Scoping Study on Natural Resources and Climate Change in Southeast Asia with a Focus on Agriculture

Report prepared for the
Swedish International Development Cooperation Agency
by
International Water Management Institute, Southeast Asia (IWMI-SEA)

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Abbreviations and Acronyms

ACFTA	ASEAN - China Free Trade agreement
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AEZ	Agroecological zone
AFD	Agence Française de Développement
ASEAN	Association of Southeast Asian Nations
AusAid	Australian Government's Overseas Aid Programme
AWM	Agricultural water management
CA	Comprehensive Assessment of Water in Agriculture (IWMI)
CASP	Core Agriculture Support Program of ADB-GMS
CCKAP	Climate Change Knowledge and Adaptation Platform
CDM	Clean Development Mechanism
CGIAR	Consultative Group on International Agricultural Research
CIFOR	Center for International Forestry Research
CPWF	CGIAR Challenge Program on Water and Food
CURE	Consortium for Unfavourable Rice Environments
ESA	European Space Agency
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO on-line statistical database
GCM	Global Circulation Model
GCP	Global Climate Program
GDP	Gross domestic product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GHI	Global Hunger Index
GMS	Greater Mekong Subregion
IFAD	International Fund for Agricultural Development
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
IUCN	International Union for the Conservation of Nature
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
LMB	Lower Mekong Basin
MAF	Lao PDR Ministry of Agriculture and Forestry
MAFF	Cambodian Ministry of Agriculture, Forestry and Fisheries
MARD	Vietnamese Ministry of Agriculture and Rural Development
MIME	Cambodian Ministry of Infrastructure, Mines and Energy
MoE	Cambodian Ministry for Environment
MONRE	Vietnamese Ministry of Natural Resources and Environment
MOWRAM	Cambodian Ministry of Water Resources and Management
MRC	Mekong River Commission
msl	mean sea level
NAPA	National Adaptation Program of Action to Climate Change
PES	Payment for environmental services
REDD	Reducing Emissions from Deforestation and Forest Degradation

SEI	Stockholm Environment Institute
SENSA	Swedish Environment Secretariat for Asia
SIANI	Swedish International Agricultural Network Initiative
Sida	Swedish International Development Cooperation Agency
SLR	sea-level rise
SRES	Special Report on Emissions Scenarios
START	Global Change System for Analysis, Research and Training
TEI	Thailand Environment Institute
UNDP	United Nations Development Programme
UNEP	United Nationals Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WREA	Lao PDR Water Resources and Environment Administration
WRI	World Resources Institute
WWF	World Wildlife Fund

In tables, standard abbreviations for country names are used, as follows:

CN	China
KH	Cambodia
LA	Lao PDR
MM	Myanmar
TH	Thailand
VN	Vietnam

Executive Summary and Recommendations

This scoping study was commissioned by Sida-Swedish Environment Secretariat for Asia (SENSA) to explore issues related to food security and environment in the context of climate change in the Greater Mekong Subregion (GMS), in order to identify opportunities to develop the agriculture sector into a vehicle for ameliorating the negative effects of climate change and environmental degradation. The study explores trends and drivers of agricultural production (including fisheries and agroforestry) in the GMS from 1990 to 2050.

Agriculture in Southeast (SE) Asia is in transition from traditional subsistence systems to modern commercial production with a wide range of commodities for both local consumption and export. Agricultural production in the GMS over the last 20 years has seen steady increases across all subsectors and all countries. Production in major commodity groups has more than doubled since 1990 and has outpaced the region's rapid population growth. These increases are attributed mainly to intensification and increases in yield, rather than to expansion in agricultural area, drawing on new technologies and approaches derived from the 'green revolution.' In some parts of the GMS, growth rates in the culture of fish, supplementing capture of dwindling wild stocks, are among the highest in the world.

Increased agricultural production has not come without environmental cost: land degradation affects between 10 and 40% of land area in each country in the region. High rates of deforestation, soil erosion, declining soil quality and changes in water quantity and quality are all directly attributable in large measure to agricultural practices. Changes in landscapes associated with agriculture have contributed to the loss of essential regulating ecosystem services such as flood-retention capacity, erosion control and biological pest control.

Projections of climate change impacts in the region to 2050 based on a downscaled regional model indicate that the major impacts up to 2050 in the GMS will be an increase in temperature of 0.02-0.03 °C per year across the entire region, with no significant change in annual rainfall across most of the region, but with some shift in seasonal patterns. Sea levels are expected to rise by up to 30 cm. Beyond 2050, climate impacts will be severe and the prospect of sea-level rise in excess of 1 m must be factored into long-term regional planning. These changes will impact on agricultural production through a range of direct and indirect pathways, with the main effects being felt through changes in water availability and loss of productive land by sea-level rise.

Rapid economic development in the region is already having profound impacts on agricultural systems and the natural ecosystems that support them. A combination of population growth and rising living standards is posing a new set of challenges in meeting future food demand. China's economic growth and reemergence as a major trading partner is placing ever-increasing demands on the natural resources of the region. Global trade is driving investment in agriculture and changes in production to meet export demands. Increased energy demands are driving large hydropower developments which will impact on the water sector and the inland fisheries resources.

Climate change is incremental with small changes from year to year that, initially at least, are within the range of observed natural climate variability and will be masked by them. In contrast, social, demographic and economic drivers are already forcing regional change at a very fast pace. Estimates of changes in crop productivity due to climate change are in the range of 2-30% over a 20-30 year period (Eastham et al. 2008; Hoanh et al. 2004); in comparison, total agricultural production has increased almost 80% in Vietnam and over 200% in Cambodia over the last 15 years, with even faster growth in specific sectors and regions. Published projections of climate-induced changes in mean annual flow in the Mekong range from 5% (Hoanh et al. 2003) to 20% (Eastham et al. 2008); planned large hydropower projects in the Mekong are projected to increase dry-season flows by 10-50% and decrease wet-season flows by 6-16% (Hang and Lennaerts 2008). Dasgupta et al. (2007) estimated that a 1 m rise in sea level would reduce Vietnam's GDP by 7%, and ADB (2009a) estimates climate-change-related reduction of GDP in SE Asia of 6.7% per year by 2100; the 1997 Asian crisis reduced Thailand's GDP by almost 10% in 1998 and the current financial crisis is similarly expected to significantly reduce or reverse GDP growth in most countries (World Bank 2009b).

Thus in the next 20 to 30 years, agriculture will be shaped by a very complex mixture of social, economic and environment factors, with impacts of at least the same order or greater magnitude as direct impacts of climate change. The challenge facing agriculture in the region is how to produce more food, more sustainably in this context of rapid change. Agriculture must be transformed to deliver not only food security but also environmental services (such as clean water and carbon sequestration) and economic security in rural areas. Global awareness of climate change has brought an enhanced awareness of the fragility of natural systems and a new, longer-term perspective to national and regional planning; this new perspective presents an opportunity to radically rethink approaches to agricultural production.

A great deal is already known about how agricultural systems need to change and, in many cases, there are "win-win" solutions that deliver both increased production and environmental benefits. The difficulty lies not in what should be done but in how to do it in a context where changes in land use practice are sought from poor farmers whose livelihood options are limited. New mechanisms for promoting sustainable land use are needed, drawing on the experience from emerging financial models based on mitigation payments through schemes such as Reducing Emissions from Deforestation and Forest Degradation (REDD), payment for environmental services and harnessing global trade to promote change. Reorienting agricultural production presents opportunities to work with rural producers to diversify and improve their livelihood options, and to build adaptive, resilient communities that are better integrated and better able to meet both food security and new market demands.

Recommendations to Sida

Sida-SENSA is well positioned to act as a champion for new regional programs drawing together the issues of agricultural production, environmental sustainability and climate change. There is a unique opportunity for Sida to promote a shift to more sustainable agricultural production systems, capitalizing on the current conjunction of rapidly changing, responsive agricultural economies; a new, longer-term, regionally oriented planning perspective stemming from international awareness of climate change; and the "breathing space" of 20-30 years that projections suggest may be available to the GMS region before radical changes in climate occur. By using this period to identify, pilot, implement and upscale measures to build more resilient communities, the GMS region will be better positioned to handle the more extreme changes predicted for the second half of the century—and more urgently, will alleviate current poverty and food insecurity.

It is recommended that Sida-SENSA can contribute most effectively through targeted research programs leading to pilot implementation of new production modes; and by promoting understanding of the policy significance of emerging knowledge through regional dialogue and analysis. By working in close collaboration with national and regional research and management agencies to achieve these objectives, Sida can contribute to a third, equally important objective: building national and regional capacity to plan and manage sustainable agricultural production systems. Examples of priority projects in each arena include:

- Research/pilot program on the provision of environmental services by agricultural systems, with an initial focus on mitigation of greenhouse gas emissions.
- Research/pilot program on redesigning rain-fed production systems: landscape approaches to agricultural planning to enhance production while maintaining environmental services.
- Roundtable discussion and review of climate models and resulting projections of water availability for the region, to bring some consistency to the technical base for adaptation planning.
- Policy dialogue on the role of agricultural development in climate change adaptation.

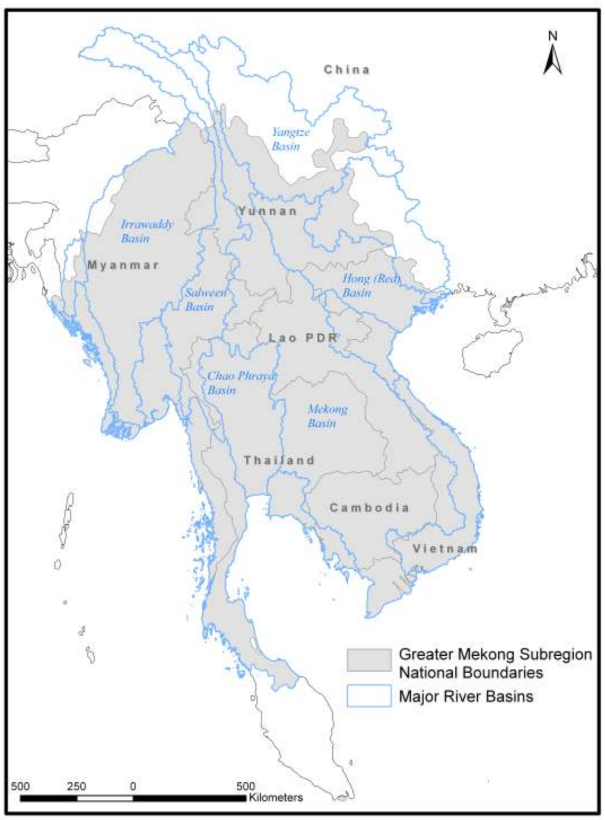
These programs would provide an opportunity at the regional level for Sida to invest in bringing the adaptation, mitigation and sustainability debates together and to spearhead an approach that explicitly recognizes their interaction, building from the substantial body of work already underway in the region.

1 Introduction

Background

The Greater Mekong Subregion (GMS) comprising Cambodia, Lao PDR, Myanmar, Thailand, Vietnam and Yunnan province of China (Figure 1.1) is undergoing rapid social, economic and environmental change. The population has doubled in the last 40 years to a current estimated level of 260 million and is expected to rise to 320 million by 2050 (World Bank 2009a). Economically, the region has been growing rapidly until the recent global financial crisis: GDP per capita has grown between 5% and 10% per annum over the last 10 years due to increasing investment in the industrial sector and infrastructure. Despite this high growth rate, many people in the region still live under the national poverty lines, and the 2008 Global Hunger Index (von Grebmer et al. 2008) indicated serious-to-alarming levels of hunger in all countries in the region except Thailand and Yunnan. These figures may not reflect well the situation in Yunnan, which is significantly below the Chinese average in terms of poverty (Ahmad and Goh 2007).

Figure 1.1 Greater Mekong Subregion.



Food security is obviously a pressing concern, and rapid expansion of agriculture to feed rising populations has placed natural systems under increasing pressure. Land degradation is widespread, with high rates of deforestation, loss of habitat, soil erosion and decline of soil fertility. Water resources in the region, though abundant, are under pressure in some areas from withdrawals for irrigation, changes in flow regime due to hydropower development and declining water quality in peri-urban and intensively farmed areas. Climate change adds a further dimension to the already complex interactions between natural resources, food production systems and development requirements.

Purpose of the Study

This scoping study was commissioned in late 2008 by the Swedish Environmental Secretariat for Asia within the Swedish International Development Cooperation Agency (Sida-SENSA) to explore issues related to food security and environment in the context of climate change in the GMS, in order to identify opportunities to develop the agriculture sector into a vehicle for ameliorating the negative effects of climate change and environmental degradation.

Structure of the Report

The report presents an overview and discussion of the trends, threats and opportunities related to agricultural production and its impact on natural resources systems in the context of climate and socioeconomic changes. "Agriculture" and "agricultural production" are used in their broadest sense to include food production from livestock and fisheries (both capture and aquaculture) as well as cultivation of food and nonfood crops. Forestry is not considered in the report, except for agroforestry as part of cropping systems.

The geographical focus of the study is the GMS, including Cambodia, Lao PDR, Thailand, Vietnam, Myanmar and Yunnan. Information (in English language) on Myanmar and Yunnan is much less available than on the other countries, and the majority of studies on climate change in the region have focused on the Mekong catchment. There is a corresponding bias in coverage in this report. Since the purpose of the report is to inform discussion on Sida program priorities, we have focused on the short to the medium term (to 2050).

To capture the interactions and dependencies between agriculture and the ecosystems that support it, production systems, trends and impacts have been analyzed in the context of five major agroecological zones (AEZs), defined on the basis of topography and land use: see section on Trends in Agricultural Production in the GMS 1990-2007. The report is divided into seven sections of which the first outlines the structure and purpose of the report; the second provides an overview of agricultural production within the GMS since 1990, with a description of production systems and trends within the major AEZs, and impacts of agriculture on the environment; the third reviews the current state of understanding of climate change and its projected impacts on agriculture in the region, based on a review of the literature plus a statistical analysis of climate variability and trends over the period 1960-2049 and outlines potential responses to adapt agricultural systems to changes in climate in different AEZs; the fourth discusses the external drivers of agricultural change in the region, and their impacts; the fifth examines the potential for rethinking agricultural systems to increase production while maintaining or enhancing environmental services in the face of rapid changes from a range of causes; the sixth discusses institutions and mechanisms needed to implement changes in agriculture; and the last outlines key knowledge gaps, conclusions and recommendations.

Data Sources Used in the Report

Agricultural statistics in the following analysis were obtained from the following sources:

- FAOSTAT 2009.
- Lao PDR Ministry of Agricultural and Forestry Website (http://www.maf.gov.la/)
- Laotian National Statistics Centre (http://www.nsc.gov.la/)
- Cambodian Ministry of Agriculture, Forestry and Fisheries (http://www.maff.gov.kh/statistics/index.html)
- Office of Agricultural Economics of the Ministry of Agriculture and Cooperative of the Royal Thai Government (http://www.oae.go.th/English/index.htm)
- Department of Fisheries, Thailand (2009) http://www.fisheries.go.th/it-stat/
- Vietnam: General Statistical Office of Vietnam (http://www.gso.gov.vn/)
- Digital Agricultural Atlas of Myanmar (FAO 2008) http://dwms.fao.org/atlases/myanmar/index_en.htm).

The most recent provincial statistics are from different years in different countries; in general: 2003/04 for Thailand, 2005 for Myanmar, 2006 for Cambodia and Lao PDR, and 2007 for Vietnam.

Data on land cover are from the European Space Agency land use data set at http://ionia1.esrin.esa.int/index.asp and from the ADB Greater Mekong Environment Outlook (UNEP and TEI 2007).

Population data were drawn from national statistical offices (above), and World Gazetteer http://world-gazetteer.com/. Data on population density were taken from Gridded Population of the World - version 3 (GPWv3) produced by the Center for International Earth Science Information Network (CIESIN) of the Earth Institute at Columbia University, USA (http://sedac.ciesin.columbia.edu/gpw/).

2. Agricultural Systems and Trends in the GMS

Trends in Agricultural Production in the GMS 1990-2007

Agriculture in SE Asia is in transition from traditional subsistence systems to modern commercial production with a wide range of commodities for both local consumption and export. The extent of travel along this trajectory varies enormously both within and between countries, but the overall direction of change is very similar: intensification, specialization, increased inputs and mechanization. The more developed countries (such as Thailand and China) can be seen as models where the less developed countries are heading.

Agricultural production in the GMS over the last 20 years has seen steady increases across all subsectors and all countries. Production in major commodity groups has more than doubled since 1990 (Figure 2.1) and has outpaced the region's rapid population growth. The average annual per capita production of rice grew from 310 to 480 kg per person, a 54% increase, between 1990 and 2007. There had been significant diversification from rice to other crops, with an increasing proportion of production in commercial commodities such as coarse grains (maize, millet, sorghum), oil crops (soybean, groundnut, sesame, sunflower), horticultural products (fruits, vegetables, flowers) and industrial crops such as rubber and pulpwood. Numbers of small livestock (pigs and poultry) had doubled, and cattle numbers had increased by 45%.

The largest increases have been seen in aquacultural production, with official increases of over 300% in brackish and over 500% in freshwater systems (FAO 2007; Department of Fisheries, Thailand 2009); even these numbers are unlikely to reflect the real magnitude of production, since statistics on fisheries are notoriously unreliable. Although the total catch in capture fisheries has risen, there has been a consistent decline in the catch per unit effort and there is general consensus that both the marine and freshwater fisheries are overfished. Aquacultural gains have been mainly achieved through increases in production area with some intensification during the past 10 years.

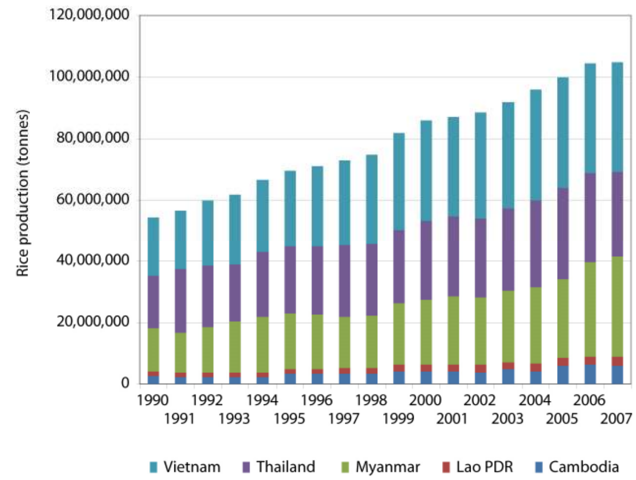
In cropping systems, most of this remarkable increase in production has come from intensification and increases in yield, rather than from expansion in agricultural area. Increases in crop yields have resulted from a range of causes: more effective irrigation, uptake of improved varieties, increasing use of fertilizers and improved farming practices. These successes can be attributed to the development and adoption of new technologies and approaches that have elements derived from the 'green' revolution. While yields continue to rise, the rate of yield growth is beginning to slow which raises concern over whether we can meet future demands.

Expansion of agricultural land has been much slower than population growth, leading to an 11% decrease in arable land per capita in the GMS between 1990 and 2003 (Table 2.1). An additional 2 million hectares (Mha) have been brought into production, with new areas opening up in the Central Highlands of Vietnam and in Yunnan, and smaller increases in Myanmar, Lao PDR and Cambodia; total agricultural area in Thailand decreased slightly over this period (UNEP and TEI 2007).

Figure 2.1. Production trends of selected commodities in the GMS.

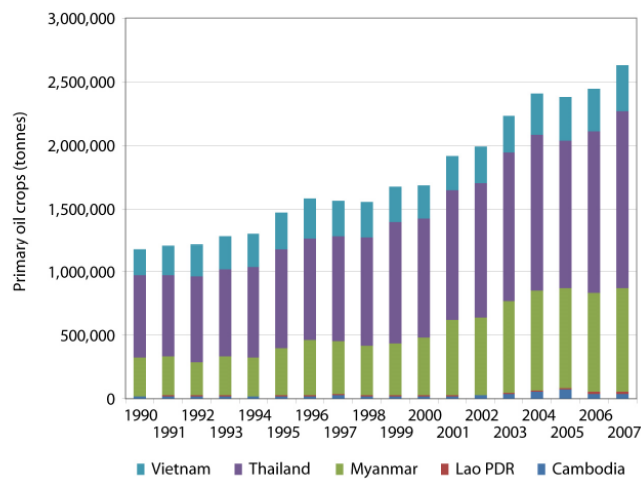
a) Rice

Source: FAOSTAT 2009.



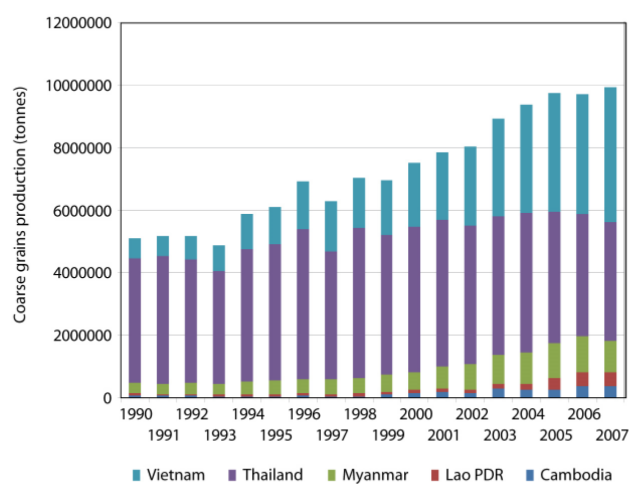
b) Primary oil crops

Source: FAOSTAT 2009.



