GMS Forest policy brief 01: investment in forest resources. Bangkok, Thailand.
FAO 2011b. FAO Greater Mekong Subregion report: Asia-Pacific forestry sector outlook study II.FAO. Bangkok, Thailand.
FAO. 2011c. *State of the World's Forests 2011.* FAO, Rome, Italy.
Friedl, M.A., McIver, D.K., Hodges, J.C.F., Zhang, X., Muchoney, D., Strahler, A.H., Woodcock, C.E., Gopal, S., Schnieder, A., Cooper, A., Baccini, A., Gao, F. and C. Schaaf. 2002. Global land cover from MODIS: Algorithms and early results. Remote Sensing of the Environment **83**: 287-302.
Friend, R., Arthur, R. and M. Keskinen. 2009. Songs of the Doomed: The continuing neglect of capture fisheries in hydropower development in the Mekong. In: Molle, F., Foran, T. and M. Käkönen (eds.). *Contested waterscapes in the Mekong region: Hydropower, livelihoods and governance*. London: Earthscan: 307-332.
Global Witness. 2009. *A Disharmonious Trade: China and the continued destruction of Burma's frontier forests*. London, UK.
Grainger, A. 2008. Difficulties in tracking the long-term global trend in tropical forest area. *Proceedings of the National Academy of Sciences* **105** (2): 818–823.
Greater Mekong Subregion Economic Cooperation Program. 2011. The third GMS Environment Ministers' meeting: Joint Ministerial Statement, 28 July 2011, Phnom Penh, Cambodia.
Grumbine, R.E., Dore, J. and J. Xu. 2012. Mekong hydropower: drivers of change and governance challenges. *Frontiers of Ecology and Environment* **10** (2): doi:10.1890/110146
Hirsch, P. 2010. The changing political dynamics of dam building on the Mekong. *Water Alternatives* **3** (2): 312-323.
Harris, N.L., Brown, S., Hagen, S.C., Saatchi, S.S., Petrova, S., Salas, W., Hansen, M.C., Potapov, P.V. and A. Lotsch. 2012. Baseline Map of Carbon Emissions from Deforestation in Tropical Regions. *Science* **336**: 1573-1576.
Hogan, Z. 2011. Pangasianodon gigas. In: IUCN Red List of Threatened Species. Version 2011.2. IUCN, Gland, Switzerland.
Hong, P.N. 1996. Restoration of mangrove ecosystems in Vietnam: a case study of Can Gio District, Ho Chi Minh City. In: Field, C. (ed.) *Restoration of mangrove ecosystems*. International Society for Mangrove Ecosystems and International Tropical Timber Organization (ITTO), Okinawa, Japan. pp. 76-79
Hortle, K.G. 2007. *Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin*. MRC Technical Paper 16, Mekong River Commission, Vientiane, Laos.
Hortle, K.G. 2009. Fishes of the Mekong: how many species are there? *Catch and Culture* **15**: 2, 4-12.
Human Rights Watch. 2011. *World Report 2011*. Seven Stories Press, New York, USA. Available at www.hrw.org/sites/default/files/reports/wr2011.pdf
ICEM. 2003. *Regional Report on Protected Areas and Development: Review of Protected Areas and Development in the Lower Mekong River Region*. ICEM, Indooroopilly, Queensland, Australia.
ICEM. 2003a. *Lessons learned in Cambodia, Lao PDR, Thailand and Vietnam: Review of Protected Areas and Development in the Lower Mekong River Region*. ICEM, Indooroopilly, Queensland, Australia
ICEM. 2010. MRC *Strategic Environmental Assessment (SEA) of hydropower on the Mekong mainstream: summary of the final report*. Hanoi, Vietnam.
Intergovernmental Panel on Climate Change (IPCC). 2007. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Katsigiris, E., Bull, G.Q., White., A., Barr, C., Barney, K., Bu, Y., Kahrl, F., King, T., Lankin, A., Lebedev, A., Shearmen, P., SheiunGauz, A., Yufang, S. and H. Weyerhauser. 2004. The China forest products trade: overview of Asia-Pacific supplying countries, impacts and implications. *International Forestry Review* **6**:237-253.
Kareiva, P., Enquist, C., Johnson, A., Julius, S.H., Lawler, J., Petersen, B., Pitelka, L., Shaw, R. and J.M. West. 2008. Synthesis and Conclusions. Pages 9-1 to 9-66 in Julius, S.H. and West, J.M. (eds) *Preliminary review of adaptation options for climate sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*. U.S. Environmental Protection Agency, Washington DC, USA.