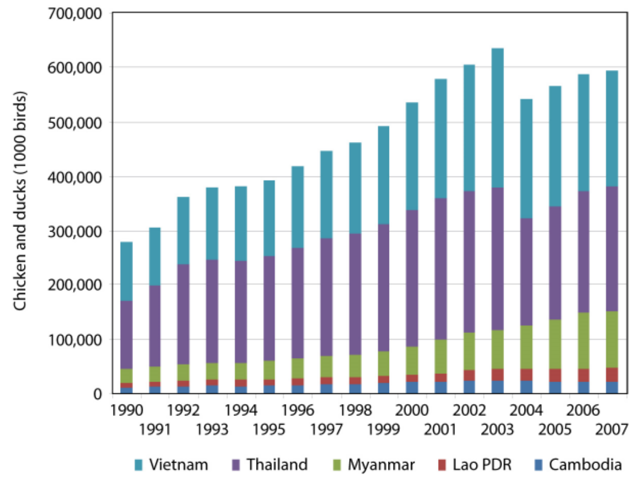
c) Coarse grains

Source: FAOSTAT 2009.



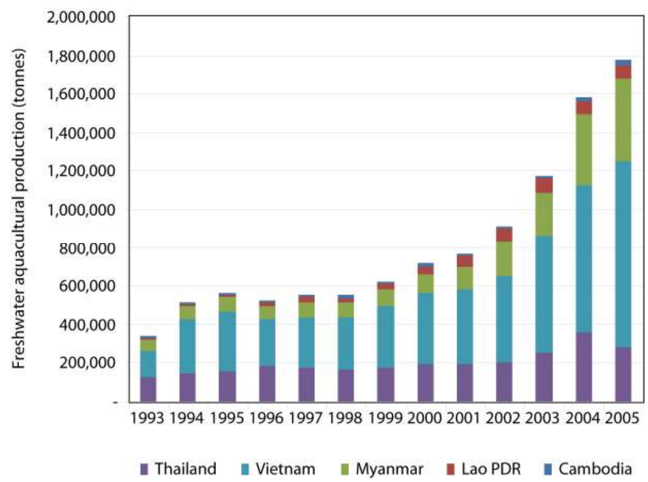
d) Poultry

Source: FAOSTAT 2009.

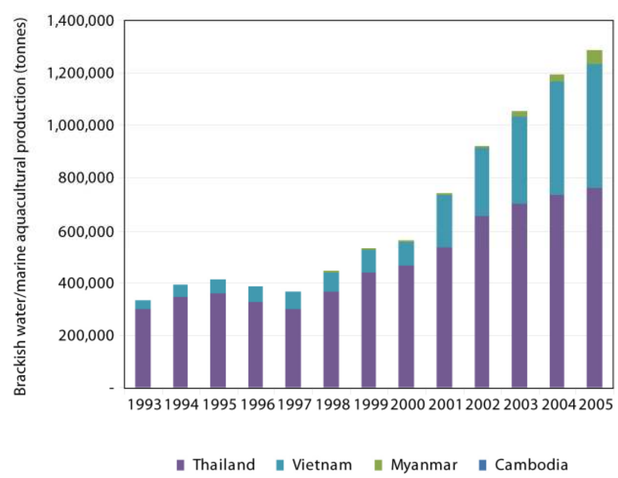


e) Freshwater aquacultural production (tonnes)

Sources: FAO, 2007;
Department of Fisheries Thailand, 2009.

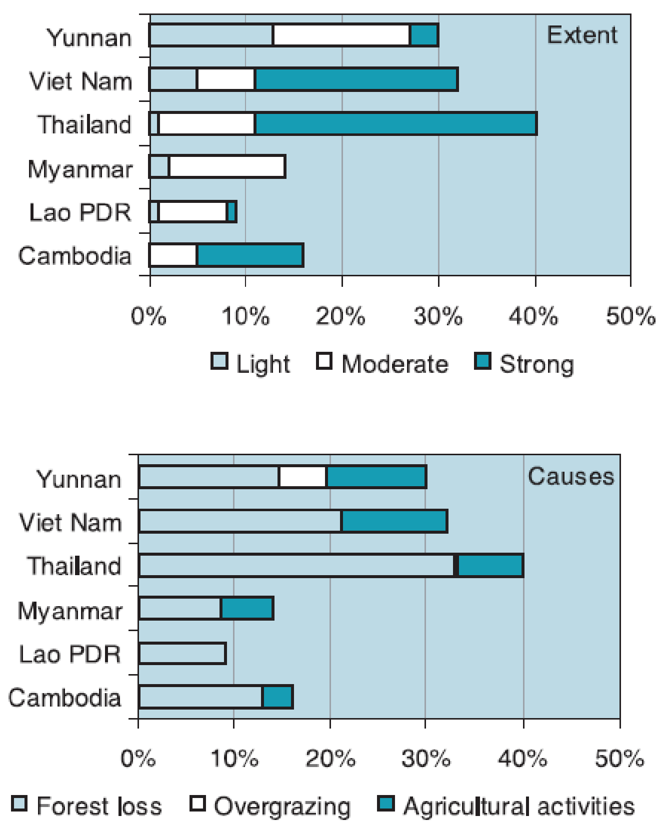


f) Brackish water/marine aquacultural production (tonnes)
Sources: FAO, 2007;
Department of Fisheries Thailand, 2009.



Increased agricultural production has not come without environmental cost: the Greater Mekong Environment Outlook (UNEP and TEI 2007) concluded that land degradation affects between 10% and 40% of land area in each country in the region, and that forest loss, agricultural activities and overgrazing (in Yunnan) are the major causes of this degradation (Figure 2.2). High rates of deforestation, soil erosion, declining soil quality and changes in water quantity and quality are all directly attributable in large measure to agricultural practices. Changes in landscapes associated with agriculture have contributed to the loss of essential regulating ecosystem services such as flood retention capacity, erosion control and biological pest control (CA 2007). Agriculture is by far the largest consumer of water, using between 68% (in Vietnam and China) and 98% (in Cambodia) of total withdrawals (WRI 2009). Irrigation development has altered natural flow regimes, with impact on natural fish populations and wetlands. Increased water withdrawals and resulting dry-season water shortages have resulted in competition for water, particularly in intensively irrigated areas such as the Red and Chao Phraya deltas. Proposed major hydropower development on the Mekong, Salween and Irrawaddy will result in even larger changes to flow regimes with accompanying implications for both fisheries and agriculture.

Figure 2.2 Extent and causes of land degradation in the GMS (note that data for Yunnan refer to the whole of China).



Source: UNEP AND TEI 2007.

Table 2.1. Land use in the GMS 1990 and 2003/05.

	Land area ('000 ha)	Arable land Share of total land area %		Cropped land per capita (ha)		Forest land[1] Share of total land area %	
		1990	2003	1990	2003	1990	2005
Cambodia	17,652	20.9	21.0	0.44	0.28	73%	59%
Lao PDR	23,080	3.5	4.1	0.21	0.18	75%	70%
Myanmar	65,755	14.5	15.3	0.25	0.21	60%	49%
Thailand	51,089	34.2	27.7	0.37	0.28	31%	28%
Vietnam	32,549	16.4	20.5	0.10	0.11	29%	40%
Yunnan [2]	38,264	7.2	15.7	0.08	0.14	25%	39%
GMS	228,389	17.3	18.2	0.21	0.19	46%	44%

[1]*Forest land includes plantations.*

[2]*Data for Yunnan are for 1992 and 2002.*

Source: Greater Mekong Environment Outlook (UNEP and TEI 2007).

Agroecological Zones in the GMS

To capture the interactions and dependencies between agricultural production systems and the ecosystems that support them, the GMS is divided into five very broad AEZs, shown schematically in Figure 2.3.

- *Tonle-Sap floodplain and the mega-deltas* of the Red, Mekong, Chao Phraya and Irrawaddy rivers.
- The *plains and plateaus* of the Isan region of northeast Thailand, Central Thai Plain, Myanmar dry region, Lao Mekong floodplains, and north and northeast Cambodia.
- *Intensively farmed uplands* of Yunnan, northern Thailand, Central Highlands of Vietnam and the Bolovens Plateau in Lao PDR.
- *Forested uplands* of northern Lao PDR, eastern and western hills in Myanmar, NW (NW) Vietnam and Yunnan.
- *Coastal zones* - narrow coastal plains rising rapidly to coastal ranges, usually within 50 km of the ocean (Vietnam, Cambodia, Thailand, Myanmar).

Although there is significant variation within these zones, they share common production systems and are subject to similar biophysical constraints and risks. They should not be considered as rigidly defined areas, but simply as a useful construct for discussing agricultural systems at the regional scale. Table 2.2 summarizes major characteristics of each zone.

Figure 2.3 Schematic map of AEZs in the GMS.

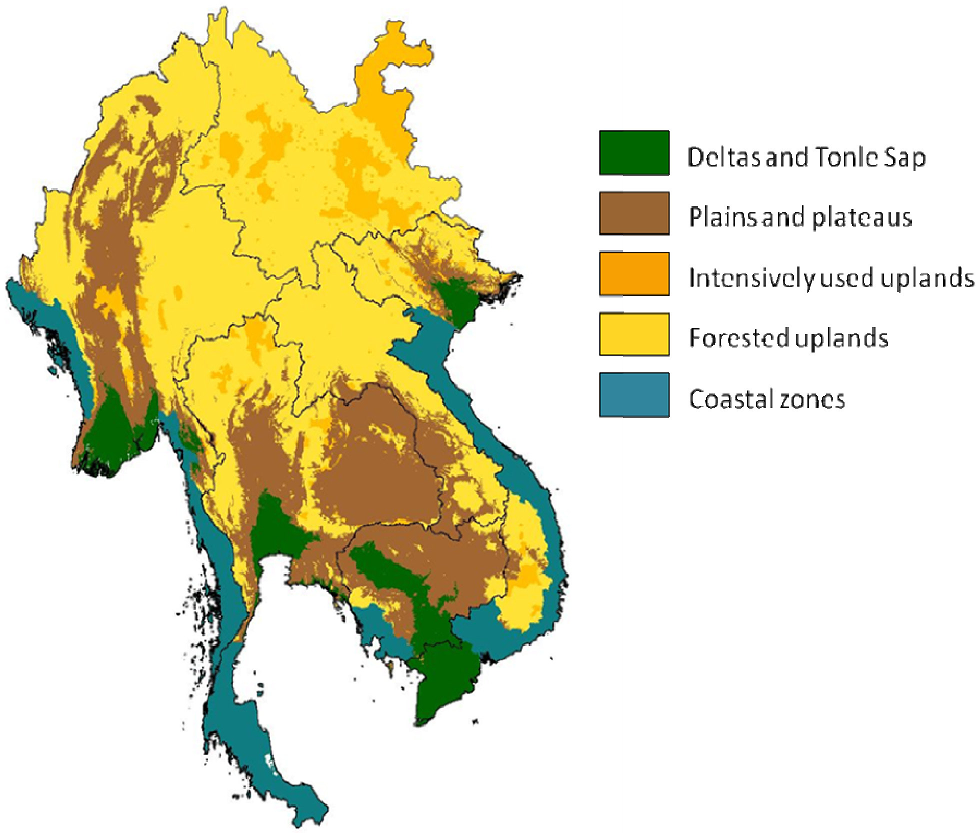


Table 2.2 Characteristics of AEZs of the GMS.

	Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
Main administrative /statistical reporting area in each AEZ †	KH Tonle Sap MM Delta TH Central (part) VN Red River Delta VN Mekong Delta	KH North + KH northeast + KH Tonle Sap LA Central + LA South (part) MM Central TH North (part) + TH northeast VN southeast	CN Yunnan LA South (Bolovens Plateau) TH North MM Hills (Shan Plateau) VN northeast + VN northwest + VN Central Highlands	CN Yunnan LA North + LA South + LA Central (part) MM Hills VN NW	CA Coast MM Coast TH South VN North Central + VN South Central + VN southeast (part)
Area	~8% of GMS land	~25% of GMS land	~10% of GMS land	~45% of GMS land	~12% of GMS land
Elevation (m)	< 20	< 250	> 250 and < 3,000	> 250	0 - 2000
Population in millions	86 (31% of GMS)	64 (23% of GMS)	65 (24% of GMS, mostly in Yunnan)	~20(7% of GMS)	~40 (15% of GMS)
Population	Each hosts a major city. High population density— very high in Red and Chao Phraya. Total urban population ~35 million.	Moderate density (50—150 persons per km^2, except in KH < 10) Area with greatest numbers of poor in TH, LA, probably MM	100- 250 persons per km^2 in permanently farmed uplands;	< 50 persons per km^2 Dominated by ethnic minorities; high poverty rates (> 30% Yunnan and > 75% elsewhere) but low total number	High density (>100) except on MM Coast.
Main characteristics	The rice bowls of the major deltas - nearing full production, problems of intensification, flooding, high population density.	Mixed agricultural systems with wet- season rice plus a second dry-season crop (irrigated rice, sugarcane, maize, legumes, pulses, cassava), stubble grazing and plantations (sugarcane, oil crops, rubber, timber and pulpwood).	Intensively farmed uplands with wide range of suitable crops in subtropical—temperate conditions at increasing altitude. Soil erosion, intensification, agroforestry options.	Poorest areas with sloping lands with forest cover, swidden systems and grazing.	Narrow coastal plains rising to coastal ranges at 500 —2,000 m. Short, steep rivers with small watersheds (<50 km^2). Mixed production systems, including agro-industrial and tree crops.

† CN = China; KH = Cambodia; LA = Lao PDR; MM = Myanmar; TH = Thailand; VN = Vietnam.

Deltas and Tonle Sap

Red River Delta, Mekong Delta, Tonle Sap floodplain,[1] Chao Phraya Delta and Irrawaddy Delta

The mega-deltas of the Red, Mekong, Chao Phraya and Irrawaddy rivers, and the Tonle Sap floodplain all lie at an elevation below 20 m msl. They represent less than 10% of the total land area in the GMS (~20 Mha), but are home to over a third of the total GMS population 86 million). Each hosts a major city[2]: total urban population is around 35 million. The cities are an important influence on agriculture in the deltas, both as markets (with high demand for horticultural crops and meat) and as alternative sources of income for rural dwellers—the “new rurality.” Even outside the urban areas, population densities are high: the Red River Delta is one of the most densely populated agricultural areas in the world.

The deltaic regions represent a development trajectory from the Tonle Sap floodplain (least developed) through Irrawaddy (partially developed) through Mekong (highly developed) to Red and Chao Phraya (essentially closed basins in terms of both water and land resources), in response to demand for increased production. The deltas are the rice bowls of the region, but are nearing full production, with problems of intensification, flooding and high population density.

Production Systems and Trends

Rice. The deltas are the rice bowls of SE Asia, with total production in excess of 46 million tonnes (almost half of the total of 100 million tons of rice produced in GMS excluding Yunnan in 2005). In Vietnam, 70% of national rice production is from the two deltaic regions, with more than half from the Mekong Delta alone. Similarly, in Cambodia, over 80% of rice is produced nationally from the floodplains. In Thailand and Myanmar, the share is smaller, due to the importance of the dryland plains (Isan, mid-Chao Phraya and Central Myanmar) as rice producing regions. The deltas produce large rice surpluses with 90% of Vietnam’s rice exports being from the Mekong. Both Cambodia and Myanmar have exported rice from their deltaic areas in the past (pre-1960s).

Rice is the major crop in all the deltas, accounting for more than 90% of planted area in Vietnam and Cambodia, and around 60% of planted area in the Irrawaddy and Chao Phraya. All deltas have at least double cropping; a third crop can be planted in Mekong and Chao Phraya, but water shortages and the low price of rice have led to a decrease in the third crop over the last 10 years. The cropping intensity in Irrawaddy and Tonle Sap is lower than in other deltaic areas, due to less-extensive irrigation coverage. Tonle Sap and the Irrawaddy retain more traditional rice cultivation methods, including substantial plantings of recession, deepwater and floating rice (24% of national total in Myanmar; ~ 100,000 ha in Cambodia).

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[1] Tonle Sap and floodplain in Cambodia are grouped with deltas because of close hydrological links to the Mekong Delta and similar production systems

[2] Ho Chi Minh City is within the geographical extent of the Mekong Delta, although it is not within the statistical division of Mekong River Delta used by the Vietnam Government Statistics Office.

Different cropping patterns are used in each of the deltaic regions. In Cambodia and the Irrawaddy, the wet-season crop still accounts for more than 75% of the total planting, with substantial (though decreasing) areas of deepwater and floating rice. Irrigated dry-season rice areas are smaller, though increasing as irrigation infrastructure is constructed or repaired. In the Red River Delta, plantings in the two seasons (spring and winter) are approximately equal. In the Mekong Delta, the traditional winter (wet-season) crop has declined to only about 10% of total plantings (0.38 Mha) compared to 1.8 Mha in autumn, and 1.57 Mha in spring. In the Chao Phraya, dry-season planting is only about half that in the wet season—due partly to water availability for irrigation, and also to a choice available to grow high-value wet-season varieties.

Rice yields in the deltas are generally higher than national averages, with significantly higher yields from the dry-season crops. Yields in Red and Mekong deltas are the highest in the region, averaging 5-6 t/ha. Yields are lowest in Cambodia (2.5 t/ha) and Myanmar (3.6 t/ha), due to much lower use of improved varieties and fertilizers.

Intensification of agriculture follows a trend with some or all of the following, each with associated environmental impacts:

- Expansion of agricultural land through clearing of wetlands and draining of swamps.
- Development of infrastructure to allow supplementary wet-season irrigation and to protect crops from flooding (levees, dykes).
- Infrastructure for dry-season irrigation (canals, pumps, storages).
- Intensification to double and triple cropping.
- Increased agricultural inputs, fertilizers and pesticides.

Other crops. While rice is likely to remain the major crop in the deltas, there has been a shift towards more diverse cropping systems in some areas. For example, the Chao Phraya has only around 60% of planted area under rice, with over 1 Mha of alternative crops, mainly sugarcane (0.43 Mha) and cassava (0.32 Mha, grown mainly for export as cattle feed). In the Red River Delta 40% of the area is planted to non-rice crops in the winter. In the Mekong, government policy encourages establishment of mixed gardens with fruit trees and vegetables (MRC-VNMC 2004). In all the deltas, horticultural production to supply cities is increasingly important and has a high value.

Livestock. The deltas support large livestock herds fed on stubble and hay (cattle and buffalo) and bran (pigs, poultry) from rice production. Increased rice production has provided the opportunity to increase the density of livestock production, which is highest in the Red River at 60 head of cattle plus buffalo per km^2 and 460 pigs per km^2, while in other deltaic areas there is a density of 20-30 head of cattle and buffalo per km^2. The Chao Phraya delta has developed a very intensive poultry industry, to supply Bangkok.

Fisheries and aquaculture. The land-sea interface is deepest in the coastal zone of the major deltas, providing a range of hydrological environments that favor a range of fish production activities such as marine and inland capture fisheries, as well as marine/brackish-water and freshwater aquaculture. The relatively higher population densities in the deltas also provide the human resources and the market for fish products. The types and level of development of the various fishery subsectors in the deltas are largely influenced by the extent to which the saline-freshwater interface and dynamics have been modified by infrastructural development and the use of the land and water resources for other food production activities and for urban/industrial development.

Two major river deltas, the Mekong and Red River are located in Vietnam; yet the pattern of fisheries and aquacultural development is very different. The extensively polderized Red River Delta, coupled with a very high population density, leaves limited resources for aquaculture. Consequently, the Mekong River Delta accounts for the bulk (70%) of aquacultural production, both brackish-water production of penaied shrimp and freshwater production of the tra catfish which are major export earners within the fisheries sector for Vietnam. The Red River Delta accounts for only about 6% of the marine capture fisheries, with the Mekong River Delta contributing 63%.

The major deltas and hinterland floodplains of the Chao Phraya in Thailand and the Irrawaddy-Salween in Myanmar are also important for marine fisheries, brackish-water and freshwater aquaculture. While in Thailand the focus of coastal aquaculture is on the production of penaied shrimp for export, the main export-oriented aquacultural commodity from Myanmar is freshwater fish, particularly the Indian carp (rohu) and the striped catfish targeted for markets in Bangladesh and India.

The Tonle Sap and floodplains, hinterland of the Mekong River Delta, deserve special mention because of their importance and linkage to the inland fisheries of the lower Mekong Basin, including Cambodia, Lao PDR and Vietnam. Inland capture fisheries dominate in this region while aquacultural production is minimal. The region is critical to the biodiversity of the wild fish stock, being important feeding grounds for an estimated 300 species that support the inland capture fishery of the Lower Mekong Basin. The Tonle Sap fishery accounts for almost two-thirds of the total inland fishery catch in Cambodia and is officially valued, conservatively, at US$233 million per annum. The Tonle Sap fishery not only accounts for a significant 7% of the country's GDP but, as a sector, also contributes more to income, jobs and food security than in any other country. The aquatic ecology of the Tonle Sap and surrounding floodplains is intricately linked with the hydrology of the Mekong, particularly the flood pulse (backflow of water from the Mekong into the Tonle Sap in summer and water discharge from the lake into the lower reaches of the Mekong in winter), and there are concerns that changes in flow resulting from climate change exacerbated by hydropower development will have serious impacts on fish populations.