Kemp, N., Dilger, M., Burgess, N. and C. Van Dung. 1997. The saola *Pseudoryx nghetinhensis* in Vietnam – new information on distribution and habitat preferences, and conservation needs. *Oryx* **31**: 37–44.
King, P., Bird, J. and L. Haas. 2007. The current status of environmental criteria for hydropower development in the Mekong Region: a literature compilation. Consultants' Report to ADB, MRCS and WWF.
Lamb, D. 2011. *Regreening the Bare Hills: Tropical Forest Restoration in the Asia-Pacific Region*. World Forests Volume 8. Springer, Heidelberg, London, New York.
Laurance, W.F. 1991. Edge effects in tropical forest fragments: Application of a model for the design of nature reserves. *Biological Conservation* **57**: 205–219.
Laurance, W.F. 2007. Forest destruction in tropical Asia. *Current Science* **93**: 1544-1550.
Laurance, W.F., Goosem, M. and S.G.W. Laurance. 2009. Impacts of roads and linear clearings on tropical forests. *Trends in Ecology & Evolution* **24**: 659–669.
Lawson, S. and MacFaul, L. 2010. *Illegal Logging and Related Trade: Indicators of the global response*. Chatham House, London, UK.
Lazarus, K.M. 2009. *In Search of Aluminum: China's Role in the Mekong Region*. Heinrich Böll Stiftung, WWF, IISD. 44 pages.
Leimgruber, P., Gagnon, J.B., Wemmer, C., Kelly, D.S., Songer, M.A. and E.R. Selig. 2003. Fragmentation of Asia's remaining wildlands: implications for Asian elephant conservation. *Animal Conservation* **6**: 347-359.
Leimgruber, P., Kelly, D. S., Mueller, T. and M.A. Songer. 2004. Forest dynamics and conservation priorities in Myanmar 1990-2000. Annual Meeting of Society of Conservation Biology, New York, USA.
Leimgruber, P., Kelly, D. S., Steininger, M., Brunner, J., Müller, T. and M.A. Songer. 2003. *Forest Cover Dynamics in Myanmar 1990-2000*. Report to the US Fish & Wildlife Service, Washington DC, USA.
Loucks, C., M.B. Mascia, A. Maxwell, K. Huy, K. Duong, N. Chea, B. Long, N. Cox, and T. Seng. 2009. Wildlife decline in Cambodia, 1953–2005: exploring the legacy of armed conflict. *Conservation Letters* **2**: 82–92.
Loveland, T. R., Reed, B. C., Brown, J. F., Ohlen, D. O., Zhu, J., Yang, L. and J.W. Merchant. 2000. Development of a global land cover characteristics database and IGBP DISCover from 1-km AVHRR Data. *International Journal of Remote Sensing* **21**:1303–1330.
Mainuddin, M. and Kirby, M. 2009. Agricultural productivity in the lower Mekong Basin: trends and future prospects for food security. *Food Security* **1**: 71-82.
Mastny, L. 2001. *Travelling Light: New paths for international tourism*. Worldwatch Paper number 159, Worldwatch Institute, Washington DC, USA.
Mascia, M.B. and Pailler, S. 2011. Protected area downgrading, downsizing, and degazettement (PADDD) and its conservation implications. *Conservation Letters* **4** (1): 9-20.
MEA (Millennium Ecosystem Assessment). 2003. *Ecosystems and Human Wellbeing: A framework for assessment*. Island Press, Covelo, California and New York, USA.
MEA. 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington DC, USA.
MRC. 2003. *State of the Basin Report: 2003*. Executive Summary. Mekong River Commission, Phnom Penh, Cambodia.
MRC. 2009. *Catch and Culture* **5** (2). Vientiane, Laos.
MRC. 2009a. *Catch & Culture* **14** (3). Vientiane, Laos.
MRC. 2010. *State of the Basin Report: 2010*. Executive Summary. Mekong River Commission, Phnom Penh, Cambodia.
Meyfroidt, P. and Lambin, E.F. 2009. Forest transition in Vietnam and displacement of deforestation abroad. *Proceedings of the National Academy of Sciences* **106** (38): 16139-16144.
Millien, V., Lyons, K.S., Olson, L., Smith, F.A., Wilson, A.B. and Y. Yom-Tov. 2006. Ecotypic variation in the context of global climate change: revisiting the rules. *Ecology Letters* **9**: 853–869.
Mittelman, A. 2001. Secondary forests in the Lower Mekong Subregion:

an overview of their extent, roles, and importance. *Journal of Tropical Forest Science* **13**: 671–690.

Moeliono, M., Trung, L.Q., Utomo, N.A. and R. Andriani. 2010. Who benefits? Small scale tree planters and companies in Vietnam and Indonesia. In: Medved, M. and Božič, M. (eds.) *IUFRO Conference: Forestry in a Changing World: opportunities and challenges and the role of extension and technology transfer – 6-12 June Bled, Slovenia*. Slovenian Forest Service, Ljubljana, Slovenia.

Nguyen, V.S. 2008. Wildlife trading in Vietnam: situation, causes, and solutions. *Journal of Environment and Development* **17**: 145-165.

Nguyen An Thinh, Nguyen Xuan Huan, Pham Duc Uy and Nguyen Son Tung. 2008. Landscape ecological planning based on change analysis: A case study of mangrove restoration in Phu Long – Gia Luan area, Cat Ba Archipelago. *VNU Journal of Science, Earth Sciences* **24**: 133-144.

Orr, S., J. Pittock, A. Chapagain, and D. Dumaresq. 2012. Dams on the Mekong River: lost fish protein and the implications for land and water resources. Global Environmental Change 22 (4): 925-932.

Packman, C.E., Gray, T.N.E., Collar, N.J., Evans, T.D., van Zalinge, R.N., Son, V., Lovett, A.A. and P.M. Dolman. 2013. Rapid loss of Cambodia's grasslands. *Conservation Biology* **27**: 245-247.

Pech, S. and Sunada, K. 2008. Population Growth and Natural-Resources Pressures in the Mekong River Basin. *Ambio* **37** (3): 219-224.

Pilgrim, J. 2007. *Effects of Sea Level Rise on Critical Natural Habitats in Vietnam***.** International Symposium on Biodiversity and Climate Change – Links with Poverty and Sustainable Development. Hanoi, Vietnam, 22-23 May 2007.

PROFOR. 2011. *Improving Forest Governance in the Mekong Region, Volume 1*. Working Paper. Program on Forests, Washington DC, USA.

Quy, V. 2005. The attack of Agent Orange on the environment in Vietnam and its consequences. Agent Orange and Dioxin in Vietnam, 35 years later. Proceedings of the Paris Conference (Senate, 11-12 March 2005).

Ratner, B.D. 2003. The Politics of Regional Governance in the Mekong River Basin. *Global Change* **15** (1): 59-76.

Rozelle, S., Huang, J. and V. Benziger. 2003. Forest Exploitation and Protection in Reform China: Assessing the Impacts of Policy and Economic Growth. In: Hyde, W.F., Belcher, B. and J. Xu (eds.) *China's Forests: Global Lessons from Market Reforms*. Resources for the Future, Washington DC, USA, pp. 109–133.

Rowcroft, P. 2005. Working Paper 16 – Gaining Ground: the socio-economic driving forces behind decisions regarding land use and land-use change: an overview. MRC-GTZ Cooperation Programme. Vientiane, Laos.

Rowcroft, P. 2008. Frontiers of Change: The Reasons Behind Land-use Change in the Mekong Basin. *Ambio* **37** (3): 213-218.

Saatchi, S.S., N.L. Harris, S. Brown, M. Lefsky, E.T.A. Mitchard, W. Salas, B.R. Zutta, W. Buermann, S.L. Lewis, S. Hagen, S. Petrova, L. White, M. Silman, and A. Morel. 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. *Proceedings of the National Academy of Sciences* **108** (24): 9899-9904.