Because of the small-scale nature of the fisheries and aquacultural subsectors, participation rate is high and fishing and fish farming activities are critical to food security and livelihoods of the rural poor; for example, 31% of households surveyed in the Tonle Sap floodplains reported deriving their main income from fishing while 98% report being involved in some kind of fishing activity throughout the year.

Irrigation. Irrigation infrastructure is highly developed in the Red, Mekong and Chao Phraya deltas, but less developed in Tonle Sap and the Irrawaddy, although there is significant irrigation development and intensive cropping in the areas around Yangon. Irrigation infrastructure in the deltas is a complex of dykes, levees and canals used to divert and retain water, rather than to function as major storages. Only the Red and Chao Phraya deltas have significant upstream storages to regulate supply.

The Red, Chao Phraya and Mekong deltas all suffer from water shortages in the dry season. The Chao Phraya is seriously overallocated and is essentially a "closed" basin (Molle 2004).. Even though the total volume of Mekong water resources is abundant, more than 80% of dry season flows are extracted for irrigation in the delta, resulting in local shortages and intrusion of seawater.

Irrigation development in the deltas began as early as the late 1800s—much of the infrastructure dates from the first half of the twentieth century—and requires substantial maintenance and repair (for example, the colmatage systems in Cambodia). Extensive modernization and extension programs have been undertaken in the Mekong and Irrawaddy over the past 10 years.

Environmental Impacts of Agricultural Production

The delta areas have been almost completely converted from marshes/wetlands to paddy; the remaining natural vegetation cover is minimal (2-5%). The loss of mangroves has been very significant, with increased rates in the last 10-15 years due to clearing for shrimp aquaculture. Only minor areas of mangroves remain in the protected areas in the Red (58,000 ha), Mekong (68,000 ha) and Chao Phraya (1,340 ha) deltas. Giri et al. (2008), using remote sensing techniques, estimated that, in the Irrawaddy delta, 98% (293,035 ha) of mangrove deforestation during the period 1975-2005 was due to agricultural expansion, while 2% (6,870 ha) was converted to aquaculture. Vietnam has lost more than 60% of its mangroves mainly through clearing for agriculture and aquaculture, especially in the Red and Mekong river deltas, with more than 2,000 km^2 lost in the last 20 years. Replanting programs are underway in the Mekong Delta: About 100,000 ha of melaleuca have been restored in lowland areas in the Plain of Reeds, Long Xuyen Quadrant, western Bassac River areas, and southern Ca Mau Peninsula; the aim is to plant 15% of the Mekong Delta to trees by 2010.

In Cambodia, it is estimated that the area of flooded forest around Tonle Sap fell from over 1 Mha in the early 1970s to 0.45 Mha by 1997, and clearing is continuing (Hubble 1997; Evans et al. 2004). The flooded forests play a critical role in the aquatic ecosystem of the lake.

All the deltaic regions suffer from soil constraints, with large areas of acid sulphate soils and poor drainage. As the area under agricultural production has expanded, swamps have been drained and areas with less suitable soils have been converted to agriculture, resulting in acid sulphate drainage. In the Mekong, there are around 1.6 Mha of acid sulphate soils; acid water movement is estimated to affect up to 1 Mha (MRC-VNMC 2004).

All the deltas are flood-prone, though the upper Mekong and Tonle Sap are most at risk. Floods affect 1.9 Mha of the upper part of the Mekong Delta which are flooded for 4-5 months at a depth of 0.5-4.0 m. Levees and dykes to protect crops from flooding are essential for early and late-season crops, but have substantially modified natural flooding patterns. Flood control systems restrict flushing of fields, and reduce deposition of sediment and nutrients, leading to deterioration of soil fertility and buildup of pesticide and herbicide residues.

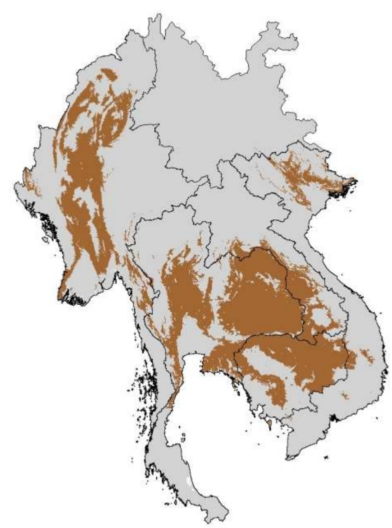
The Mekong Delta is particularly prone to intrusion of saline water in the dry season.Saline intrusion is seriously exacerbated by excessive dry-season withdrawals for irrigation: over 1.4 Mha of the coastal area are affected (MRC-VNMC 2004). Excessive pumping of groundwater to supplement surface water results in saline intrusion to aquifers.

Serious water-quality issues occur in all the deltas, though these are only partly due to agricultural inputs. Water-quality problems are associated with high population density and inadequate treatment of sewage effluent, particularly downstream of the major cities, for example, the large decrease in water quality of the Chao Phraya observed below Bangkok (Wijarn et al. n.d.). Fertilizer, pesticide and herbicide inputs from agriculture are significant in the Chao Phraya, Red and Mekong deltas while levels of inputs in Cambodia and Irrawaddy are lower.

Certain forms of aquaculture, particularly pond culture, have not only resulted in clearing of natural forest (especially mangroves) but also caused environmental pollution. The previous lack of regulation had allowed shrimp farmers to adopt a "shifting cultivation" strategy of abandoning problem areas (polluted waters, disease outbreaks) for new areas, even trucking hypersaline water to freshwater areas in Thailand. This practice has largely been checked, although the wastewater discharge problem persists where there are concentrations of intensive culture ponds such as in the Chao Phraya and the Mekong River deltas. The culture of certain omnivorous and carnivorous species (freshwater catfish, penaeid shrimp, groupers, seabass) that are based on trash fish as feed is not only polluting but also placing heavy demands on the marine catch, particularly the small pelagic species which are highly climate-sensitive. The history of shrimp farming in the Chao Phraya Delta suggests that the aquaculture sector (particularly that targeted at producing high-value species) will continue to explore a wide range of alternatives in an effort to maintain or increase production levels and profits in spite of systemic management problems and unresolved environmental concerns (Szuster 2003).

Lowland Plains and Plateaus

Central Myanmar Plain includes Dry Zone); Central/Northern Thai Plain; Isan Plateau; Lao Mekong Plains; North and Northeast Cambodia



The lowland plains and plateaus comprise around 25% of the total land area in the GMS, with 23% of the total GMS population (64 million). They are characterized by relatively flat lowlands and plateaus below 250 m, extensively cleared, except in NE Cambodia where a large area of dry forest remains. Agriculture is predominantly rain-fed, with wet-season rice supplemented in the dry season by stubble grazing or a second crop of irrigated rice, irrigated or rain-fed sugarcane, maize, legumes, pulses or cassava. Annual rainfall is generally low (1,200-1,500 mm), but higher in Lao PDR and Cambodia (up to 2,000 mm).

Population densities are moderate (50-150 persons per km^2), except in northern Cambodia where population density is very low (<10). Less densely populated areas have been recently targeted for development of commercial plantations.

Poverty is a significant issue in these areas. The Isan Plateau has the highest poverty headcount (income basis) in Thailand, followed by the Central Thai Plain (Jitsuchon undated); in Lao PDR, although the poverty rates are lower than in the upland regions, the highest numbers of poor live along the Mekong corridor (Messerli et al. 2008).

The plains and plateaus represent a development trajectory from the largely uncleared plains of NE Cambodia to partially irrigated extensive agriculture on the Isan Plateau and Myanmar Dry Zone, to intensively irrigated production of rice and field crops on the Central Thai Plain.

Production Systems and Trends

Rice. The lowland plains and plateaus are very important agricultural areas, accounting for 25% of rice production in the GMS, with over 60% of national rice production in Thailand and Lao PDR and over a third in Myanmar. Production is mainly traditional wet-season cultivation—less than 15% of rice production is in the dry season. Irrigated area in the dry season is generally much lower than irrigable area (for example, in 2006, in Lao PDR only 65,000 ha were planted from an irrigable area of 136,000 ha; in NE Thailand, 0.88 Mha were planted out of the available 1.88 Mha). Rice is the dominant crop (75-90% of total plantings) except in Myanmar, where it constitutes only 40% of crop area. Rice yields are low in Isan and NE Cambodia (~2 t/ha), moderate in the Thai Central Plain (2.8 t/ha) and higher in Myanmar and Lao PDR (~3.5 t/ha). Yields in the dry season are considerably higher (3.5-4.5 t/ha), but still significantly below those achieved in the deltas. In NE Cambodia, paddy and lowland rice are grown along the Mekong floodplain. In other areas, upland rice is grown in swidden agricultural systems. In NE Thailand, cultivation of the second (dry-season) rice crop waxes and wanes depending on prevailing prices of rice. If price increases substantially, there could be a significant increase in dry-season rice, with accompanying competition for scarce dry-season water.

Other crops

In Thailand and Lao PDR, sugarcane, maize, cassava and soybean are the most common dry-season crops; in Myanmar, oilseeds and pulses dominate. In Thailand, sugarcane, previously rain-fed, is now increasingly irrigated. The Government of Thailand provided 2 billion baht in irrigation subsidies for sugar growers to lift production.[3] In NE Cambodia, swidden agriculture is still common, with upland rice, cassava, vegetables and maize supplemented by collection of non-timber forest products.

In all countries, there has been a significant move to establish large-scale plantations for industrial crops (oil palm, rubber, eucalypt, sugarcane, cassava) on the plains, promoted by government policies. Eucalypt plantations have been established in NE Thailand since the 1970s; between 1990 and 2003, the area of rubber plantation in NE Thailand trebled, from 0.19 Mha to 0.59 Mha.[4]

In Lao PDR, there has been a rapid increase in plantations, driven mainly by foreign investment. By 2007, land concession had been granted to 123 large-scale plantation projects covering 165,794 ha nationally, with 60% in the lowland plains of central and southern Lao (MPI2008). No information is available on the areas of medium and small-scale plantation projects (less than $3 million in investment and less than 100 ha of production area), which are approved at the provincial level. Estimates from the Ministry of Agriculture and Forestry give the main plantation crops in Lao PDR as para rubber (40%), eucalypt (20%), palm tree, kathinnalong, jatropha and sugarcane (Voladet 2008) In Cambodia, there has been a similar granting of large-scale land concessions. For example, in Mondulkiri the government has given an in-principle agreement to grant 200,000 ha to the Chinese company Wuzhishan; plus other large concessions for oil palm, rubber and plantation timbers (MAFF 2009a). In Myanmar, government-sponsored eucalypt plantations have been established for fuelwood and paper in the dry zone (Ohn Lwin 1993).

[3] http://www.mfa.go.th/web/2645.php?id=21250
[4] http://www.wrm.org.uy/countries/Thailand/Rights_of_rubber_farmers_in_Thailand.pdf

Livestock. Large livestock herds are supported mainly by stubble grazing. While cattle are dominant, there is a much higher proportion of buffaloes than in the deltaic areas, though buffalo numbers have declined significantly in the last 15 years, particularly in Thailand, due to mechanization and growing dietary preference for beef.

Fisheries and aquaculture. Inland fishing, carried out in the rivers and water bodies (including reservoirs), provides substantially more fish for the rural populations in this region than fish culture, particularly in Cambodia, Lao PDR and NE Thailand. The hydrological changes brought about by hydropower development along the Mekong and its major tributaries in Lao PDR are feared to disrupt the migration of important food fish species on which the inland fisheries of the Lao and Cambodian parts of this agroecological region depend. On the other hand, two countries have reported significant increases in actual production in recent years. Thailand's increase is attributed to fish stocking in reservoirs; while Myanmar reports a 65% increase in production from already substantial river and floodplain fisheries over the past 4 to 5 years, achieved through improved aquatic resources management (environmental restoration and rehabilitation, restocking floodplains and improved governance) not requiring any substantial physical resource inputs. This is an achievement that challenges the widely held view that river fisheries cannot be improved (Coates 2002).

Irrigation. Very little irrigation has been developed in the lowland plains of north and northeast Cambodia, but in all other countries, there has been substantial investment in irrigation infrastructure. In Thailand, the Chao Phraya Basin is highly developed, with two large storages (Bumiphol, 9.6 billion cubic meters [Bm^3] and Sirikit, 6 Bm^3) and thousands of small dams and reservoirs with a total command area of 2.4 Mha, of which about a third is in the Central Plain (Molle 2004). In Isan, a total irrigable area of 1.4 Mha is serviced by several large hydropower/irrigation schemes (Ubon Ratana, Sirindhorn, Lam Pao, Pak Mun) and more than 20,000 small to medium schemes. Ambitious “greening Isan" projects involving large interbasin transfers have been proposed but never realized (Molle and Floch 2008). Serious water shortages occur in both basins in the dry season, with conflicts of water use between urban, industrial and agricultural uses. For this and other reasons, the area of dry-season irrigated crops planted is always significantly lower than the total irrigable area.

In Myanmar, programs begun in the 1980s have expanded irrigation to cover approximately 25% of crop area. Around 45% of irrigated areas are served by river-pumped systems; reservoir and river diversion systems account for only 32% and private, village-based systems for only around 12%. Large-scale irrigation development has been concentrated in Sagaing, Mandalay and Bago provinces (UNDP 2006).

In Lao PDR, the current irrigation command area in the lowland plains is 190,000 ha in the wet season and 136,000 ha in the dry season. Most irrigation water is pumped directly from rivers, in over 4,000 small to medium projects. The Government of Lao PDR aims to double the irrigated area by 2020 (MRC-LNMC 2004). Ambitious hydropower development plans in Lao PDR (see section under Improving Livelihoods for the Rural Poor) may provide opportunities to expand irrigation in downstream areas.

Environmental Impacts of Agricultural Production

The lowland plains have largely been cleared for agriculture, and the remaining native vegetation is on higher, steeper country and ridges. In Isan, for example, forest and forest mosaic constitute only about 10% of the total area. In Myanmar, Lao PDR and Cambodia, the remaining forest cover is more extensive, but rates of forest loss are high due both to logging and clearance for agriculture, especially plantations (the two are often linked). For example, annual rates of forest loss ranged from 1.3% in Sagaing to 5% in Mandalay between 1989 and 1998 (UNDP 2006) due to exploitation of teak forests in Bago and upland forests in Sagaing, as well as clearance for agriculture.

The lowland plains in NE Cambodia and Lao PDR are theoretically prospective areas for opening up new agricultural land, but three constraining factors need to be taken into account: much of the area has poor soils; access to water is limited; and the remaining forests in these areas have significant conservation value. The World Wildlife Fund (WWF) lists the Lower Mekong Dry Forests (covering NE Cambodia and southern Lao PDR) as one of its Global 200 priority ecoregions.[5] In Myanmar, 40% of arable farming land (7.2 Mha), mainly in the dry zone, is currently classified as "cultivatable wasteland." It is not clear how much of this is suitable for conversion to permanent agriculture, but there is apparently potential to bring at least some of this area into production, subject to an analysis of suitability for agriculture. There are significant environmental and social risks associated with unregulated expansion of agricultural land

Except in alluvial areas around the major rivers, soils on the plains tend to be of poor quality. Saline and alkaline soils cover large areas of the Isan Plateau and Myanmar (660,000 ha; UNDP 2006) and low fertility, stony soils are common in the dry zone of Myanmar. Irrigation-induced salinization is common in Isan, and soil erosion is widespread. The dry zone of Myanmar is particularly vulnerable to soil degradation, with serious decline in soil fertility (the use of chemical fertilizers in Myanmar is about 10% of the regional average; UNDP 2006). Water is a limiting production factor in most of these areas, with significant conflicts of water use in some areas (Chao Phraya Basin, Isan, Myanmar).

Coastal Regions

Vietnam: North Central Coast; South Central Coast; Southeast;[6] Cambodian Coast; southern Thailand; Myanmar: Tanintharyi; Mon; Rakhine

The coastal zones cover around 10% of the total land area in the GMS with around 10-15% of land area for Thailand, Myanmar and Cambodia but over a third for Vietnam. They are home to a population of 40 million, i.e., 15% of the total GMS population (almost a third of Vietnam's population). Population density is generally moderate (>100 persons per km^2) except on the Andaman Coast of Myanmar, which is sparsely populated. The coastal zones have varied production systems, with a high dependence on marine resources and a significant proportion of agroindustrial and tree crops (rubber, oil palm, eucalypt and other pulpwood). They are characterized by narrow coastal plains (<25 km wide) rising rapidly to coastal ranges at 500-

[5] http://www.panda.org/what_we_do/where_we_work/greatermekong/area/ecoregions/

[6] Ho Chi Minh City is considered to lie within the Mekong Delta although it is within the southeast statistical area defined by the Vietnam Government Statistical Office.

2,000 m. Rivers tend to be short and steep, with small watersheds (<50 km^2). There are significant coastal floodplains on the Salween (Moulamein) and Rakhine rivers. The average annual rainfall is high in Myanmar (3,300 mm) and Cambodia (2,700 mm) and lower in southern Thailand (2,300 mm) and Vietnam Coast (average 1,800 -2,000 mm).

Production Systems and Trends

In *Vietnam,* the coastal regions have a diverse range of production systems from paddy rice (in wetter and irrigated areas) to rain-fed field crops (legumes, cassava, sugarcane, peanut); tree cropping (fruit, nuts, eucalypt for paper pulp, jatropha, rubber); crop/livestock/grazing systems; intensive livestock production (cattle, pigs) and intensive horticulture (vegetables). Plantations constitute about 25% of cropped area. Crop residues and by-products from peanut, cassava, sugarcane and some other crops also have an important role in livestock feed, while manure from livestock is critical to improve the structure, water-holding capacity and fertility of sandy soils. The coastal plains are quite densely populated and the coastal ranges steep and often unsuitable for agriculture. Farm sizes are small, and areas for grazing limited so there has been a move to semi-intensive to intensive livestock raising, integrated with cropping. Rice and vegetables are irrigated from rivers and groundwater.

Coastal *southern Thailand* has very extensive plantations, with over 2 Mha of mainly rubber and oil palm; 75% of farm area is tree crops. Small-scale lowland rice production (0.3 Mha) occurs mainly in the wet season—only 10% of the crop is irrigated. Field crops are a very minor component of production in these areas, but vegetables and fruit trees are common. Livestock density is moderate. Coastal tourism is a very important sector, with accompanying demands for horticultural products.

The *Cambodian coast* has a mix of lowland paddy on the coastal plains and upland rice in the foothills of the coastal ranges. Rice production is supplemented by collection from wetlands and forests, and fishing. Pepper has traditionally been an important crop. Economic land concessions covering 118,000 ha have been granted for oil palm, sugar, corn and cassava plantations (MAFF 2009a).

Coastal Myanmar is characterized by production of paddy rice and floating/deepwater rice in the small deltas of Rakhine and Moulamein, and extensive rubber plantations in Tanintharyi and Mo. Areas planted to tree crops are expanding rapidly. The Government of Myanmar plans to expand the area planted to rubber from 225,000 ha in 2005-06 to 600,000 ha by 2030, mainly in the peninsula;[7] and to expand area of oil palm in Tanintharyi from 100,000 to more than 200,000 ha by 2020.[8] Eucalypt plantations have been established in Mon to supply pulpwood for a paper mill (Ohn Lwin 1993).

Fisheries and aquaculture. The coastal zones of all countries have traditionally been, and still are, important for capture fisheries, with landings conservatively estimated at 2.2 million tonnes (about 40% of the total marine landings, including the region of deltas). Coastal fisheries are substantial in Vietnam (having the longest coastline), Thailand (particularly the elongated Isthmus of Kra) and Myanmar (both the southwestern and southeastern coasts). Marine fishing activities are still mainly conducted in the water of the coastal shelves (between the shoreline and at a depth of 200 m), particularly in the shallower parts (from 0 to

[7] http://english.peopledaily.com.cn/200606/14/eng20060614_273957.html

[8] http://www.chinadaily.com.cn/world/2008-11/18/content_7215146.htm

50 m) by large numbers of small-scale artisanal fishers operating a wide range of gear to catch multiple species.

Despite the use of improved technologies in fishing equipment, preservation of catch and navigation and position fixing aids, there has been a consistent decline in the catch per unit effort, leading to the generally accepted conclusion that the coastal water is overfished. There has also been a reduction in the catch of some long-lived species, and a shift to those that are smaller and short-lived, thus reducing the value of the catch. This shift in species composition of wild fish catch is symptomatic of increased fishing pressure, leading to overfishing of the natural stocks. Tapping the offshore marine fish stocks requires substantial investments that many small-scale fishers can ill-afford; hence the large-scale commercial fisheries tend to be dominated by nonlocal and foreign investors. Coastal aquaculture is relatively limited because of the sparsely populated, narrow coastal land strips with generally light-textured soils and short rivers. Marine/brackish water aquaculture is presently limited in non-deltaic coastal areas but there is a possibility of specialized culture systems that take advantage of the relatively cleaner seawater along the exposed coastline. For example, in the southeastern coast of Vietnam there is an active aquaculture subsector including specialized mariculture of sea cucumber as well as pond-based production of fry to supply the shrimp ponds in the Mekong River Delta.