Sanderson, E., Forrest, J., Loucks, C., Ginsberg, J., Dinerstein, E., Seidensticker, J., Leimgruber, P., Songer, M., Heydlauff, A., O'Brien, T., Bryja, G., Klenzendorf, S. and E. Wikramanayake. 2006. *Setting Priorities for the Conservation and Recovery of Wild Tigers: 2005-2015. The Technical Assessment*. WCS, WWF, Smithsonian, and NFWF-STF, New York – Washington DC, USA.

Sathirathai, S. and Barbier, E.B. 2001. Valuing mangrove conservation in Southern Thailand. *Contemporary Economic Policy* **19**: 109–22.

Schaller, G.B. and Rabinowitz, A. 1995. The saola or spindlehorn bovid *Pseudoryx nghetinhensis* in Laos. *Oryx* **29**: 107-114.

Sheil, D. and Murdiyarso, D. 2009. How forests attract rain: an examination of a new hypothesis. *Bioscience* **59**:341-347.

Sindorf, N., and Wickel, A.J. 2011. Connectivity and fragmentation: Hydrospatial analysis of dam development in the Mekong river basin. Technical report CSPFW2011.1. WWF, Washington DC, USA. 27pp.

Smith, B.D. and Beasley, I. 2004. *Orcaella brevirostris* (Mekong River subpopulation). IUCN Red List of Threatened Species. Version 2011.2. Available at: www.iucnredlist.org.

Sodhi, N.S., Koh, L.P., Brook, B.W. and P.K.L. Lg. 2004. Southeast Asian biodiversity: an impending disaster. *Trends in Ecology and Evolution* **19**: 654-660.

Song, C. and Zhang, Y. 2010. Forest Cover in China from 1949 to 2006. In: Nagendra, H. and Southworth, J. (eds.) 2010. *Reforesting Landscapes: Linking Pattern and Process,* pp. 341–356.

Springer, Dordrecht, Netherlands.

Stacey, P.J. and Leatherwood, S. 1998. The Irrawaddy dolphin, Orcaella brevirostris: a summary of current knowledge and recommendations for conservation action. *Asian Marine Biology* **14** (1997): 195-214.

Stenke, R. and Chu Xuan Canh. 2004. The golden-headed langur (*Trachypithecus poliocephalus poliocephalus*) on Cat Ba Island – status, threat factors, and recovery options. In: Nadler, T., Streicher, U. and Ha Thang Long (eds.) *Conservation of Primates in Vietnam*, pp.72–77. Frankfurt Zoological Society, Hanoi, Vietnam.

Stibig, H-J., Stolle, F., Dennis, R. and C. Feldkötter. 2007. *Forest Cover Change in Southeast Asia: The Regional Pattern*. European Commission Joint Research Centre.

Sverdrup-Jensen, S. 2002. Fisheries in the Lower Mekong Basin: Status and Perspectives. MRC Technical Paper No. 6, Mekong River Commission, Phnom Penh, Cambodia. ISSN: 1683-1489.

Tanaka, N., Sasaki, Y., Mowjood, M.I.M., Jinadasa, K.B.S.N. and S. Homchuen. 2007. Coastal vegetation structures and their functions in tsunami protection: experience of the recent Indian Ocean tsunami. *Landscape and Ecological Engineering* **3**:1.

Taylor, R. (ed). 2011. *Forests for a living planet. WWF Living Forests Report*: Chapter 1. WWF-International, Gland, Switzerland.

Ten Brink, P. (ed). 2011. *The Economics of Ecosystems and Biodiversity in National and International Policy Making*. Earthscan, London, UK.

The Center for People and Forests. 2012. *Forests and climate change adaptation in Asia*. RECOFTC – The Center for People and Forests, Bangkok, Thailand.

Thompson, C. 2010. *Tigers on the brink: facing up to the challenge in the Greater Mekong: Cambodia, Laos, Myanmar, Thailand and Vietnam*. WWF-Greater Mekong, Vientiane, Laos.

Thompson, C. 2011. *Wild Mekong: New species in 2010 from the forests, wetlands and waters of the Greater Mekong, Asia's land of rivers*. WWF-Greater Mekong, Vientiane, Laos.

Thompson, C. 2012. *Extra Terrestrial. Extraordinary new species discovered in 2011 from the Greater Mekong*. WWF-Greater Mekong, Vientiane, Laos.

Thompson, I., Mackey, B., McNulty, S. and A. Mosseler. 2009. *Forest Resilience, Biodiversity, and Climate Change. A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems*. Technical Series no. 43. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Timmins, R.J., Robichaud, W.G., Long, B., Hedges, S., Steinmetz, R., Abramov, A., Do Tuoc and D.P. Mallon. 2008. *Pseudoryx nghetinhensis*. IUCN Red List of Threatened Species. Version 2011.2. Available at: www.iucnredlist.org.

Tsechalicha, X. and Gilmour, D.A. 2000. *Forest Rehabilitation in Laos*. IUCN, Vientiane, Laos.

Turner, W.R., Brandon, K., Brooks, T.M., Gascon, C., Gibbs, H.K., Lawrence, K.S., Mittermeier, R.A. and E.R. Selig. 2012. Global Biodiversity Conservation and the Alleviation of Poverty. *BioScience* **62**: 85-92.

UNEP. 2006. Sub-regional Environmental Performance Assessment (EPA) Report. United Nations Environment Programme, Regional Resource Centre for Asia Pacific: GMS Environment Operations Centre, Bangkok, Thailand.

United Nations. 2010. Preview: Green growth, resources and resilience. Environmental sustainability in Asia and the Pacific. United Nations. Bangkok, Thailand.

Vrieze, P. and Naren K. 2012. Carving up Cambodia one concession at a time. *The Cambodia Daily **730:*** 4-11. Available at: www.licadho-cambodia.org/land2012

Welcomme, R.L., Cowx, I.G., Coates, D., Béné, C., Funge-Smith, S., Halls, A. and K. Lorenzen. 2010. Inland Capture Fisheries. *Philosophical Transactions of the Royal Society B* **365**: 2881-2896.

Wikramanayake, E., Dinerstein, E., Loucks, C., Olson, D., Morrison, J., Lamoreux, J., McKnight, M. and P. Hedao. 2001. *Terrestrial ecoregions of the Indo-Pacific: a Conservation assessment*. Island Press, Washington DC, USA.

World Bank. 2010. World Development Report 2010: Development and Climate Change. Available at www.worldbank.org/wdr

Wright, H.L., Collar, N.J., Lake, I.R., Net, N., Rours, V., Sok, K., Sum, P. and P. M. Dolman. 2012. First census of white-shouldered ibis *Pseudibis davisoni* reveals roost-site mismatch with Cambodia's protected areas. *Oryx* **46**: 236-239.
WWF. 2009. *The Greater Mekong and climate change: biodiversity, ecosystem services and development at risk*. WWF-Greater Mekong Programme, Bangkok, Thailand.
WWF. 2009a. *China's Role in Global Trade: Opportunities and risks in the forestry and mining sector*. WWF, Beijing, China.
WWF. 2012b. *Living Planet Report 2012: Biodiversity, biocapacity and better choices*. WWF International, Gland, Switzerland.
WWF and the Asian Development Bank. 2012. *Ecological Footprint and Investment in Natural Capital in Asia and the Pacific*. WWF, Gland, Switzerland and ADB, Manila, Philippines.
WWF-Germany. 2011. *Rivers for Life: The Case for Conservation Priorities in the Face of Water Infrastructure Development*. Berlin, Germany.
Yang, J., Huang, J., Qiu, H., Rozelle, S. and M.A. Sombilla. 2009. Biofuels and the Greater Mekong Subregion: Assessing the impact on prices, production and trade. *Applied Energy* **86**: S37–S46.

APPENDIX II SOURCES FOR FIGURES

1. INTRODUCTION

Figure 1.2. Global ecosystem services values

Used by permission from author and publisher. Original citation: Turner, W.R., Brandon, K., Brooks, T.M., Gascon, C., Gibbs, H.K., Lawrence, K.S., Mittermeier, R.A. and E.R. Selig. 2012. Global Biodiversity Conservation and the Alleviation of Poverty. BioScience 62: 85-92.

Figure 1.3. Spatial distribution of estimated carbon (tonnes per hectare) stored in GMS forests.

The map is derived from: Saatchi et al. 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. PNAS June 3, 2011. This paper provides a reference map of biomass carbon stocks on three continents. The total carbon stock in live biomass (above- and below-ground) was mapped using a combination of data from in situ inventory plots and satellite light detection and ranging (Lidar) samples of forest structure, plus optical and microwave imagery (1km resolution).