Irrigation. In Vietnam, small-scale irrigation from rivers and groundwater has been developed on the floodplains of the coastal rivers, mainly for rice (e.g., 50,000 ha in Quang Binh). Thailand has limited areas of irrigation for oil-palm plantations in Nakhon si Thammarat. Irrigation development in coastal areas of Myanmar and Cambodia is very limited.

Environmental Impacts of Agricultural Production

There is very little natural forest cover remaining in southern Thailand (<20%) as a result of conversion to plantations over a long period—southern Thailand has been an important rubber-producing area since the early 1900s. In Vietnam, there are significant areas of forest cover remaining in the coastal ranges (40-60%), but forest quality has declined very significantly due to commercial logging and thinning; and native forests have been replaced by monoculture plantations. Some stands of good-to-medium-quality forest remain in the south central zone. The impacts of defoliants from the war in the 1960-70s can still be seen in forests in the southeast. In the coastal zones of Myanmar and Cambodia there are significant areas of forest remaining (70-75% forest plus forest mosaic), but both have high rates of deforestation in the coastal area, including rapid loss of mangroves and clearance for establishing plantations.

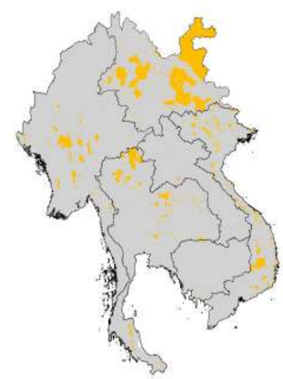
There is a high incidence of erosion in coastal uplands, exacerbated by flash flooding along short, steep coastal rivers. The coastal strip has sandy, low fertility soils which present significant management challenges to maintain productivity.

Urban and agricultural pollutants cause water-quality impacts on nearshore marine environments in more densely populated coastal zones of Vietnam and Thailand. Coastal degradation (loss of mangroves, destruction of coral habitats) and pollution of the coastal water take a heavy toll on the multispecies fishery resources that are ecologically most abundant in the nearshore, shallow water and are within reach of the limited gear capacity of small-scale and artisanal fishers. This exacerbates the problems associated with overfishing in the zone. A high level of fishing effort on the coastal fish stocks, particularly in the nearshore traditional fishing grounds, is a common management concern in all these countries. There is concern over surplus fisher capacity, but alternative livelihood prospects are limited by the generally low productivity of the narrow coastal strips, both in the primary and secondary economic sectors.

Uplands

Areas above 250 m elevation in the region are generally sloping lands with hilly to mountainous terrain interspersed with highly productive river valleys. The total area of uplands is over 1.6 m km^2, or 55% of the region; the total population is about 85 million (of which 46 million are in Yunnan). In terms of agricultural production, a distinction can be made between *intensively farmed uplands* (population density >100 persons per km^2) and *forested uplands* with shifting cultivation and livestock grazing (population density <100 persons per km^2).

There is obviously a gradation between the two, and moves to develop permanent, more intensive farming in the less intensively used areas. However, there are large tracts of forested uplands that are steep and have poor soils and so are not suitable for intensive agriculture. The distinction between the two systems will remain, though the relative areas and boundaries between them may shift as population pressure increases, or as degraded lands are taken out of production. This boundary is one of the main agricultural pressure points in the region, as inappropriate land use in steep lands can result in very rapid degradation.



a. Intensively farmed uplands

Yunnan: Northeast and central zones
Vietnam: Northeast, Central Highlands
Thailand: Northern Thailand (Chiang Mai — Chiang Rai)
Lao PDR: Bolovens Plateau
Myanmar: Southern Shan Plateau (Lake Inle)

Production Systems and Trends

Intensive agriculture is practiced on upland plains and river valleys, often with terracing for rice. In Yunnan, cultivation is forbidden on slopes greater than 25 degrees. Major food crops grown are rice (irrigated in the river valley upland on slopes), maize, vegetables, wheat and cassava (on marginal lands). Major cash crops include vegetables, flowers (Yunnan, Chiang Mai), tobacco (Yunnan), coffee (Central Highlands, Bolovens Plateau), sugarcane, tea, rubber, pepper, fruit trees, cocoa, and mulberry. A wide range of suitable crops can be grown in the in subtropical to temperate conditions at increasing altitudes.

Rice production in Yunnan is split between irrigated or rain-fed paddy in flat river valleys and terraced slopes and rain-fed upland rice cultivation in sloping areas. Agricultural production in Yunnan has undergone a transition in the last 20 years from shifting cultivation to more commercially oriented, predominantly fixed cultivation. The adoption of improved rice technologies during the 1990s has resulted in significant yield increases (from less than 2 t/ha in 1990 to more than 3 t/ha in 2003 in the Simao province; Pandey et al. 2005). This allowed farmers to diversify to cash crops with higher returns, resulting in an overall decrease in planted area of upland rice.

Irrigated rice in the wet season is usually supplemented by a non-rice dry-season crop (faba bean, wheat, oil rape, sugarcane).Dry-season rice constitutes only about 20% of the rice crop in northern Thailand, and less in NE Vietnam. Livestock are raised semi-intensively using fodder from stubble, crop by-products and fodder crops including cassava and maize. Partial irrigation is used for some cash crops including tobacco, vegetables and coffee. Groundwater has been widely used to establish coffee plantations in the Central Highlands of Vietnam, and supplies have been seriously depleted. Intensive irrigation is used for high-value horticultural crops such as flowers and vegetables (Yunnan, Chiang Mai, Lake Inle).

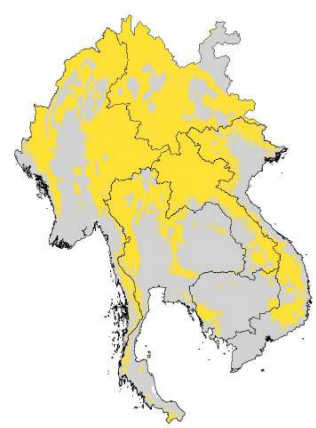
There is a trend for progressive intensification of agriculture, including the following:

- The establishment of small-scale irrigation from rivers, streams and lakes. In Thailand and Yunnan particularly, there is considerable investment in irrigation for horticulture.
- Intensification.
- Increased use of chemical fertilizers, pesticides and herbicides.
- Terracing for upland rice—Chinese government programs in Yunnan in the 1980-90s provided technical and financial assistance to construct terraces (UNEP and TEI 2007).
- Improved varieties and hybrids.
- Commercialization and diversification, with increased cash cropping.

In Yunnan, previously cultivated lands on steeply sloping areas are being returned to forest in response to regulations forbidding cultivation on slopes greater than 25 degrees, with financial incentives for farmers to return land to forest. There has been a rapid increase in the establishment of plantations for tree crops (timber, rubber, coffee) in some upland areas.

b. Forested uplands—shifting cultivation and grazing

Yunnan:Southern and western zones
NW Vietnam
Northern Lao PDR
Annamites mountains (Lao PDR and VN)
Northern, eastern and western mountains in Myanmar



The forested uplands are socioeconomically distinct, with a high proportion of ethnic minorities. There is a very high incidence of poverty: more than 75% of people live below the national poverty line in most areas outside Yunnan with more than 30% within Yunnan. They are physically remote, with poor road access and a very low level of services.

Production Systems

Traditionally, upland farming has been primarily subsistence shifting cultivation and livestock grazing, with limited cash cropping. Swidden systems vary between

- Pioneering (slash-and-burn)—clearing for monocropping of cereals and legumes; needs long fallow period (10-5 years) and
- Established—rotational cultivation of trees, annual crops, cereals and legumes.

In Myanmar, 23% of land is officially classified as forest affected by shifting cultivation, and is estimated to provide resources for as many as 2 million families (UNDP 2006). In Lao PDR, estimates vary widely, but government figures indicate that about 200,000 families (around 25% of the total population) were dependent on shifting cultivation in 1995 (MRC-LNMC 2004), decreasing to 120,000 families in 2000. This is possibly a significant underestimate.

There is a well-documented trend to shorter fallow periods in shifting cultivation as population density increases. Valentin et al. (2008b) calculate that, in Northern Lao, land available for cultivation has fallen from 1.7 to 0.27 ha per capita since the 1990s, with a consequent shortening of fallow periods from 8 years to between 1 and 4, resulting in very serious erosion and soil fertility decline.

All governments in GMS have programs to eradicate shifting cultivation and resettle ethnic minorities, driven partly by concerns about sustainability of shifting cultivation, partly by policies to concentrate populations in areas where services can be provided, and partly by a range of political and security considerations. In the past, opium was an important crop; opium eradication programs from both national and international sources have sought to replace opium with other livelihood options. Timber extraction from primary forests is an important economic sector in some areas, particularly in Myanmar and Lao PDR.

These policies have inevitably resulted in the expansion of permanent upland agriculture, often in unsuitable areas. In addition, there has been rapid expansion of commercial plantations, primarily for rubber, and also for timber (including teak) and oil crops, in southern Yunnan, northern Lao PDR and parts of Myanmar.

Fisheries and Aquaculture in the Uplands

People in the uplands catch fish in the rivers, lakes and reservoirs, mainly for domestic consumption or the local market. Although insignificant as an economic activity, fishing provides supplementary protein to the highland communities in these countries.

With the anticipated increase in dam construction in Lao PDR, there is potential for reservoir fisheries to be further developed. For example, fisheries involving native species, particularly a small pelagic clupeid, developed in the Nam Ngum reservoir, has yielded 173 kg/ha per year since the late 1990s, but at the expense of at least 10 migratory species that are no longer found upstream of the dam. Cage culture of snakehead is reportedly practiced in the reservoir as well, depending on fry and feed collected in the wild.

In other areas of Yunnan and NE Thailand where there are large lakes and a concentration of population, fish culture is practiced, but mainly at subsistence or semi-subsistence level. The Yunnan province has six large natural lakes in the catchment of Lancang Jiang (Mekong River) besides over 30 other lakes, each of surface area greater than 1 km^2, and both fishing and culture are carried out in these lakes. Some forms of rice-fish culture are also practiced in the river valleys and floodplains.

Environmental Impacts of Agricultural Production in the Uplands

A relatively high proportion of forest cover remains in the uplands, but there have been rapid rates of forest loss over last 50 years which have now stabilized in Yunnan and Vietnam where extensive forest planting programs have resulted in an increase in forest cover. Rates of forest loss are still high in Myanmar and Lao PDR (UNEP and TEI 2007).

Shifting cultivation and forestry activities to extract timber have resulted in a serious decline of forest quality. In Lao PDR, 42% of total land area is classified as "unstocked forest," affected by either shifting cultivation or timber extraction (Messerli et al. 2008). A significant reduction in area and quality of secondary forest occurs due to the reduced fallow period in shifting cultivation, since there is insufficient time to reestablish crown cover.

Very high rates of soil loss occur in intensive upland cultivation systems, resulting in soil losses at the catchment scale, decreased soil fertility at the field scale and decline in stream water quality. Erosion is caused both by water and tillage on steep slopes. Sedimentation associated with erosion can cause serious problems in waterways—for example, Inle Lake has shrunk in length from 56 km to 15 km during the last 50 years (UNDP 2006). Traditional swidden systems have low to moderate overall soil loss (high in cultivated years, low in fallow years), but decreased fallow period and change in cropping systems can result in very serious erosion. Valentin et al. (2008a) report a 600% increase in soil loss in shifting cultivation systems in Lao PDR. High erosion rates are also associated with plantations/tree crops (e.g., teak, rubber, coffee) except when the understory is maintained.

The introduction of exotic species into Yunnan's lakes, particularly the grass carp, crustacean carp and goby, has reportedly caused the disappearance of some native endemic fish species in some of the lakes. It has been documented that the goby eats eggs of native fish species.

3. Climate Change and Agriculture in the GMS

Projections of Climate change in the GMS

Previous Studies

Several climate change analyses have been undertaken in SE Asia with different purposes: characterizing likely future climate changes (Ruosteenoja et al., 2003; Snidvongs et al., 2003; Mac Sweeney et al., 2008a, b, c), projecting future river discharge and water level (Eastham et al., 2008; TKK and SEA-START 2008), assessing vulnerabilities (Anshory-Yusuf and Francisco, 2009), and proposing recommendation for mitigation and adaptation (ADB, 2009a; Eastham et al., 2008; TKK and SEA-START, 2008).

Most of the climate change studies undertaken in the GMS have attempted to quantify the impact of global warming on the regional climate by comparing mean annual temperature and rainfall averaged over successive periods whose length generally varies from 10 to 30 years. For instance, Mac Sweeney et al. (2008c) detected possible change in rainfall and temperature time series in South-East Asia by comparing averages from a base line period (1970-1999) with mean values for the 2030s, 2060s and 2090s. Ruosteenoja et al. (2003) calculated changes in seasonal surface air temperature and precipitation in SE Asia between a baseline period (1961-90) and three 30-year periods centered on the 2020s, 2050s and 2080s. Projections resulting from these studies are compared in Table 3.1. In most of these analyses, the natural climate variability is either confounded with climate change or not properly accounted for. These limitations are of particular concern when dealing with rainfall variability which is much higher than that of other climate variables such as temperature, air humidity, evaporation and solar radiation. In order to highlight the flaws of the climate-change quantification method consisting in comparing rainfall averaged over successive multiyear periods, the multi-annual rainfall variability (unpublished as yet) was analyzed using three time series from Thailand, each 52 years long (1953-2004). Running means including 10 and 30 years were successively applied to each of the three time series, resulting in 43 and 23 values, respectively. The maximum difference obtained between two values from the same group (10-year means or 30-year means) and from the same time series is high (30% and 12%, respectively), but no monotonous trend (indicating either a long-term decrease or increase) was observed in the three time series. Thus these changes cannot be attributed to global warming, but to natural climate variability.

Confounding climate variability and climate change (and even possibly land use changes) is also apparent in the discussion of the extent of *observed* hydro-climatic events. For example, ADB (2009a) quotes Mekong floods in 2000 and droughts in Lao PDR and Vietnam in 1997 and 1998 as examples of extreme events attributed to climate change. However, there is no convincing evidence that these events are outside the range of “normal” climate variability, or that the frequency of such events has increased, at least in the mainland SE Asia (this study; MRC 2005). In the Mekong Delta, for example, the increase in flood damage observed can be attributed to demographic and land use changes, with recent settlement of areas previously not intensively used precisely because of their vulnerability to floods.

An Analysis of Rainfall and Temperature Change in the GMS 1960-2049

To better distinguish natural climate variability from climate change in the GMS, we applied a statistical test designed to detect monotonous trends in annual time series to daily temperature and rainfall values calculated by the PRECIS regional climate model over the period 1960-2049 under the SRES scenarios A2 and B2.

The PRECIS model was calibrated for the GMS by the Regional START center, using the ECHAM4 global climate model output. Fourteen annual climate variables were derived from these daily rainfall and temperature values to describe regional climate: cumulative rainfall depths per year, per season and per range of daily rainfall; timing of the rainy season; minimum, average and maximum temperature; and intra-annual distribution of the temperature values. The rank correlation test of Kendall and Stuart (1943) was applied to annual time series of each climate variable at 2°×2° spatial resolution to detect possible monotonous changes significant at the 95% confidence level.

The major outcomes of this analysis are presented in Figure 3.1. Temperature increases over the entire GMS during the period 1960-2049 in both cold and warm seasons (+0.023°/year). The highest rates of temperature increase (+0.035 °C/year) are anticipated in the northern parts of the GMS (north Myanmar and north Yunnan). The lowest rates correspond to maritime areas (+0.016 °C/year).

Annual rainfall increases in Myanmar and the Gulf of Thailand from 1960 to 2049 (+23 to +55 mm and +341 to +693 mm, respectively). Areas getting dryer are located in central Vietnam and southern Lao PDR (from 0 to -189 mm from 1960 to 2049), in the Andaman and South China Seas (-204 to -402 mm from 1960 to 2049). In general, the increases of annual rainfall are due to increases of heavy rainfall during the rainy season, and the rainfall decreases are explained by a reduction of light rains during the dry season (Figure 3.2). Time lags in the seasonal patterns mostly result in a very slight delay at the onset, the peak and the end of the rainy season. From 2009 to 2049, these delays range from 0.1-0.4 days in the NW of the GMS to 3.8-7.1 days in the SE.

Most of these results are consistent with those from Snidvongs et al. 2003, Mac Sweeney et al. 2008a, b and Ruosteenoja et al. 2003. However, the spatial extent of the areas which experience rainfall changes is smaller in the present case. This discrepancy is probably due to the differences in the length of the study periods (which are deliberately shorter in the current study since it targets the short- to medium-term changes), methods used to detect changes (the rank correlation test only detects significant changes within a specific confidence interval) and the use of distinctive climate models.

Table 3.1. Comparison of projected climate changes from different studies.

Authors	Snidvongs et al. (2003)	Hoanh et al. (2003)	Ruosteenoja et al. (2003)	TKK and SEA-START (2008)	Eastham et al. (2008)	Mac Sweeney et al. (2008a, b, c)	ADB (2009a)	Lacombe (2009)—this study
Location	Lower Mekong catchment	Mekong Basin	SE Asia	Lower Mekong catchment	Lower Mekong catchment	Cambodia, Vietnam	Thailand, Vietnam	Greater Mekong Subregion
Models	CCAM	HADCM3	7 GCMs	ECHAM4-PRECIS	11 GCMs	15 GCMs	MAGICC (GCM)	PRECIS/ECHAM4
Scenarios	Not specific	A2, B2	A1F1, A2, B1, B2	A2	A1B	A2, A1B, B1	A1F1, B2	A2, B2
Period	From [$1\times CO_2$] to [$2\times CO_2$]	1960-2099	1961-2095	1960-2099	1976-2030	1970-2090	1990-2100	1960-2049
Projected changes in annual rainfall	Not explicitly quantified	-1.64 mm/yr. to +4.36 mm/yr.	Either >0 or <0, depends on models and scenarios. Almost always insignificant	Increase (not explicitly quantified)	+0.1mm/year to 9.9mm/year	+0.3 mm/yr. to +0.6 mm/yr.	**1990-2050**: +1.26 mm/yr. to -1.62 mm/yr. (B2); 0.66 mm/y to -1.14 mm/yr. (A1F1) **1990-2100**: +3.27 mm/yr. to +4.91 mm/yr. (A1F1) and -1.63 mm/yr to -2.45 mm/yr. (B2)	No significant change at the whole GMS scale

Changes in seasonal rainfall pattern	Dry season drier and longer Wet season delayed by 1 month		Dry season drier and longer Wet season delayed by 1 month	Dry season drier and longer Wet season delayed by 1 month	Wetter wet season (+1.7 to +6.1 mm/yr.) Drier dry season (-0.3 mm/yr. not significant)	Wetter wet season : +0.8 to +1.5 mm/yr. (KH); +0.4 to +1.5 mm/yr. (VN) Drier dry season: -0.7 to -0.1 mm/yr. (KH); -0.3 to -0.1 mm/yr. (VN)		Wetter wet season in North Myanmar and Gulf of Thailand (from +0.2 to +0.6 mm/yr.) Drier dry season on both sides of Gulf of Thailand (-2.5 to -2.8 mm/yr.)
Temperature	+ 1° C to +3° C (over a 100-yr. period)	+0.026 C /yr. to +0.036 °C /yr.	+0.01°C/yr. to +0.05 °C /yr.	Increase (not explicitly quantified)	+0.012 °C/ to +0.014 °C/ yr.	0.00 °C /yr. to +0.06 °C /yr.	+0.03 °C/yr. to +0.06 °C/yr.	+0.023 °C/ yr. to +0.024 °C/yr.

Figure 3.1. Annual temperature and rainfall changes over the period 1960-2049.