2. FORESTS

Figures 2.1: A.1-A.4. Forest cover change maps Assumptions

The forest cover change maps were created by overlaying forest cover data for each of four years and calculating the loss of forest in each time period using arcGIS v. 10 (Earth Systems Research Institute - ESRI). The main assumption used to produce the forest cover maps for each point in time has been to consider as forest everything that was classified as forest in the most recent point in time. This conservative approach was followed because the data available had already been processed, was derived from different sources, with different resolutions, and often without a clear description of the season during which satellite images were obtained from the forest cover maps. Spatial errors due to image co-registration may remain, particularly in older datasets. The dataset from 1992 was incomplete (missing Vietnam) and had spatial errors; hence forest cover change from 1992 to 2002 is not shown here.

Data sources

Forest cover of the GMS for 2009

The map was derived from a modified GlobCov2009 map (© ESA 2010 and UCLouvain). Modifications were made to correct for deciduous forests based on local experts. Land cover is derived by an automatic and regionally tuned classification of a time series of global MERIS FR mosaics for the year 2009, the spatial resolution is 300m. The global land cover map counts 22 land cover classes defined with the United Nations (UN) Land Cover Classification System (LCCS).
GlobCov 2009 free download at http://ionia1.esrin.esa.int

Forest cover of the Greater Mekong Subregion (GMS), 1973-1992

Satellite data for 1973 and 1985 (b) was generated by Landsat Multi Spectral Scanner (MSS), with a spatial accuracy of 1000m; satellite data for 1992 was sourced from the Landsat Thematic Mapper (TM) with a spatial accuracy of 500m, 1992 forest cover data was generated by the Tropical Rain Forest Information Center (TRFIC) at Michigan State University. An overestimation of forests in Thailand in 1992 led to a calculation of 17% forest loss between 1992 and 2002, which contradicts FAO data for the same period. Data for China's Guangxi Zhuang Autonomous Region and Yunnan Province was not available prior to 2009.

Forest cover of the GMS for 2002

The 2002 map was generated using the "Tiger Land Cover" dataset (Sanderson et al., 2006), which is derived from the combination of two types of data: Landsat satellite imagery (e.g., Leimgruber et al. 2003, 2004), and coarse-resolution regional land cover data sets based on 1km AVHRR or MODIS satellite data (e.g., Loveland et al., 2000; Friedl et al. 2002). The purpose of this aggregate map was to show the entire tiger range and the decision to use this data for this publication has been driven by the experts-based evidence that this data was more reliable to show the distribution of dry-deciduous forests in the GMS: a particularly difficult class to detect from satellite images. The source data years go from 1992 to 2004 in the different areas. Some other modifications have been made in order to correct the distribution of scrub, which was overestimated. For additional details, please see Online Methodology)

Figures 2.3a - 2.3d; 2.6a - 2.6b. Forest fragmentation index maps

These four maps were developed using a moving window, or neighbourhood analysis, approach to determine the position of a central forest pixel, relative to its neighbours (here a neighbourhood of 7x7 pixels) on a raster image surface. As an example, a pixel that is completely surrounded by forest is classified as "core." The other classes are variations of the quantify of forested or non-forested neighbours (presented in figure 3 of Riitters, K., Wickham, J., O'Neill, R., Jones, B. and E. Smith. 2000. Global-scale patterns of forest fragmentation. Conservation Ecology 4(2): 3. Available at: www.consecol.org/vol4/iss2/art3

Forest fragmentation index maps for 2030

Forests in five levels of predicted fragmentation are presented for the year 2030, under (2.3e) an unsustainable growth scenario and (2.3f) a green economy scenario, using the levels of fragmentation and methods for generating the fragmentation index as in Figures 2.3a - 2.3d, above. Both 2030 scenarios were generated using the following values for each individual pixel: distance to roads, distance to non-forest, distance to water (coasts and rivers), elevation, distance to cities. See boxes 4 and 5 for assumptions of these 2 scenarios.