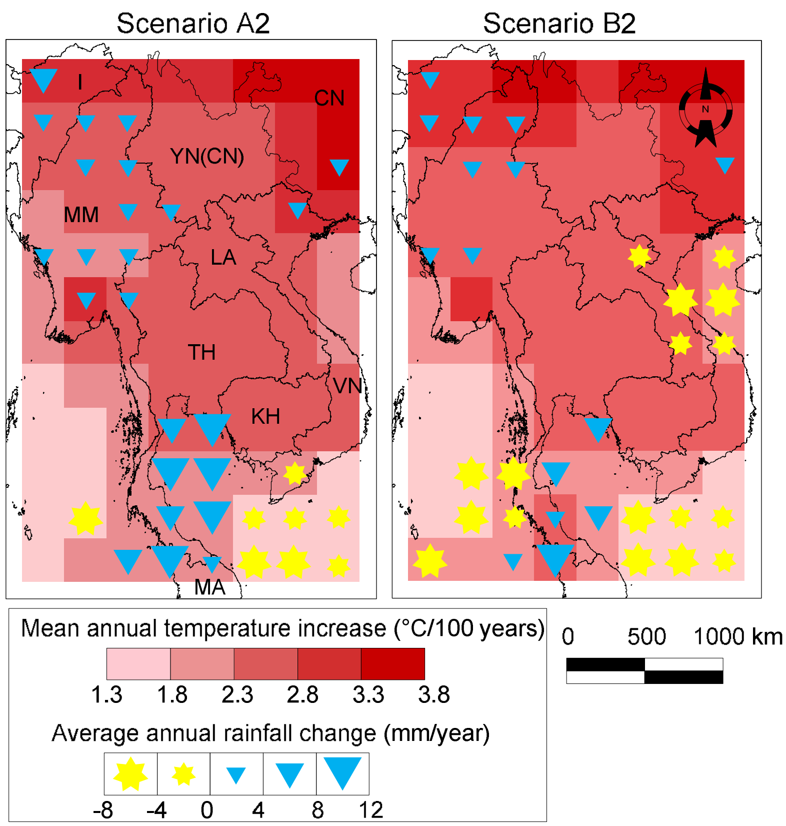
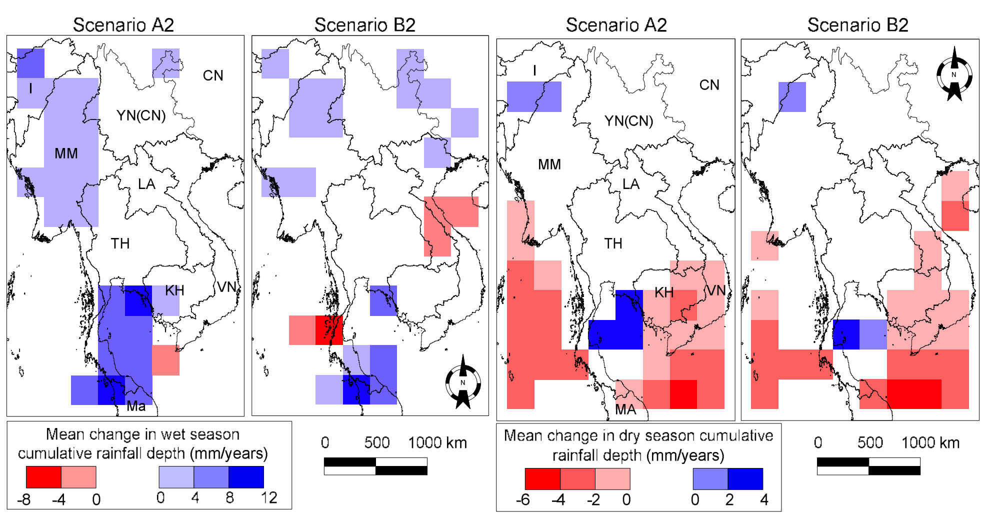


Figure 3.2. Changes in wet and dry season cumulative rainfall depths over the period 1960-2049.



Summary of Anticipated Changes of Climate in the GMS by 2050.

Based on the results of IWMI and other studies in the region, the main anticipated climate changes in the GMS to 2050 can be summarized as:

- Increase in temperature of 0.02 - 0.03 ^oC per year across the entire region in both warm and cold seasons, with higher rates of warming in Yunnan and northern Myanmar; and corresponding increases in evapotranspiration.
- No significant change in annual rainfall across most of the region.
- Some seasonal shift in rainfall, with drier dry seasons, and shorter, more intense wet seasons.
- Sea level is expected to rise by 33 cm by 2050 (MoNRE 2008) in addition to observed rise of 20 cm over the last 50 years (Hien 2008).
- Increase in the temperature of the sea surface may increase the intensity and incidence of typhoons during El Ninõ years (MRC 2009b).
- The impact of glacier melt is negligible in the two main catchments of the GMS (Mekong and Irrawaddy). The situation may slightly differ in the Salween catchment where the contribution of ice melt to total runoff is higher.

There is a high level of uncertainty associated with all these projections, with the exception of rising temperatures. In addition, the rise in CO_2 emission during 2000-2007 was higher than that in the worst-case scenario analyzed by the IPCC (IPCC 2007), and global warming may accelerate much more quickly than current models indicate (GCP 2008).

Projected changes in rainfall for the GMS vary (Table 3.1) with a high degree of uncertainty and the likelihood of significant differences across the region. Translating changes in rainfall into changes in availability of surface water and groundwater depends on a complex set of hydrological factors. In large river basins, small changes in precipitation can accumulate to very significant changes in flow. For example, Eastham et al. (2008) modeled hydrological impacts of climate change in the Mekong, and based on the assumption of an average increase in rainfall of 0.2 m (13%) they projected a 21% increase in overall flow in the river and an increase in probability of "extreme wet" flood events from 5% to 76%. Such projections are very specific to the input climate scenario, including both the volume and timing of rainfall, and to other assumptions including land use, but the results illustrate the magnifying effect that hydrological conditions can have on climate impacts. There are ongoing studies in the Mekong (for example, under the Water and Development Research Group and SE Asia START Regional Center, and through collaboration between MRC and CSIRO) which aim to improve estimates of hydrological impacts of climate change, but hydrological tools to translate climate impacts into changes in flow are not available for the other large river basins in the region.

Most regional studies project some changes in the seasonal distribution of rainfall, with drier and/or longer dry seasons and shorter, more intense wet seasons. Thus even with no change in annual rainfall the availability of water for agriculture may change, with increases in the incidence of both droughts and floods.

Given the high degree of uncertainty around projections of rainfall and runoff, it is counterproductive to use them as the basis for adaptation planning until more consistent estimates are available. It is more useful to characterize likely change as an increase in the variability and uncertainty of water availability and to take a precautionary approach to water management, with actions to improve water use efficiency, improve access to on-farm and off-farm storage, and reduce water-related risks (see section on *Closing the Nutrient Cycle*).

Changes beyond 2050 have not been analyzed in this study, but global studies (IPCC 2007) suggest that rise in temperature will become nonlinear and much faster, and that rainfall will increase. Impacts due to climate change by 2100 are projected to be correspondingly much severer (ADB 2009a). Sea-level rise is expected to accelerate to reach at least 1 m above current levels by 2100 (GCP 2008; IPCC 2007), posing a very significant threat to the deltas and coastal regions. Dasgupta et al. (2007) estimate that more than 5% of Vietnam's total land area and 10% of population would be affected by a 1 m rise in sea level, with 5,000 km^2 of the Red River Delta and 15,000-20,000 km^2 of the Mekong River Delta being flooded. Smaller but still significant impacts are expected for the Irrawaddy and Chao Phraya. While the severer impacts of sea-level rise will not be felt until after 2050, it is essential to take longer-term impacts into consideration in planning and investment.

Impacts of Climate Change on Agriculture

Impacts of climate change manifest themselves in agricultural systems through three different pathways:

- Directly, at local scale, due to changes in temperature, precipitation and sea-level rise.
- Through changes in water regimes, at local to regional scale.
- Indirectly, at global and regional scales, in physical (e.g., sea-level rise), social (e.g., migration) or economic (e.g., changes in food prices) dimensions.

A general discussion of potential impacts on agricultural production systems in the short to the medium term (to 2050) is given below, and an analysis of the impacts within the five agroecological zones is set out in Table 3.2.

Impacts on Cropping and Livestock Systems

Impacts on productivity of crops and livestock come through the following:

Increased temperature: This can reduce yields of crops and pastures by preventing pollination, and through dehydration. Studies at the International Rice Research Institute (IRRI) indicate that the yield of rice decreases by 10% for every 1 °C increase in the minimum temperature during growing -season (Peng et al. 2004). Similar impacts have been reported for wheat and other crops (Cruz et al. 2007). High temperature at flowering of rice can induce floret sterility and can limit grain yield (Matsui and Osama 2002), which can be offset by promoting the adoption of high temperature-tolerant cultivars.

Increase in pests and diseases: Higher temperatures and longer growing seasons could result in increased pest populations (FAO 2003). Changes in temperature could affect ecology, and warmer winters may result in decreased winter mortality of insect populations. Increases in temperature may speed up growth rates or crop pathogens and so increase reproductive generations per crop cycle, making the crop more vulnerable. Increased CO_2 levels could enhance the competitiveness of C3weed species (Ziska 2003).

Table 3.2. Impacts of climate change on agriculture in five AEZs.

Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
Water: • Higher temperature: *Increased water demands at upstream and in the deltas.* • Changing rainfall pattern and subsequent flow regime: *Increased flood frequency and magnitude; increased conflicts among water-dependent activities.* • Sea-level rise: *More waterlogging and salinity intrusion in the low elevation parts (60% of VN Mekong elevation is below 0.75 m).* *Crops/livestock:* • Higher temperature: *Changes in soil fertility and nutrient uptake, increased pest outbreaks; potential decrease in crop yields.* • Changes in rainfall pattern and water conditions, including sea-level rise: *Changes in suitable rain-fed crop seasons; unstable crop yields; crop damages due to salinity intrusion.* • Increased exposure to storms: *Increased crop and livestock damages.* *Fisheries/aquaculture:* • Higher temperature: *Mass coral bleaching, decreasing primary production and changes in food web, change in fisheries distribution, especially in pelagic fisheries, and reduced biodiversity and production.* • Sea-level rise*: Loss of coastal habitats for breeding and nursery habitats for fish, including mangroves and coral reefs, saline intrusion into coastal areas.* • Increased frequency of storms and other extreme coastal events*: Increased risks associated with fishing; reduced profitability of larger-scale*	*Water* • Higher temperature: *Increased water demands for all water uses.* • Changing rainfall pattern and subsequent flow regime: *Increased flood frequency and magnitude; increased conflicts among water-dependent activities; increased soil erosion; particular pressure to new agricultural areas.* *Crops/livestock:* • Higher temperature: *Changes in soil fertility and nutrient uptake, increased pest outbreaks, potential decrease in crop yields.* • Changes in rainfall pattern and water conditions: *Shifting of rain-fed crop seasons, unstable crop yields.* *Fisheries/aquaculture:* • Higher temperature: *Increased fish kills in reservoirs and ponds; increase in animal metabolism, feed input, fish diseases, yield variability.*	Same impacts as in the lowland plains and plateaus, but some impacts as soil erosion and land degradation could be more serious due to higher elevation and steeper slopes in this region.	Same impacts as in the intensively used uplands.	Same impacts as in the deltas, but frequency and magnitude could be higher (flood, storms) and in smaller extents (sea-level rise) but more significant because of high dependence on marine and wetland resources - vulnerable to ecological changes due to SL rise or increase in temperatures of the sea surface.

Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
enterprises; increased vulnerability of coastal communities; damage to fishing and aquacultural installations. • Ocean acidification: *Increased mortality in mollusk culture; reduce calcification rates of corals and other invertebrates like mollusks; predispose corals to increased storm damage and weaken their shoreline protection function.* • Modified flood pulse in the floodplain*: Reduced fish catch due to drop in the water level, reduction of wild seed stock, reduced successful spawning and negative impacts on the physiology of fish; decreased yield from inland capture fishery, limitation for freshwater abstraction for aquaculture.* *Land cover* • Higher temperature and changes in water conditions: *Changes in land cover composition and plant growth.*	• Change in water conditions: *Decreasing primary production and changes in food web, change in fisheries distribution, especially in pelagic fisheries, reduced fish catch due to drop in water level in rivers and reservoirs, limitation for freshwater abstraction for aquacultural reduction of wild seed stock, reduced successful spawning and negative impacts on the physiology of fish; decreased yield from capture fishery.* *Land cover:* Higher temperature and changes in water conditions: *Changes in land cover composition and plant growth.*			

Increased CO_2 has a *fertilization effect*, increasing the size and dry weight of most C3 plants (Allen et al. 1996). Poorter (1993) compiled information from 156 plant species and found that doubling CO_2 provided an average growth increase of 37%, though this may give an impression of greater response than would be observed throughout the life cycle since vegetative growth responses may be greater than reproductive (seed yield) responses. C3 plants (including rice, wheat, grasses and most trees) show a larger response than C4 plants (maize, sorghum, sugarcane).

Increased water demand: Higher temperatures will increase evapotranspiration, thus increasing the water demand of crops and pastures in both rain-fed and irrigated systems. Irrigation demand in semiarid regions of Asia is estimated to increase by at least 10% for each 1 °C rise in temperature (Fischer et al. 2002). Livestock demands per head will also increase. Increased water use by crops and pastures will impact on the availability of water for environment and other uses.

Change in viability of crops: Changes in temperature and rainfall patterns could change the viability of particular crop types or varieties, requiring new varieties or a shift in the cropping pattern.

Vertical shifts in ecosystems: Humboldt's law gives as a rough rule of thumb that average annual temperature decreases by about 1 ^{o}C for every 100 m of elevation in tropical to subtropical areas. While there will be considerable time lags, some vertical shift in ecosystems can be expected as temperatures rise, particularly in the Tibetan Plateau and the montane regions of Yunnan. This may result in changes in the area and productivity of temperate grasslands in Yunnan, with impacts on livestock production (Cruz et al. 2007).

Changes in timing of the wet season could affect irrigation demand (either positively or negatively, depending on the crop calendar); and impact on crop yields. For example, Hasegawa (2006) reports that in NE Thailand, rice transplanted early gives substantially higher yield than when planted later.

Increased incidence of extreme events: Global projections are that the incidence of extreme climate events is likely to increase (IPCC, 2007). Wassmann et al. (2004) projected that a rise of 20-45 cm will seriously aggravate flooding, with impacts in all three rice cropping seasons. Dasgupta et al. (2007) projected that a sea-level rise of 1 m would affect more than 5% of Vietnam's land area (mainly in the deltas of the Red and Mekong). These projections do not take account of storm surge or the impact of salinity intrusion.

Sea-level rise and saline intrusion will reduce viable crop areas in the deltas and coastal areas. Rice production will be affected through excessive flooding in the tidally inundated areas and the longer-flooding period. Saline intrusion already affects 1.4 Mha in the Mekong Delta; further rises in the sea level will require extension and enhancement of existing infrastructure to protect crop areas. In the longer term, sea-level rise could have catastrophic impacts on deltas in the region. Thailand, Myanmar and Cambodia would see similar but smaller impacts.

Impacts on Fisheries Production

Direct impacts on the wild fish population will occur over a longer term through the effects of temperature on metabolism, growth, and distribution of aquatic organisms, and the effects on the food web through changes in the lower trophic-level production or in the abundance of higher-level predators. Fish recruitment patterns are strongly influenced by hydrological processes (for rivers and lakes) and oceanographic processes (for marine environments) that trigger the timing of spawning and affect fecundity rates, larval survival rates and food availability. Very little is known of the biology and ecology of the diverse species, and differences in how they respond to these changes will result in shifts in species composition, community structure and the distribution ranges of species. Patterns of change are nonuniform and highly complex, and the impact on wild fish stocks will remain a knowledge gap for a long time. Empirically, it has been observed that exploitable biomass in fisheries is more sensitive to dry, than flood-season conditions (Halls et al. 2001); so fisheries are very vulnerable to decline in dry-season flows.

Indirect impacts include changes of the aquatic regime and habitats due to sea-level rise and saline intrusion, eutrophication of coastal waters and lakes with effects on wild fish and cage culture (Thanh et al. 2004), and acidification impacting calcification and shell formation of mollusks. Increased frequency and severity of coastal events such as storm surges can cause loss of stock, and a large number of escapees from aquaculture of exotic species can impact on natural populations and biodiversity (Na-Nakorn et al. 2004). Storm damage to fishing infrastructural and aquacultural installations has also serious local economic implications (Kleinen 2007). Rise in water temperature tends to increase the spread of disease organisms, affecting wild and cultured fish.

Effects of direct temperature change on fish species and growth physiology are not likely to be as significant for aquaculture as it might be on capture fisheries dependent on wild fish stocks. In aquaculture, it is possible to select appropriate species and strains. Temperature rises may favor production; all cultured aquatic organisms are poikilotherms and, hence, increases in water temperature would increase growth rates and feed conversion efficiency. This, however, increases the demand for feed inputs or else the increased metabolism would not result in biomass accumulation. Aquaculture could also be constrained by water availability and exposed to greater disease risk, offsetting the benefits of temperature-induced growth enhancement.

Impacts of climate change on the production of wild fish could potentially affect supply of fishmeal and fish oils, which are key diet components for aquaculture. In the Greater Mekong countries, trash fish are also used for the culture of carnivorous and omnivorous fish species.

Sea-level rise will increase the tidal reach and salinity intrusion of flat and low-lying coastal areas, which are more extensive in the deltas. Areas thus rendered unsuitable for crop and livestock use may pose opportunities for brackish-water aquaculture.

Socioeconomic Implications of Climate Change Impacts

It is generally recognized that those who are most vulnerable and marginalized would be most severely affected by the cumulative impacts of climate and other anthropogenic activities that degrade the natural resources. Climate change itself, as an issue, may pose opportunities for governments to redress this historical neglect through rights-based protection of these vulnerable groups that have longer-term benefits—land tenure, access to and use of water resources, secure access to grazing and fishing grounds—while easing their diversification of livelihoods or entry into other economic sectors. The most disadvantaged groups include women, children and the elderly whose roles and participation throughout the value chain of agricultural production are undervalued and their specific vulnerabilities to the impacts of climate change under-recognized (Box 3.1: Climate change impacts on women in fisheries).

BOX 3.1 Climate change impacts on women in fisheries

In fishing communities, women are predominantly involved in land-based jobs (such as repairing fishing nets, fish processing and marketing) that are vulnerable to supply and demand changes (FAO/FishCode 2005). Climate change impacts that reduce or cause variability in fisheries production will also have adverse livelihood impacts on these women (Fabres and Hoang 2008).

- In the coastal communities in Vietnam, women dependent on marine resources for their livelihoods encountered the following challenges: less access to and control of resources; limited education, skills, and information access; lower mobility and persistence of traditional gender stereotypes including subordinate roles in the home and community. Few women were involved in decision-making processes in comanagement projects in the Mekong region, with 20% of women involved in Vietnam and Laos, and 30% in Cambodia (MRC 2006). The low mobility of women cage culturists in Thailand affected them from fully benefiting and receiving innovative technology (Kusakabe et al. 2003).
- In Cambodia, women, despite contributing up to 20% of the annual fisheries production, have been neglected in the policies and programs for fisheries development (ADB 2008). In the Tonle Sap, where the fishing sector is organized around a privatized fishing lot system that restricts local access to the best fishing grounds, poorer women experienced great difficulty in meeting household food security. They had to spend longer hours looking for fish with their husbands/partners, and older daughters had to leave school to care for younger siblings, thus enforcing gender-based poverty and discrimination against girls (Tarr 2003).

Women are also generally less prepared and are more vulnerable during times of inland floods and natural disasters hitting the coastal areas. Disproportionately more women than men perished in the December 2004 Asian tsunami because many of them could not swim or climb trees . Emergency aid and financial support are also not gender-equitable and women often receive less attention from governments and donors.

The United Nations (2009) has explicitly recognized that climate change will have implications for basic human rights. A cross-sectoral review of adaptation or mitigation policies and strategies is needed to ensure that initiatives in one sector do not disadvantage vulnerable people in another. This is particularly pertinent in the agriculture sector where large numbers of small-scale producers are heavily dependent on climate-sensitive natural resources (including water and its living aquatic resources) for their livelihoods but are grossly under-enumerated and under-represented in initiatives and negotiations related to climate-change responses. There should also be policy formulation to support livelihood sectors that have been largely marginalized, particularly migrant or mobile natural resource-based activities, such as uplands farming, migratory livestock rearing and small-scale fisheries.

Responding to Climate Change

Adapting Agriculture to Climate Change

Over the last few years, considerable effort has gone into initiating response strategies for climate change. All countries in the region are preparing National Adaptation Action Plans (NAPAs) or equivalents (see section on Agriculture in the National Climate Change Adaptation Strategies), and many other studies have examined options for adaptation (see, for example, Resurreccion et al. 2008; MRC 2009b). A wide range of technical and social responses have been identified.

Given the high degree of uncertainty associated with both the impacts and timing of climate change, all countries in the region have recognized the importance of building resilience and adaptive capacity in communities so that they are better able to deal with unforeseen changes. Thus social adaptation will be as important as technical measures in ensuring the long-term viability of rural communities and agricultural production. It is widely recognized (Anshoury-Yusuf et al. 2009; IPCC, 2007) that capacity to adapt to change is very closely linked to socioeconomic factors such as poverty, diversification of income sources, level of education, and access to infrastructure and technology. Promoting broadly based agricultural development to lift rural communities out of poverty is probably the most effective adaption strategy available.

At a technical level, there is a large body of knowledge about changes in agricultural systems that could help safeguard production—improved land and water management, flood- and drought-resistant crop and livestock varieties, diversification (see, for example, Cruz et al. 2007; Eastham et al. 2008). Producers in the region have always lived with climate variability and have many coping strategies for droughts and floods that will form the basis for adapting to climate change (Friend et al. 2006).

Many of these adaptation measures are "no-regrets" responses, which also provide benefits in terms of production or environmental outcomes, including reducing greenhouse gas (GHG) emissions to mitigate the impacts of climate change (see below). Table 3.3 outlines some of the synergistic benefits of proposed climate-change adaptation measures.

Mitigation of Greenhouse Emissions from Agriculture

All countries in the region have small, but rapidly growing, GHG emissions. The majority of emissions from GMS countries are from land use change, forestry and agriculture sectors, which contributed 80% of total emissions from Lao PDR and Cambodia, and 60% from Vietnam (Morton 2008 ADB 2009a). Emissions result mainly from release of CO_2 due to land use change, deforestation and forest degradation, release of CO_2 and N_2O from soils, and methane emissions from rice paddies and livestock.