Figure 2.4. Likelihood of conversion from forest to no forest in the GMS

Data: The likelihood of conversion of a given pixel between a forest and a non-forest land use is based on the distances of each pixel to roads, non-forest areas, water, cities, as well as its elevation and slope. The neural network process evaluates the likelihood of forest loss based on historical trends relative to the spatial variables.
Software credit: Eastman, J.R., 2009. IDRISI Taiga (Worcester, MA: Clark University).

3. FRESHWATER

Figure 3.1. The freshwater ecosystems of the Mekong river system

Sindorf, N. and Wickel, A.J. 2011. Connectivity and fragmentation: Hydrospatial analysis of dam development in the Mekong river basin. Technical report CSPFW2011.1, August 2011. WWF, Washington DC, USA.

Figure 3.2. Impact of existing dams and the planned main stem Xayaburi dam on inter-ecosystem connectivity

Sindorf, N. and Wickel, A.J. 2011. Connectivity and fragmentation: Hydrospatial analysis of dam development in the Mekong river basin. Technical report CSPFW2011.1, August 2011. WWF, Washington DC, USA.

Figure 3.3. Classification of the free-flowing systems of the Mekong River with 50 large existing dams

Each reach of river was designated as one of the following types: Free-Flowing 1 (FF Type 1): no significant dams upstream and open connectivity to delta/sea; Free Flowing 2 (FF Type 2): river system upstream of dam that supports river of 100km length without significant dams upstream AND remains connected to main stem; Compromised 1 (C Type 1): river system with significant dam upstream; Compromised 1b (C Type 1b): river system with significant dam upstream AND upstream of a dam; Compromised 2 (C Type 2): river system upstream of dam NOT supporting river of 100km length without significant dams upstream; or Compromised 2b (C Type 2b): river system upstream of dam that supports river of 100km length without significant dams upstream.
Sindorf, N. and Wickel, A.J. 2011. Connectivity and fragmentation: Hydrospatial analysis of dam development in the Mekong river basin. Technical report CSPFW2011.1, August 2011. WWF, Washington DC, USA.

4. SPECIES

Figure 4.1. Historical and current distribution of tiger (Panthera tigris)

Historical distribution map adapted from Luo, Shu-Jin, Jae-Heup, K., Johnson, W.E., van der Walt, J.; Martenson et al. 2004. Phylogeography and genetic ancestry of tigers (Panthera tigris). PLoS Biology 2 (12): e442. Available at PLoS Biology.

Figure 4.2. Historical and current distribution of elephant (Elephas maximus)

Historical distribution map adapted from Shoshani, J. and Eisenberg, J.F. 1982. Elephas maximus. Mammalian Species 182: 1–8.

Figure 4.3 Historical and current distribution of Irrawaddy dolphin, Mekong River subpopulation (Orcaella brevirostris)

Historical distribution map adapted from IUCN. 2009. IUCN Red List of Threatened Species. Version 2009.1 Available at: www.iucnredlist.org.
Current distribution map based on WWF-Cambodia surveys.

Figure 4.4. Historical distribution of Javan rhino (Rhinoceros sondaicus)

Historical distribution map derived from range map in Foose, T.J. and van Strien, N. 1997. Asian Rhinos – Status Survey and Conservation Action Plan. IUCN, Gland, Switzerland, and Cambridge, UK.
The latest distribution from IUCN. 2009. IUCN Red List of Threatened Species. Version 2009.1. Available at: www.iucnredlist.org

Figure 4.5. Potential distribution of saola (Pseudoryx nghetinhensis)

IUCN. 2009. IUCN Red List of Threatened Species. Version 2009.1. Available at: www.iucnredlist.org

Figure 4.6. System of protected areas across the GMS.

The data is based on government data collected by WWF country offices in the GMS.

5. DRIVERS OF ECOSYSTEM CHANGE

Most of the data for this chapter is from the GMS Infrastructure Mapping project, which was implemented by WWF's Macroeconomic Programme Office in 2007. This project mapped existing and planned infrastructure within the GMS to provide a GIS database to facilitate and prioritize conservation activities in this area. This data was the best available at the time this report was developed.

Figure 5.1. Current and planned mineral and coalmines in the GMS

Mine sites layer contains 1448 data points and its main sources include Mineral Resource Data System (MRDS), Raw Material Database, USGS report, World Bank report and other web resources.