Smith et al. (2007) estimated that emissions from agriculture in Asia will continue to rise steeply due to continued conversion of forests to cropland, expansion of irrigated rice areas, growing livestock herds and increasing use of nitrogen fertilizers, and that SE Asia has the greatest technical potential for mitigation of any region globally, through a combination of direct reduction of emissions (by reduction of forest clearing and conversion), enhancing removal of GHGs (by increasing carbon sinks in both vegetation cover and soil carbon) and displacing emission (for example, by the use of biofuels).

Mitigation opportunities include the following:

- *Increasing soil carbon storage* by improved agronomic practices such as low tillage, residue return, use of cover crops, legume rotations (though there may be offsets between C storage and release of N_2O, depending on the nutrient status of soils).

- *Reversion of cropland* to pasture or tree cover, over the entire land area, or in localized spots, such as grassed waterways, field margins or shelterbelts.

- *Reforestation/improvement of forest quality* is being addressed under the United Nations Framework Convention on Climate Change (UNFCCC), through the REDD program, a system of financial incentives and payments for reducing carbon emissions associated with deforestation. Cambodia, Lao PDR, Thailand and Vietnam are all participating in REDD (Angelsen 2008; Vickers 2009).

- *Reduction of methane emissions from rice:* Methane emissions from rice production can be reduced significantly by wet-dry cultivation (periodic drying of flooded rice fields; Allen et al. 1996) and by minimizing incorporation of crop residues prior to planting (Sass et al. 1991). There is also evidence that methane emissions decrease as yields increase (Denier van der Gon et al. 2002).

- *Reduction of methane emissions from livestock* through the use of improved forages, improved pastures and breeding of animals with a higher efficiency of feed conversion (Steinfeld et al. 2006).

- *Production of biofuels* from sugarcane, maize and oil crops has potential benefits in mitigating GHG emissions; but with the risk of competing with food crops for land and water and increased food prices. Biofuel crops such as sweet sorghum, which use much less water, may be a viable option in rain-fed areas and on marginal lands; and tree crops such as jatropha could be incorporated into the agroforestry systems (de Fraiture et al. 2008).

- *Promoting biogas technology* at different scales—domestic, community to municipal—as a means of harnessing methane from livestock wastes and reducing dependence on firewood and other fuels (Morton 2008).

- *Culture of aquatic organisms lower down the food chain* brings environmental benefits of carbon sequestration as opposed to carbon emission. Culture of mollusk and seaweed can contribute to carbon sequestration.[9] Niche markets exist for single-celled organisms such as spirulina, which can be produced in a range of management systems from village production by women in Madurai, India,[10] to commercial-scale production in China by an international company dealing with health food and supplements.[11]

- *Promotion of small-scale renewable energy options in rural areas* (microhydro, biogas, solar, wind) could have benefits in terms of rural development and reduce deforestation pressure due to fuelwood collection (Morton 2008).

Mitigation practices can be effective for more than one GHG, or may involve trade-offs (for example, increasing soil carbon may release N_2O) and proposed practices must be evaluated for individual agricultural systems.

The distinction between adaptation and mitigation measures in agriculture is somewhat artificial, in that every land and water management practice has a 'carbon' dimension. In many cases, adoption of more sustainable land use practices will have benefits for both adaptation and mitigation, as well as other environmental outcomes (see Table 3.3) but, in some cases, trade-offs will be required. In general, mitigation options in agriculture will have

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9 The rapid turnover in seaweed culture (3 months per crop in the tropics) with yields of over 2,500 t/ha far exceeds the potential carbon sequestration from other agricultural activities for a comparable area (de Silva and Soto 2008).
10 http://www.youtube.com/watch?v=U6cslNtc6P4
11 http://evergreen-eni.com/culture-pond/

lower priority than adaptation, unless a synergistic production or livelihood benefit can be demonstrated. Uptake of mitigation options could be encouraged through the payment for environmental services (as under the REDD scheme) (Morton 2008) or through other incentive-based mechanisms.

Table 3.3. Environmental impacts of climate change adaptation and mitigation strategies in agriculture.

Subsector	Response strategy	Adaptation	Mitigation	Environmental impacts/ interactions
Crops	Diversification of production systems	√		Reduction of monocultures, improved biodiversity, more resilient systems
	Improved crop varieties (drought, pest resistance)	√		Increased yield, reduced pressure for additional agricultural land
	Double cropping / intensification of agriculture	√		Increased water extraction; increased agricultural inputs. *Increased use of fertilizers, pesticides, herbicides—soil and water degradation unless managed well;* *CH_4 emissions from paddy higher in the dry season*
	Improved rice cultivation methods (direct seeding, wet-dry cultivation)	√	√	Reduced water use; increased yield; lower emissions of CH_4
	Biofuels - irrigated / annual crops		√	*Increased water extraction; increased demand for agricultural land—competition with food crops*
	Biofuels - dryland / perennials	√	√	Increased C storage; increased vegetation cover. *Increased demand for land—competition with food crops*
	Conservation agriculture—reduced and zero tillage	√	√	Enhance C sequestration; restoration of soil fertility and rehabilitation of degraded land.
Water	Improve irrigation efficiency	√		Reduced water use. *Reduction of return flows to natural systems*
	Improve access to supplementary irrigation to reduce crop risk	√		*(Less impact than dry-season water extractions)*
	Multiuse water management	√		Minimize changes to flow regimes

Subsector	Response strategy	Adaptation	Mitigation	Environmental impacts/ interactions
	Expansion of dry-season irrigation	√		*Increased water extraction*
	Groundwater use for irrigation	√		Reduced pressure on surface water. *Impact on surface water resources if highly connected*
Forestry/ Agroforestry	Restoration of degraded forests/ regrowth/reversion of cropland to forest	√	√	Carbon storage; increased vegetation cover—erosion control; biodiversity benefits
	Plantation forestry	√	√	Carbon storage; erosion control. *Replaces diverse native forests with monoculture*
	Agroforestry/ perennial crops integrated into cropping systems	√	√	Carbon storage; erosion control
Livestock / pastures	Intensive forage-based livestock production	√	√	Reduced grazing pressure; reduced CH_4 emissions, increased C storage in pastures
	Improved pastures	√	√	Reduced grazing pressure; reduced CH_4 emissions. increased C storage in pastures
Fisheries / aquaculture	Integrate fish farming into irrigated production systems	√		Improved water productivity
	Aquaculture in reservoirs	√		Reduced pressure on native fisheries (*unless depending on native fish as food source)*
	Improved brackish water aquaculture—feed alternatives, proper infrastructure design for water management, land and water use policies	√		Reduced dependence on trash fish from marine capture; improved effluent water quality
	Restoration of mangroves	√	√	Protection from storm surge, habitat and biodiversity benefits
	Diversification of aquaculture—mussels, seaweed, spirulina	√	√	Cultivation lower down the food chain—carbon sequestration as opposed to carbon emission

Response to Climate Change in AEZs

Both adaptation and mitigation responses to climate change are highly context-specific, depending on the physical and social conditions as well interactions with measures that might be recommended in other sectors. Examples of possible strategies within the different AEZs to address particular climate change impacts are set out in Table 3.4.

In the deltas the threat of sea-level rise will dominate longer-term planning, with difficult decisions to be made regarding protecting or abandoning low-lying productive land and infrastructure. Flood protection and disaster-preparedness programs have high priority in these zones under all the NAPAs, to protect vulnerable coastal populations. Major investments in infrastructure to protect crops from floods and sea-level rise (dykes, pumps) are already planned and/or underway in some areas, for example, in the Mekong Delta. Because they are the end points of the river systems, water impacts from the upstream will be passed on to the deltas and basin-scale planning and water allocation agreements are needed to reduce vulnerability of deltas to upstream use. Conjunctive use of groundwater and surface water may reduce the pressure on surface water resources, but in most cases, very little is known about the extent of groundwater resources, and this should be a high priority for research. Overpumping from groundwater has already resulted in saline intrusion into aquifers in the Mekong and subsidence in urban areas of Bangkok. Improvements in brackish water aquaculture, integrated mangrove/shrimp cultivation, expansion of freshwater aquaculture and integration into rice production systems will be important components of maintaining and increasing productivity in the deltas. Options for reducing GHG emissions from agriculture in the deltas are limited. Changes in rice cultivation methods to reduce methane emissions (wet-dry cultivation) may involve trade-offs against aquacultural potential in flooded systems. Aquaculture of mollusks and seaweed can provide carbon sequestration as well as very high productivity.

In the *plains and plateaus*, responses to climate change will be mainly about management of scarce water. Rainfall conservation practices in rain-fed areas (small-scale water storage, conservation farming) can improve crop yields and reduce production risks. Supplementary irrigation and the use of crops with low water demand can reduce irrigation demands. Low levels of utilization of irrigation over much of the plains suggest potential to increase production by expanding and improving irrigation, but Molle and Floch (2008) caution that ambitious projects for irrigation expansion (such as “Greening Isan” and Thai Water Grid) have not come to fruition for a range of social and economic reasons. Wet-dry rice cultivation to reduce methane may be more feasible here than in the deltas, with co-benefits through decreased water use. Large-scale agroforestry plantations and production of biofuels could provide significant carbon sequestration, but these options need to be assessed very carefully since there are significant risks of competition with food crops (both land and water); and social disruption accompanying large-scale plantations. Land suitability assessment of lowland zones is urgently needed to identify areas of high potential for conversion to permanent agriculture (and conversely, to identify areas not suitable for conversion), taking into account possible changes in crop suitability over time.

In the *coastal zones*, significant areas of the coastal plains are vulnerable to sea-level rise, particularly in Vietnam, and the Rakhine Delta in Myanmar. Production in these areas is more dispersed than in the deltas, and protection works are less likely to be economically viable. The coastal fishing populations are most vulnerable to inclement coastal and sea-weather conditions, and being located right at the water's edge, fishing and fish farming equipment and structures bear the brunt of storms. High dependence on marine and wetland resources means that these areas are very vulnerable to ecological changes due to sea-level rise or increase in temperature of the sea surface, and diversification of livelihoods will be an important priority. Reduction of disaster risk and preparedness for storms, floods and post-disaster interventions can reduce vulnerability to climate-related disasters. There is some potential for mitigation of GHG emissions through agroforestry, and improved livestock management.

In the *uplands,* there are a range of "win-win" solutions which offer improved production, environmental benefits and reductions in GHG emissions. Conservation-farming techniques (reduced tillage, improved fallow, mulching) sequester carbon and reduce soil erosion as well as increased production. Improved livestock management systems (forage crops, improved pastures, semi-intensive cultivation) reduce grazing pressure on steep lands and have potential mitigation benefits through decreased methane emissions. Reversion of steep lands to forests (already observed in parts of Vietnam, Yunnan and Thailand) reduces soil erosion and increases carbon sequestration. Protection and reestablishment of forests have potentially very significant reduction in GHG emissions, recognized by initiatives such as REDD.

Table 3.4. Responses to climate change in AEZs.

Objectives	Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
Water management	• Basin-scale planning and water allocation agreements to reduce vulnerability of deltas due to upstream use and optimize multiuse water systems, including hydropower. • Integration of infrastructure for long-term flood control and protection from sea-level rise into current planning. • Improve irrigation efficiency. • Balancing supplementary irrigation vs. full dry-season irrigation. • Reuse of wastewater from major cities for peri-urban agriculture. • Conjunctive use of groundwater and surface water in critical periods.	• Land suitability assessment of lowland zones to identify areas of high potential for conversion to permanent agriculture and expansion of irrigation. • Range of water storage and management options, such as rainfall conservation practices, small-scale water storage, conservation farming, improved supplementary irrigation, improved soil management, especially in plantations, to reduce water use and prevent soil degradation, and investigation of groundwater potential.	Same responses in the lowland plains and plateaus.	Same responses as in the intensively used uplands.	Same responses as in the deltas, but more vulnerable to sea-level rise, particularly in MM and VN where production is more dispersed and protection works such as dikes and seawalls are less likely to be economically viable; therefore regeneration of mangroves is the most suitable alternative. Implement integrated coastal zone management

Objectives	Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
Crop and livestock management	• Continuing/enhancing the role as major food production areas by increasing overall production. • Diversification with cropping systems that optimize water use. • Improved crop varieties (drought, flood and pest resistance). • Retention of traditional cultivation methods which use the flood pulse/rainfall. • Changes in rice cultivation to reduce water use (e.g., direct seeding, wet-dry alternative irrigation). • Yield increases by integrated nutrient management and improved cultivation practices. • Intensification to double cropping where water is not yet limiting factors (KH Tonle Sap and MM Irrawaddy). • Intensive forage-based livestock production with improved pastures. • Develop policy strategies to	• Applying cropping systems, including agroforestry/perennial crops that optimize water use. • Retention of traditional cultivation methods which use the flood pulse/rainfall. • Balancing supplementary irrigation vs, full dry-season irrigation. • Changes in rice cultivation to reduce water use—direct seeding, wet-dry cultivation. • Amelioration of soil degradation through the use of conservation farming practices to reduce soil erosion and increase soil fertility. • Diversified sustainable smallholder agricultural systems incorporating cropping, livestock and	Same responses in the lowland plains and plateaus, with additional responses for sloping features: • Conservation farming approaches to protect and enhance productive capacity. • Reduced tillage and direct seeding, mulch-based conservation (DMC) farming. • Improved fallow systems. • Cultivation of understory with tree crops in the plantations. • Improved livestock management systems: forage crops, improved pastures, semi-intensive cultivation to reduce grazing pressure on steep	Same responses as in the intensively used uplands.	Same responses as in the deltas for the small coastal deltas, and responses in the intensively used uplands for the upland coastal areas, with highest priority for maintenance / enhancement of food production capacity in the face of large and growing populations and possible loss of productive land, in particular in MM and VN. Implement integrated coastal zone management

Objectives	Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
	assist and protect small-scale farmers from livelihood and financial losses due to increasingly severe weather hazards.	aquaculture to reduce risk for small-scale producers. • Optimizing opportunities for agriculture from hydropower development.	lands—potential mitigation benefits through decreased methane emissions. • Reforestation of steep lands— "win-win" erosion reduction and mitigation benefits.		
Fisheries / aquacultural management	• Diversify targeted species, adjust fishing effort/strategies, and implement community-based fisheries management. • Invest in improved vessel design (for better stability, safety and sea-to-shore communication). • Exit the fishery and diversify livelihood. • Introduce aquaculture to salinized and flooded areas. • Replace the use of trash fish with formulated feeds. • Diversify culture species especially those lower in the food chain such as seaweed, high-value invertebrates (mollusks, sea cucumber, sea urchins, abalones and giant	• Assessment of climate-change impacts on hydropower development and, subsequently, on capture fisheries to find out suitable alternatives for mitigation. • Developing reservoir fisheries and expansion of aquaculture in reservoirs/lakes. • Investigation of potential synergies or opportunities for aquaculture, in particular rice-fish systems. • Banning stocking of	Same responses in the lowland plains and plateaus.	Same responses as in the intensively used uplands.	Same responses as in the deltas for the small coastal deltas, and responses in the intensively used uplands for the upland coastal areas, with highest priority for maintenance/ enhancement of food production capacity in the face of large and growing populations and possible loss of productive land, in particular in MM and VN. Implement

Objectives	Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
	clams). • Develop salinity-tolerant strains of freshwater species, move culture further upstream, select faster-growing species or strains. • Improve aquaculture (e.g., proper infrastructural design and water management, enhance aquacultural skills and provide infrastructure). • Promote ecologically friendly integration of aquaculture with other food production activities, e.g., rice-fish systems, mangrove-crab, mangrove-shrimp systems. • Hatchery technology to replace wild seed stock. • Increase monitoring of harmful algal blooms (HAB).	certain exotic fish species in the natural water bodies (in LA), but accompanied by enhancing natural populations to grow.			integrated coastal zone management
Land cover management	• Strengthen or build physical defenses. • Rehabilitate vegetation buffer (regrowth of degraded forests) e.g., 100,000 ha of melaleuca in VN Mekong.	• Restoration of degraded forests for mitigation benefits. • Applying suitable agroforestry/perennial crops.	Same responses in the lowland plains and plateaus.	Same responses as in the intensively used uplands.	Same responses as in the deltas for the small coastal deltas, and responses in the intensively used uplands for the upland coastal areas.

Objectives	Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
Safeguarding communities	• Introduce insurance schemes. • Implement disaster preparedness programs (e.g.. teach survival skills to vulnerable groups; have early warning systems; have in place gender-sensitive post-disaster response plans). • Enhance capacity for livelihood transition and diversifying economic activities. • Implement managed retreat-move settlements inland.	• Introduce insurance schemes. • Implement disaster-preparedness programs (e.g., teach survival skills to vulnerable groups; have early warning systems; have in place gender-sensitive post-disaster response plans), • Enhance capacity for livelihood transition and diversifying economic activities.	Same responses in the lowland plains and plateaus.	Same responses as in the intensively used uplands.	Same responses as in the deltas.

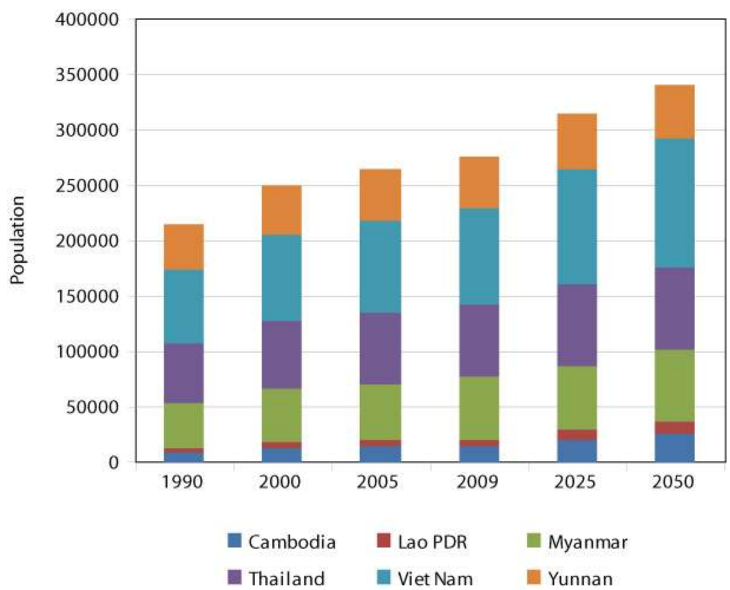
4. Other Drivers of Agricultural Change

Climate change is only one of the factors affecting agricultural development in the GMS. Rapid economic development in the region is having profound impacts on agricultural systems and the natural ecosystems that support them. A combination of population growth and rising living standards is posing a new set of challenges in meeting future food demand. China's economic growth and reemergence as a major trading partner is placing an ever-increasing demand on the natural resources of the region. Global trade is driving investment in agriculture and changes in production to meet export demands. Increased energy requirements are driving large hydropower developments that will impact on the water sector.

Population Growth and Food Security

Population growth in the region is high, though the rate of growth is now declining. The population in the GMS including Yunnan is projected to reach 315 million by 2025 and over 340 million by 2050, from the current level of 275 million (Figure 4.1). Thus, based simply on population growth, food demand in the GMS will rise by at least 25% by 2050. Changes in diet and globalization of food markets mean that the picture is much more complex.

Figure 4.1. GMS population growth**. (**FAOSTAT 2009, World Gazetteer 2009. Yunnan figures calculated from total population for China apportioned using the Yunnan population from 2009).

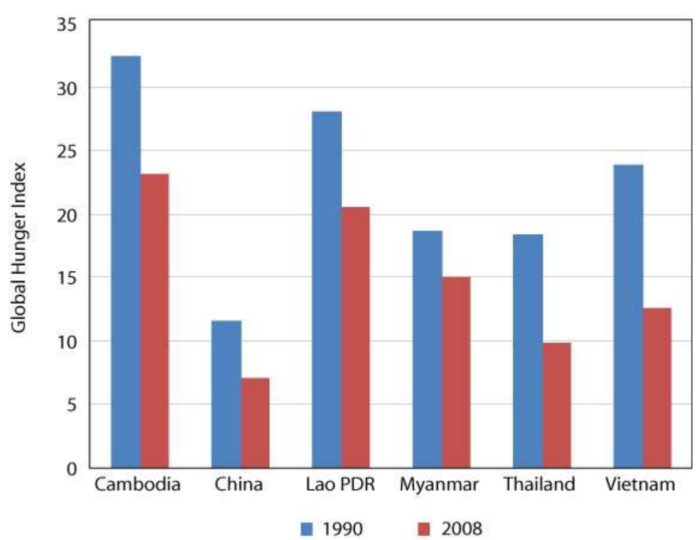


By 2003, all GMS countries produced sufficient food to meet the minimum daily dietary requirements for their populations (Table 4.1) but average calorie intake remained below the world average of 2800 kcal/capita/day (except for China). Even though there has been a significant improvement in levels of nutrition since 1990, the incidence of undernourishment in the region remains significant in all countries of the region , with levels of hunger assessed as "moderate" in Thailand, "serious" in Vietnam and Myanmar, and alarming" in Lao PDR and Cambodia in the Global Hunger Index (GHI) for 2008 (Figure 4.2). The impacts of malnutrition show up as high infant mortality and prevalence of underweight children (both used as inputs to GHI).

Table 4.1. Food consumption patterns in GMS (FAOSTAT 2009).

	Cambodia	Lao PDR	Myanmar	Thailand	Vietnam	China
Food consumption (kcal/capita/day), 1990	1,808	2,157	2,619	2,149	2,148	2,708
Food consumption (kcal/capita/day), 2003	2,074	2,338	2,912	2,424	2,616	2,940
Minimum dietary energy requirement (kcal/person/day)	1,750	1,690	1,800	1,850	1,800	1,900
Increase in protein consumption, 1990 to 2003	16%	18%	20%	13%	22%	20%
% of calories from animal sources	9	7	5	13	13	22

Figure 4.2. Improvements in nutrition 1990-2008. (von Grebmer et al. 2008).



Food insecurity in all GMS countries is concentrated mainly in remote mountain areas with low levels of rice production. In general, ethnic minorities have higher levels of poverty and food insecurity. There is a strong correlation between food insecurity and poverty, but it is not simple: households with very low income and expenditure may have higher food security due to access to wild resources; even households with reasonable income may not be able to afford to purchase food if prices rise as they did in 2008. Food shortages are a result of a range of factors, including local crop failures, lack of access to markets (The et al. 2003 and poverty or lack of funds to buy food even when it is available. Floods and droughts often cause local food shortages. For example, a study in the Attire province in Lao PDR found that floods were a major cause of food insecurity, and that coping strategies included collection of wild food (fishing, hunting, gathering of forest products); diversifying production (growing vegetables, fruit); selling labor or making goods for sale (Friend et al. 2006). Thus at the village/household level, strategies to improve food security rely as much on reducing risks to production, diversifying food sources and utilization of natural resources, as they do on increasing production and yields.

Food security cannot be seen simply as a local or national issue. The GMS countries have become significant exporters of food products, and a reduction in food availability regionally could have significant consequences elsewhere. For example, rice exports from Thailand and Vietnam in 2006 totaled over 12 million tonnes, with almost half of Thai rice exports going to African countries, where food shortages are most acute. The value of food exports from the region to China is increasing rapidly. China's population is projected to grow by 125 million to 1.45 billion by 2025. With China's recent policy changes allowing a move away from food self-sufficiency to relying on imports, a significant proportion of increased food requirements will be sourced from its neighbors (see below).

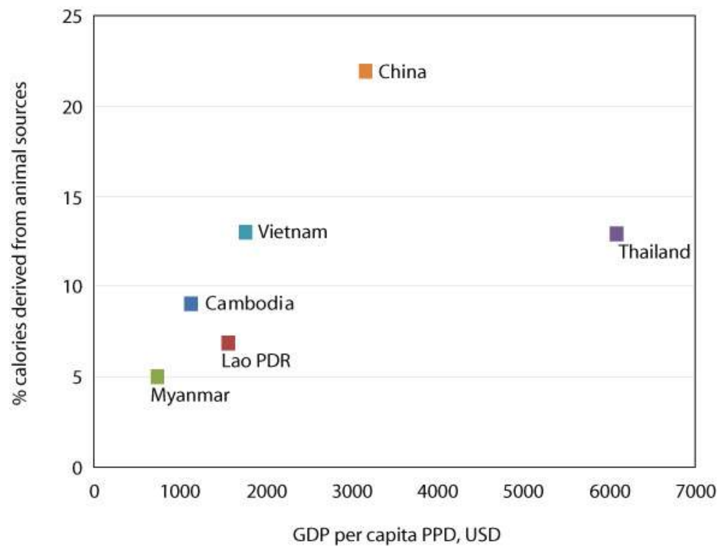
Dramatic increases in food prices regionally in 2008 due to global shortages were a reminder of the interdependence of food markets internationally. The spike in prices in 2008 has been attributed at least in part to production of biofuels from food crops (Rosegrant 2008). The developing global biofuel industry is changing agricultural production patterns, with potentially significant impact for global food demands and prices (de Fraiture et al. 2008).

Impact of Changing Diets

As incomes increase, there is a general trend common across the world, to more diversified diets, with a higher proportion of food from animal sources, a shift from cereals to non-cereals, and an increase in consumption of high-value foods such as fruit, sugar and edible oils. Globally, meat consumption tripled between 1967 and 1997 (CA 2007). These trends are observed across SE Asia although cultural and regional differences are pronounced; for example, Thailand consumes significantly less animal products than China, even with a much higher GDP (Figure 4.3).

Changes in dietary preferences have very significant implications for food production systems: a more meat-based diet requires a much higher level of resource inputs. Total global population is estimated to grow by 30% to 2050 (FAOSTAT 2009), but the Comprehensive Assessment of Water in Agriculture (CA 2007) estimated that global food demand would double in the same period: 25% of the projected increase in grain demand was attributed to increasing demand for livestock feed, due to higher demand for animal products. If China's food consumption patterns in 2031 emulate current US patterns, China would consume 1.35 billion tonnes of grain—a billion tonnes more than today and equivalent to two-thirds of the current global grain harvest (Brown 2005). Production of an additional billion tonnes of grain with existing technologies would either require converting a large part of remaining forests to agricultural land with associated increases in demand on limited water resources, or the adoption of biotechnology and intensification of chemical agriculture, all with critical environmental implications.

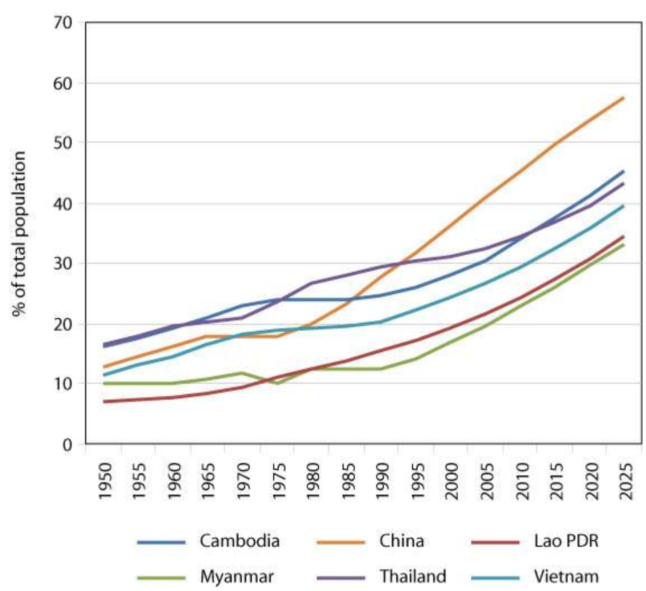
Figure 4.3. Changes in diet with increasing income: data from 2003 (FAOSTAT, 2009; World Bank 2009b).



Urbanization

The region has seen a substantial growth in urban population, a trend projected to increase over the next 20 years (Figure 4.4). Between 20 and 30% of people in the regions now live in cities, with total urban populations approaching 63 million in mainland SE Asia (excluding Yunnan). Almost a third of these live in the five mega-cities of the major deltas (Bangkok, Hanoi, Ho Chi Minh City, Yangon, Phnom Penh). This pattern of urbanization has meant a very strong centralization of services and markets, which impacts on rural development in areas outside the deltas. It has also seen the development of large peri-urban zones around the major cities which act as feeder zones for the urban areas in terms of both labor and food.

Figure 4.4. Urban population growth and projections. (FAOSTAT 2009)



.Urbanization impacts on agriculture in several ways, including the following:

- *Changes in labor availability for agriculture*: drift of labor to the cities can influence agricultural production patterns. In the "new rurality" (Rauch 2009), options for cash income from seasonal work in urban areas may be more attractive to rural workers than planting a second crop. Low plantings of dry-season rice in the Isan Plateau are attributed at least in part to seasonal movement of labor to Bangkok; similar patterns are emerging around Ho Chi Min City. Remittances from migrant labor in urban areas (or neighboring countries) contribute significantly to rural household incomes. For example, it is estimated that over a million Burmese work in Thailand, remitting an average of US$300 per person annually to their home villages.[12] Similarly, the 1992 National Migration Survey in Thailand (Osaki 2003) indicated that over 85% of households with incomes below 500 baht, and a third of households with incomes below 5,000 baht, were receiving remittances which constituted an average of 26% of household income.
- *Land use conflicts* around cities due to urban encroachment: the mega-cities are situated in the most intensively used and productive agricultural areas; competition for access to land between urban and rural uses raises the need for zoning and urban planning both of which are often neglected in developing and emerging economies.
- *Intensification of peri-urban agriculture*: Concentrated demand for agricultural produce from a large population with changing food preferences leads to a change in agricultural patterns in peri-urban areas, with growth of intensive horticulture, aquaculture and livestock production. Increased market integration of small-scale farms in peri-urban areas stimulates income generation, but encourages a move away from highly diverse farming systems towards monocultures.
- *Decline in water quality and water-use conflicts*: Agricultural intensification in peri-urban areas occurs in a context where urban demand for, and impacts on, water are already very high. Opportunities exist for agricultural reuse of urban wastewater, which provides multiple benefits in terms of enhancing food supply and recycling nutrients although health risks from the use of polluted water must be managed carefully (Raschid-Sally and Jayakody 2008).

Peri-urban zones act as both environmental and economic buffers around the major cities. They are important sources of ecosystem services for cities: for example, many of the region's cities depend on adjacent wetlands for primary sewage treatment (Vientiane, Phnom Penh). Agricultural intensification and wastewater reuse can be a way of cleaning up cities by reusing nutrient streams. Urban zones present different sets of risks and opportunities for agriculture that need to be explicitly considered and addressed.

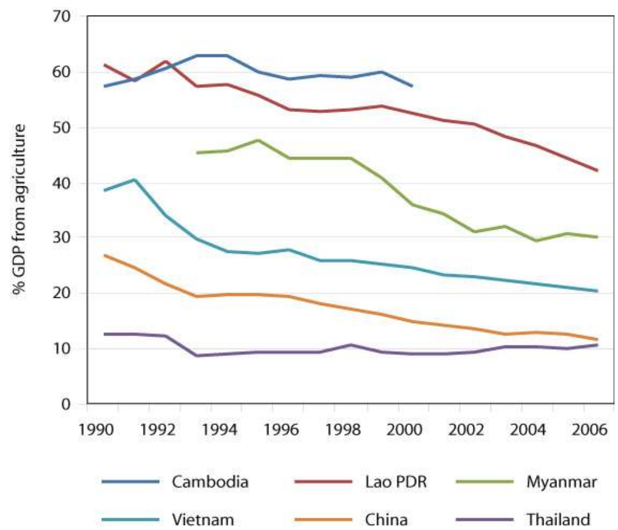
Economic Growth and Poverty Alleviation

All countries in the region see agriculture as a vital part of their strategy for economic growth and poverty alleviation. With development, agriculture has declined as a proportion of GDP (Figure 4.5) but remains a very important sector, employing between 30 and 40% of the labor force. The proportion of the population economically active in agriculture has not changed significantly since 1990, except in Thailand (Figure 4.6).

[12] Economist, Mar 21-27 2009.

Governments have traditionally focused on achieving poverty reduction by promoting growth through exports, investment and modernization. For example, in Lao PDR the National Growth and Poverty Eradication Strategy covering the period 2003-2005 (GOL 2003) has as major objectives: maintaining a growth rate in agricultural output of 4-5% annually; encouraging food and commercial production, to establish food security; and promoting the export of agricultural commodities. Agriculture is a priority sector for promotion of investment through the Law on the Promotion of Foreign Investment and under the Industrialization and Modernization Strategy for the Years 2001-2020 (Voladet 2008). Similarly, the Government of Vietnam has an agricultural development plan for the next 10 years that includes maintaining the average annual agricultural growth rate at 4-4.5%; and increasing total export value from the agriculture sector to $10 billion from the current level of $3.2 billion (Rutherford et al. 2008).

Figure 4.5**.** Proportion of GDP derived from the agriculture sector in GMS countries (World Bank 2009b)



The agriculture sector has been an important contributor to economic growth in Thailand and Vietnam that has driven significant reductions in overall poverty in the last 15 years (Figure 4.7). GDP growth in agriculture has been demonstrated to benefit the poorest proportionately more (Ligon and Sadoulet 2007 in World Bank 2008). The greatest depth of poverty remains in remote rural areas, and absolute gaps between the richest and poorest quintiles are widening, which leaves rural areas lagging. Combating poverty effectively will require specifically pro-poor policies and programs that look beyond economic growth to the overall development needs of the communities.

Osmani (2005) argues that agriculture was the key to Vietnam's success in reducing poverty in the period since 1990. While industry drove economic growth, generation of employment in the agriculture sector (aided by egalitarian land reforms) ensured that the benefits of growth were shared equitably. In contrast, Lundstrom and Ronnas (2006) concluded that stagnation of the agriculture sector was the major constraint to poverty reduction in Cambodia in the same period, with a fall in agricultural employment and productivity (exacerbated by concentration of landownership by the wealthy) resulting in highly inequitable and less sustainable growth. They conclude that for Cambodia to achieve sustainable economic development and poverty reduction "agriculture will have to resume its role as a main contributor to employment and income generation."

Figure 4.6. Proportion of population economically active in agriculture, total agricultural population and proportion of GDP derived from agriculture (FAOSTAT 2009 – figures for 2006).

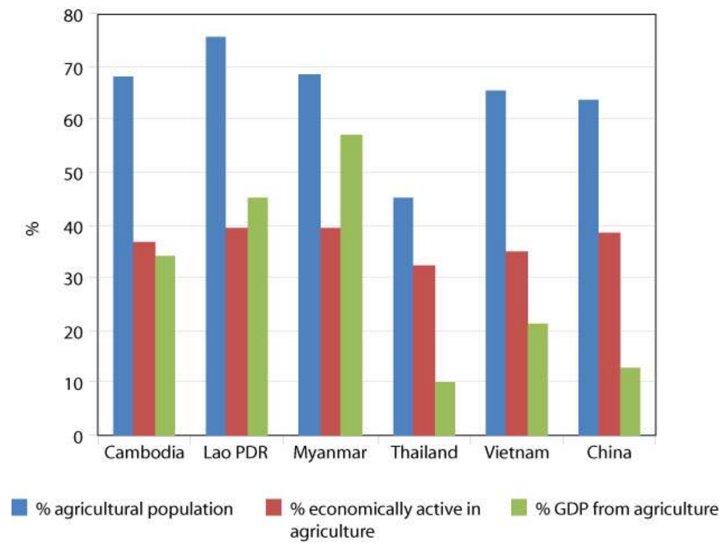
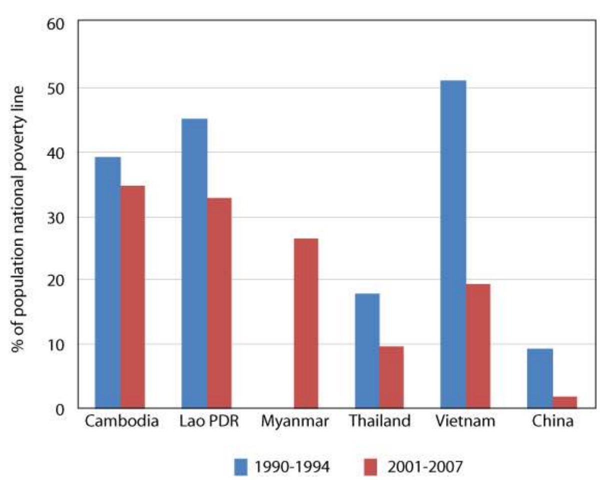


Figure 4.7. Progress in reducing poverty. (ADB 2008)



The Current Global Financial Crisis

Policies for economic growth were framed in a context of global economic expansion, with national growth rates of 5-10% commonplace for most of the last 20 years (except for the Thai financial crisis in 1997-98). The current economic downturn has impacted severely on the region, with all countries of the region experiencing a sharp decrease in GDP growth. The fall in export demand resulted in a rapid decrease in production, with an accompanying increase in unemployment. However, SE Asia has been less severely affected than other regions due partly to the low exposure of the smaller economies to global financial markets, and partly to improved financial management in the wake of the Asian crisis of 1997-98. Cambodia has seen the largest impacts, due to a fall in exports and adjustment of credit markets that had fueled a real-estate boom.

Recovery in the region will be determined largely by China; the World Bank predicts that the Chinese economy will bottom out in mid-2009 but that recovery will be slow. China's rebalancing of its economy towards domestic consumption could boost imports of raw materials, which could benefit the agriculture sector of SE Asian economies. The downturn will slow the pace of poverty reduction. Cambodia and Thailand are expected to see increases in poverty rates. Loss of employment opportunities in the manufacturing sector may mean the return of large numbers of workers to rural areas; this trend has already been observed in China where it is estimated that up to 20 million workers[13] have lost their jobs and that many have returned to rural areas in the last few months (World Bank 2009a; von Braun 2008).

Global Trade and the Role of China

It can be argued that global trade is transforming agriculture in the GMS region more profoundly than any other factor. There are two interdependent pressures at work: export demand driving increased production and changes in crop choice; and foreign direct investment in agriculture driving commercialization and the establishment of large-scale plantations. Export has been a major driver of agricultural change in Thailand and Vietnam; but investment is a more significant driver in Lao PDR, Cambodia and Myanmar.

Trade as a driver of agricultural change is not a new phenomenon: development of rice export markets in Thailand in the 1970s and in Vietnam from the late 1980s was a critical factor in transforming rice production. Rising exports have gone hand in hand with intensification, expansion of irrigated areas, increased agricultural inputs and mechanization. Similarly, the rise of aquaculture in the Mekong delta and coffee production in the Central Highlands are strongly linked with export growth. Export demand for cassava (for livestock feed in Europe) has transformed cassava in Thailand from a low-yielding subsistence crop grown on marginal lands to an important commercial crop yielding increased production from a reduced crop area, as a result of improvements in varieties and cultivation methods.

The emergence of China in the last decade as a major global economic, trading and manufacturing power has had profound impacts for the SE Asian region generally, and for agriculture in particular. With a population more than five times that of its mainland SE Asian neighbors combined; and an enormous and rapidly growing manufacturing economy, China has a seemingly insatiable demand for natural resources including agricultural products that will be a major determinant of the way agricultural production develops over the next 20 years (see below).

Agricultural Exports

Thai agricultural exports have almost tripled from $0.54 billion in 1990 to $1.51 billion in 2006 (FAOSTAT 2009), driving development of a significantly commercialized agricultural sector. Major exports are rice and natural rubber, with processed foods, refined sugar, and tapioca (processed cassava) and other stock feeds.

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[13] http://news.xinhuanet.com/english/2009-02/02/content_10750749.htm

In Vietnam, agricultural exports have increased $740 million in 1990 to $4.3 billion in 2006 (FAOSTAT 2009). Agriculture and fisheries make up 25% of Vietnam's total exports, and the Government of Vietnam has an agricultural development plan for the next 10 years that includes increasing total export value from the agriculture sector to $10 billion. Export growth has been a major driver of agricultural development, especially in coffee, rice, fruit and aquaculture.

Exports of agricultural commodities from Cambodia, Lao PDR and Myanmar have been low and variable, but there are signs of rapid increases in agricultural exports over the last few years, with China being a major market (see below).

In Myanmar, the Government and State Economic Enterprises retain monopoly positions in the export and processing of many commodities, which have discouraged export development and depressed production. In the early 1990s, the market for pulses and beans was liberalized, including the right to export without state intervention. As a result, the area sown to pulses and beans has expanded threefold to more than 2.5 Mha, and total export shipments reached 938,000 tonnes in 2002/2003. Conversely, in 1988 the private export of sesame seed was prohibited and in response exports fell by 50% (UNDP 2006).

Foreign Direct Investment (FDI) into Agriculture

The Governments of Lao PDR and Cambodia are promoting commercialization and industrialization of agriculture, and seeking private investment (foreign and domestic) to fund the transition. This has resulted in an upsurge of large- and small-scale investment in the plantation agriculture, which is profoundly altering agricultural production, with a rapid rise in plantings of commercial (often nonfood) crops such as rubber, oil palm, grains and legumes for feed stocks.

In Lao PDR, FDI in agriculture between 2001 and 2007 totaled $665 million, with a huge influx of $458 million in 2006. Much of this investment went to plantations: concessions have been granted for over 165,000 ha, with the majority of investors coming from China, Thailand and Vietnam (Voladet 2008). Investments were mainly for the establishment of plantations for rubber, oil palm, pulpwood (eucalypt) and cassava. This has driven an explosion of land clearing concentrated in northern Lao PDR (Luang Namtha) and in Central Lao PDR (Borikhamxay and Savannakhet). Large concessions are only a small part of the picture; investments less than $3 million or 100 ha are approved at the provincial level, and so do not enter the national statistics. Rutherford et al. (2008) estimate that large concessions account for only 12% of rubber cultivation in Luang Namtha, with 88% of plantations belonging to local smallholders or informal investors.

Similarly, recent investment flows into Cambodia have been very large: in 2007, $363 million went to agriculture and agro-industry. Land concessions (domestic and foreign) covering a total area of 943,069 ha (15% Cambodia's arable land) had been granted in 2006 (MAFF 2009a). Chinese nationals owned 13 of the 26 foreign-owned concessions. Crops targeted for cultivation included several tree species (teak, sandalwood), oil palm and unspecified agricultural crops (MAFF 2009a; Rutherford et al. 2008). If realized, these concessions will change the face of Cambodian agriculture, bringing extensive new areas into production. The suitability of land for development has not generally been assessed, and previous plantations have frequently shown poor productivity and low returns.

The extent of foreign investment in agriculture in Myanmar in the past has been limited (UNDP 2006). However, in 2008, there was a very large increase in overall FDI from China, and although most has gone to mining, there are press reports of Chinese investment in plantations for rubber, palm oil and pulpwood (Associated Press 2009).