Figure 5.2. Locations of principal national roads planned, major roads and important cities (red dots) in the GMS

Existing national roads and ADB planned regional roads are based on ADB report (www.adb.org/GMS/gms_corridors02.jpg). Using Geo-reference function in ArcMap, the ADB map (JPEG format) was firstly overplayed with other layers and then screen digitalized.

Figure 5.3. Map of current and planned dams in the GMS

The dam layer contains 392 data points and its main sources include personal contact with Dr Darrin Magee and the hydropower database composed by WWF-Great Mekong. The database is based on EVN 2004, ADB 2005, WWF 2006. To ensure accuracy, we reviewed the literature (International Journal of Hydropower and Dams) and web resources. The data is updated until 2007; thus, not all the dams currently present are shown on the map.

ABBREVIATIONS

ADB	Asian Development Bank
EIA	Environmental Investigation Agency
ELC	Economic Land Concession
ESRI	Earth Systems Research Institute
FAO	Food and Agriculture Organization of the United Nations
FLEGT	Forest Law Enforcement, Governance and Trade Action Plan of the European Union
GMS	Greater Mekong Subregion
ICEM	International Centre for Environmental Management
IPCC	Intergovernmental Panel on Climate Change
MEA	Millennium Ecosystem Assessment
MRC	Mekong River Commission
PADDD	Protected area downgrading, downsizing and degazettement
PES	Payment for Ecosystem Services
PROFOR	Program on Forests, multi-donor initiative
REDD+	Reducing Emissions from Deforestation and Forest Degradation "plus" conservation
TEEB	The Economics of Ecosystems and Biodiversity
UNEP	United Nations Environment Programme
WWF	World Wide Fund for Nature (known as World Wildlife Fund in North America)

ACKNOWLEDGMENTS

Many people contributed to the production of this report. Recognizing the power of maps to convey key ideas Stuart Chapman (WWF-GM Conservation Director) suggested producing a map report to document changes in the Greater Mekong Subregion's forests modelled after the WWF Heart of Borneo Global Initiative's report entitled Borneo: Treasure Island at Risk. Geoffrey Blate (WWF-GM Technical Advisor, Landscape Conservation) and Peter Cutter (WWF-GM Manager, Landscape Conservation) worked closely with Barbara Pollini (WWF-GM Landscape Ecologist and Spatial Analyst), Aurélie Shapiro (WWF Germany Remote Sensing Specialist), Sarah Bladen (WWF-GM Communications Director) and Nigel Dudley (Equilibrium Research) to produce the current product. Barbara and Aurélie conducted the forest change analyses and produced the forest change and species distribution maps. Nigel wrote the final narrative. Sue Palmentieri wrote the initial draft. George Powell provided invaluable inputs to the forest change analysis. Victor Cowling and Marc Goichot contributed ideas and content to the freshwater chapter. Nick Cox and Thomas Gray contributed ideas and content to the species chapter. Barney Jeffries proofread and copy-edited the report. Jonathan Gledson designed and prepared the report for publication. The report was improved immensely thanks to critical feedback and suggestions provided by WWF-GM colleagues (Gordon Congdon, Victor Cowling, Louise Gallagher, Thibault Ledeq, and Mark Wright) and WWF Network colleagues (Nirmal Bhagabati, Michael Mascia, Richard McLellan, Rodney Taylor). Three independent peer reviewers – Barry Flaming, Lucy Emerton, and Peter Jipp – provided invaluable insights and suggestions, which have greatly improved this report. WWF-Greater Mekong assumes responsibility for any errors, and all of the assumptions and conclusions in the report.

WWF-Greater Mekong in numbers

100% RECYCLED

850+

The Mekong has at least 850 species of freshwater fish

60 MILLION

The Lower Mekong River provides food and livelihoods for 60 million people

1,700+

Since 1997, an incredible 1,710 new species were newly described by science in the Greater Mekong

290,000

WWF aims to conserve 8 priority areas covering 290,000km²

The Greater Mekong region is one of the biologically richest places on the planet; its varied natural resources support the livelihoods and well-being of millions of people in mainland Southeast Asia. WWF-Greater Mekong – on the ground in Cambodia, Laos, Myanmar, Thailand and Vietnam – is working to conserve the region's biodiversity and build a secure and sustainable future for people and wildlife.

WWF®

Why we are here

To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

panda.org