Conversion of large tracts of land to plantations poses social risks, with potential displacement and conflicts between commercialization and livelihoods dependent on forest resources. In Lao PDR, the Prime Minister suspended new land concessions over areas of more than 100 ha in May 2007, following concerns that the large number of concessions granted had negative impacts on the environment and local communities (Phouthonesy 2007). There are also concerns that long-term contracts are very risky for smallholders, who may not possess the specialized skills to make plantation agriculture viable (e.g., rubber in Luang Namtha).

Role of China in Agriculture in GMS

The reemergence of China in the last decade as a major global economic, trading and manufacturing power has had very significant impacts for the SE Asian region generally, and for agriculture in particular. China has a population of 1,320 million compared with 218 million for mainland SE Asian neighbors combined; and a total GDP of $2,645 billion compared with $206 billion for Thailand, $60 billion for Vietnam, $7.5 billion for Cambodia, and $3.3 billion Lao PDR. China's GDP has been growing steadily at 8-10% per year since the 1970s, and this growth is spreading both within and outside the country. According to Brown (2005) if China grows at only 8% per year, it will overtake current US per capita income in 25 years.

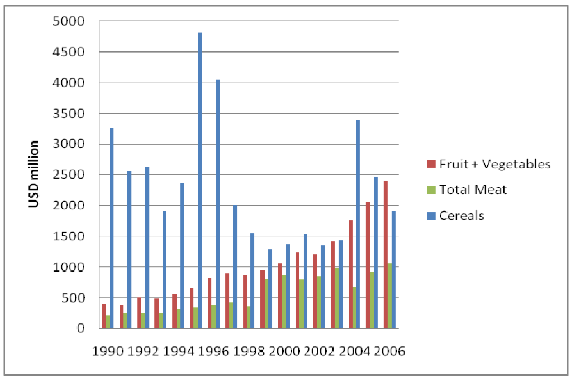
China's huge population and rapid economic growth have resulted in a seemingly insatiable demand for resources. To meet this demand, Chinese government policy has made a deliberate move away from agricultural production towards sourcing both food and nonfood products externally. The 11th Five-Year Plan (2006-2010) includes objectives to reduce the total acreage of cultivated land from 122 Mha in 2005 to 120 Mha in 2010; and to transfer 45 million rural laborers to nonagriculture sectors over 5 years (Fan 2006). The 2004 "Going Global Strategy" introduced policies to subsidize investment by Chinese companies in overseas natural resources. While the most visible aspect of this policy, globally, has been the acquisition of mineral resources, the policy is having a very significant impact on agriculture in the region, particularly in Lao PDR, Cambodia and Myanmar. This impact is being felt in two ways: indirectly, as an increase in imports to China from neighboring countries influences production trends; and directly through investment in agriculture, particularly large-scale plantations.

In 2002, China launched the ASEAN China Free Trade Area (ACFTA). Under the ACFTA "Early Harvest" program, tariffs were removed from a wide range of agricultural products immediately and special status was given to the least-developed members of Association of Southeast Asian Nations (ASEAN) (Lao PDR, Vietnam, Cambodia, Myanmar), opening up export markets from these countries (Sheng Lijun 2003). Chinese imports of agricultural commodities have more than doubled since 2000, with increases in both foodstuffs and industrial crops (Figure 4.8a, b). Cereal imports have been variable, depending on the internal harvest but fruit and meat imports are rising steadily.

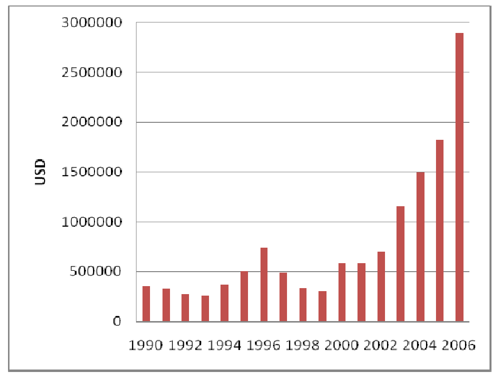
China has become a major market for agricultural produce from neighboring countries, and agricultural imports from all GMS countries rose substantially after 2002. Rubber imports have trebled since 1999; China is now the world's largest consumer of natural rubber (Rutherford et al. 2008). It is the major market for rubber from Vietnam, and the second largest for Thailand. In recent years, China has also begun importing large quantities of tapioca from Thailand, which is used as a raw material in the production of ethanol and biofuel.

Figure 4.8. Value ($) of Chinese imports (FAOSTAT 2009).

a) Value of food imports



b) Value of rubber imports



As a result of the ACFTA, export of rice and rubber to China is likely to increase, but it is possible that import of vegetables, fruit and oil seeds from China may also increase (Zamroni 2006). For example, recent import of Chinese vegetables (particularly garlic) to Thailand has been controversial, with Thai farmers complaining of dumping of low-priced garlic into Thai markets.

In Lao PDR, Myanmar and Cambodia, direct Chinese investment in plantations, particularly for rubber, is driving a major boom, resulting in conversion of large tracts of land to plantations.

Hydropower Development

Demand for energy within the region is growing very quickly, and all governments are considering major hydropower developments to meet part of that demand (King et al 2006). Box 4.1 and Figure 4.9 illustrate the main planned developments within each of the six main basins in the region. Construction of dams will have three main impacts: changes in the flow regime; blocking the passage of migratory fish with serious impacts on recruitment and spawning (van Zalinge et al. 2004; Thanh et al. 2004); and changes in sediment transport, with negative impacts on ecosystem productivity and increased bank erosion (Kummu and Varis 2007).

In general, storage of water for hydropower development will shift flows from the wet season to the dry season, and increase water-level fluctuations. The Mekong River Commission (MRC) has released a preliminary assessment of the hydrological impacts of hydropower development on the Mekong (Hang and Lennaerts 2008) including the large Chinese dams, and expects an increase in dry-season flow of around 50% at Chiang Saen, reducing downstream to an increase of between 9-13% at Chau Doc. Accompanying decreases in wet-season flows are proportionately smaller (15% to 4-7%, respectively). The projected increase in dry-season flows is larger than projected irrigation demands from all Lower Mekong Basin (LMB) countries and could provide significant opportunities for irrigation development and for mitigation of current dry-season shortages and saline intrusion in the delta.

The ecological consequences of such large changes are not well understood but there are potentially very large impacts on wild fish populations. There are specific concerns that changes to the flow regime could impact negatively on the ecology of the Tonle Sap system, which underpins two-thirds to three-quarters of the inland capture fisheries of Cambodia. At Kratie, upstream of the confluence with the Tonle Sap, dry-season flows are projected to increase between 20-30% and wet-season flows to fall by 4-8% (Hang and Lennaerts 2008), Kummu and Sarkkula (2008) concluded that relatively small rises in the dry-season level would permanently inundate a disproportionately large area of the floodplain, threatening the gallery forest; and that a smaller flooding amplitude would decrease ecosystem productivity. Changes in the pattern and timing of flooding are also likely to disrupt physiological cues for fish migration.

Box 4.1 Existing and proposed hydropower development in GMS basins.

Mekong: The Mekong River Commission lists 23 existing large and small dams, 13 under construction and up to 80 planned or proposed dams in the Lower Mekong, including 11 proposed dams on the mainstream Mekong. This is in addition to a cascade of eight dams on the Lancang (Upper Mekong) of which two are complete and three are under construction— these include the Xiowan and Nuozhadhu dams with a combined storage of 22,000 Mm^3 (MRC 2009a).

Red River: Currently, there are two operating hydropower projects, with another four proposed (ADB 2009b) in addition to a total of 27 existing and planned small dams for irrigation (Water Resources eAtlas).

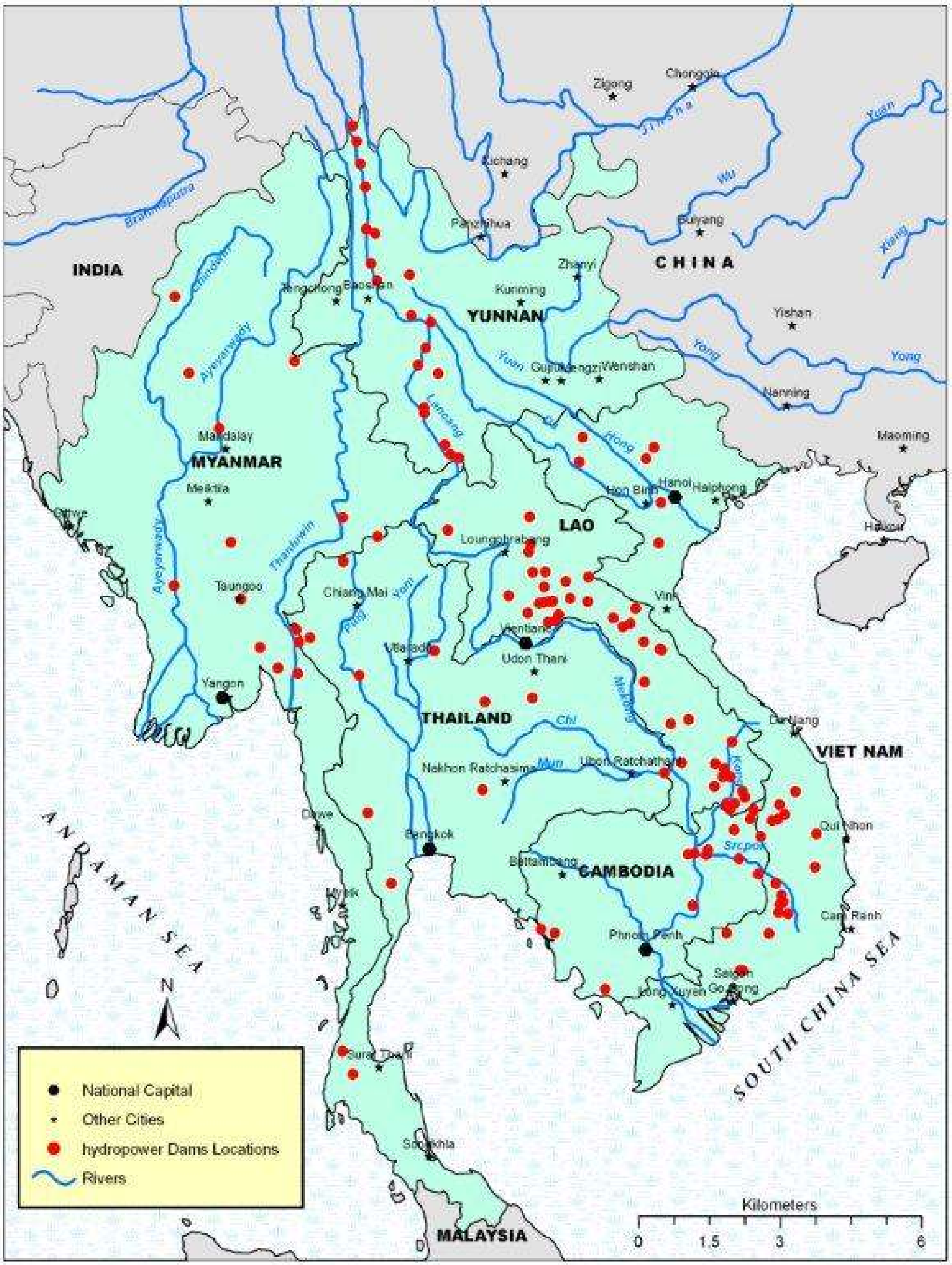
Chao Phraya: There are three operating dams for hydropower and irrigation with no additional dams planned.

Yangtze: A series of eight dams are planned on the Upper Yangtze in Yunnan (upstream of the Three Gorges Dam), including a controversial proposal for a dam at Tiger Leaping Gorge (IRN 2009a).

Salween: In 2006, the Governments of Thailand and Myanmar signed an agreement to build the Ta Sang Dam, the first of a cascade of five large dams on the Salween. Plans for a cascade of 13 dams in the Upper Salween (Nu) in China have apparently been shelved (IRN 2009b).

Irrawaddy: Two dams are currently under construction, including the Myitsone Dam being built in cooperation with China, one of seven hydropower developments planned for the Irrawaddy (Irrawaddy 2009).

Figure 4.9. Location of operating and planned hydropower developments in the GMS. (ADB 2009b)



Climate Change in the Context of Other Drivers of Change

These large-scale drivers operate at a range of spatiotemporal scales, with complex and, sometimes, unpredictable interactions. Export opportunities and commodity prices drive incremental changes in land use year to year as producers respond to market opportunities, but can produce significant changes in land use over quite short periods, as seen in development of coffee in the Central Highlands of Vietnam and aquaculture in the Mekong Delta. In many cases, the primary focus of response to these large-scale drivers is outside of agriculture, and policy decisions are not primarily directed at agricultural outcomes. For example, although Chinese investment is an important driver of agriculture in the region, agriculture receives only a small fraction of total Chinese investment, the majority of which is in minerals and energy: overall investment policies are determined by priorities in other sectors, but they have a large influence on agriculture. Economic shocks, such as the 1997 Asian economic crisis and the current global financial crisis, can impact very significantly on agriculture: the return of large numbers of unemployed workers to rural areas and falling export prices can combine to cause social and economic hardship as well as changes in production. The role of agriculture as fallback employment in hard times emphasizes its social as well as economic importance.

Climate change is incremental with small changes from year to year that, initially at least, are within the range of observed natural climate variability and will be masked by them. In contrast, the range of social, demographic and economic drivers discussed above are already forcing visible regional change at a very rapid pace. Estimates of changes in crop productivity due to climate change are in the range of 2-30% over a 20-30 year period (Eastham et al. 2008; Cruz et al. 2007; Hoanh et al. 2004); in comparison, total agricultural production has increased almost 80% in Vietnam and over 200% in Cambodia over the last 15 years, with even faster growth in specific sectors and regions. Published projections of climate-induced changes in mean annual flow in the Mekong range from 5% (Hoanh et al. 2003) to 20% (Eastham et al. 2008); planned large hydropower projects in the Mekong are projected to increase dry-season flows by 10-50% and decrease wet-season flows by 6-16% (Hang and Lennaerts 2008). Dasgupta et al. (2007) estimated that a 1 m rise in the sea level would reduce Vietnam's GDP by 7% and ADB (2009a) estimated climate-change-related reduction of GDP in SE Asia of 6.7% per year by 2100; the 1997 Asian crisis reduced Thailand's GDP by almost 10% in 1998 and the current financial crisis is similarly expected to significantly reduce or reverse GDP growth in most countries (World Bank 2009).

Thus in the next 20 to 30 years, agriculture will be shaped by a very complex mixture of social, economic and environment factors, with impacts of at least the same order or greater magnitude as direct impacts of climate change. Some, like climate change and population growth, are cumulative while others, such as food prices, oil prices, financial crises and political fluctuations, can have immediate and severe effects, but these effects fluctuate over time and tend to even out. In the longer term (beyond 2050) climate may become the most urgent driver of agricultural change, at least in some parts of the region, as sea-level rise and increased incidence of flooding force abandonment of significant areas of productive land, requiring a radical rethinking of production systems to maintain food sources for the inevitable increase in population.

The section on Responding to Climate Change and Table 3.4 set out proposed responses in agriculture to climate change; Table 4.2 provides an analysis of some of the potential impacts and responses to economic and demographic drivers in the different agroecological zones. Responses range from planned macro-economic policies to decisions by individual producers to change crops in the face of fluctuating prices and demand. It is unlikely that it will be possible to disentangle the various drivers, and there are no defined boundaries between climate-specific and non-climate-specific adaptations (Resurreccion et al. 2008). Response strategies must be formulated in the context of the whole range of impacts and drivers. Since there is such a high degree of uncertainty about the pace and direction of change, most of the response strategies proposed have at their core measures to build resilience of production systems and adaptive capacity of rural communities.

Agricultural systems in the GMS are changing rapidly in response to a wide range of drivers: a mix of short-term, high impact (for example, the global financial crisis) and those that are longer-term and less obvious but with cumulative impacts (climate change, environmental degradation). All have a high degree of unpredictability, and most are operating much more broadly than the agriculture sector. If agriculture is to meet the challenge of increasing production in this context of change, then agricultural systems must be reoriented to include the concepts of environmental and social sustainability that are fundamental to resilience. The term sustainability implies both that high yields can be maintained, even in the face of major shocks and that agricultural practices have acceptable environmental impacts. Achieving sustainable, resilient agricultural production systems will require a significant rethinking of agricultural priorities and new approaches to production.

Table 4.2. Impacts and responses to global drivers of change.

Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
• Variations in global food prices increase demands and local food prices. *Responses: Continuing /enhancing the role as major food production areas by increasing overall production.* • Global financial crisis causes reduction of demands and prices in exporting high-value agricultural/aquacultural products. *Responses: Adjusting production to current demands, reducing production costs and targeting to domestic market.* • Variations in global fuel prices cause changes in costs of pumping irrigation and transport. *Responses: Change in domestic food prices; biofuel is not considered because of rice-oriented for food security.* • Changes in country diet with higher demand for meat, vegetables and fruit lead to diversification, including livestock.	• Variations in global food prices increase demands and local food prices. *Responses: Opening up new agricultural areas and expanding irrigated areas (causing potential water shortage and conflicts); increasing overall production to maintain local food security.* • Global financial crisis causes reduction of demands and prices in exporting high-value agricultural products. *Responses: Adjusting production systems to products with stable market demands such as industrial crops.* • Variations in global fuel prices cause changes in costs of pumping irrigation and transport. *Responses: Biofuel*	• Variations in global food prices: *Not much influence in this region.* • Global financial crisis causes reduction of demands and prices in exporting high- value agricultural products. *Responses: Adjusting production to market demands (e.g., coffee), revision of plantation projects (rubber).* • Variations in global fuel price cause changes in pumping irrigation and transport costs. *Responses:Biofuel crops considered; proposed large-scale hydropower in CN Yunnan, LA North and South, and VN NW and Central Highlands.* • In-migration to areas with expanding production (LA North, VN Central Highlands). *Responses: Proper*	Impacts of global events are not significant yet in this region. Pressure of demands from dense population in other regions on this region is more relevant, in particular for timber and non-timber forest products.	• Global food price variations strongly influence this region because local rice production is insufficient. *Responses: Increase overall production to maintain food security*. • Global financial crisis causes reduction of demands and price in exporting high-value agricultural products. *Responses: Adjusting production to market demands (e.g., coffee), revision of plantation projects (rubber).* • Global fuel price variations cause changes in pumping irrigation and transport costs. *Responses: Applying water- and energy-saving techniques; reduce dependence of aquaculture on trash fish thus reducing demand on*

Deltas and Tonle Sap	Lowland plains and plateaus	Intensively used uplands	Forested uplands	Coastal areas
Responses: Reduction of rice land and rice planted areas; diversification of aquacultural products. • Urban growth causes rural labor shortages. *Responses: Mechanization in all deltas, contract farming as started in TH Chao Phraya.* • Competition for water (urban areas, industries, upstream hydropower) causes seasonal water shortage. *Responses: Changes in production systems and adjusted crop calendar to avoid water risks.* • Increased vegetation cover for improved environment: *Significant reforestation (e.g., 100,000 ha of malaleuca in the VN Mekong Delta, rehabilitation of mangrove forest).*	*crops considered; proposed large-scale hydropower in KH, LA and possibly MM.* • Changes in diet. *Response: Not strong as in the deltas because the greater part of the population is rural without much influence by city life.* • Maintain vegetation cover for improved environment. *Responses: Agroforestry systems and intercrops in plantations.*	*policies and institutional strengthening to eliminate social conflicts and environmental damages.* • Changes in diet and food preferences. *Responses: Expand and increase production of temperate-zone horticultural products.* • Maintain vegetation cover for improved environment. *Responses: Agroforestry systems; intercrops in plantations; increase grazing for livestock.*		*low-value products from marine capture.* • Out-migration to other regions. *Responses: Proper policies and institutional arrangement to keep expertise and high skill labor in the region.* • Changes in diet and food preferences with increased demand for protein. *Responses: Improved livestock to provide more meat; integrated agriculture-aquaculture.* • Retention of native forests for conservation/ biodiversity/tourism values and maintenance of vegetation cover for improved environment. *Responses: Agroforestry systems; Intercrops in plantations; increase grazing for livestock; rehabilitation of mangrove forest.*

5. Rethinking Agriculture in the GMS

In the past, agricultural development policy in GMS countries focused on two main objectives: food security, and economic growth from export-driven agriculture. Improving livelihoods of the rural poor was a priority, but there was an implicit assumption in most government policy that achieving the first two would also achieve the third. To a significant extent, environmental quality has been a casualty of agricultural development, with associated losses in productivity and ecosystem services. Securing future production will require revisiting and broadening these priorities, to include

- Securing and increasing food production under changing climate and market conditions and the looming water crisis.
- Protecting and restoring ecosystem functions and services in agricultural landscapes, including opportunities for mitigation of GHG emissions from agricultural sources.
- Improving the capacity of large numbers of small-scale producers to adapt and improve productivity and income in sustainable ways.
- Reducing the vulnerability of the poor and groups that are marginal to economic production to climate and other global changes.

Securing Food Production

Given the projections for population growth both regionally and globally, the overwhelming priority for agriculture must remain the sustainable production of food. More food must be produced by a dwindling agricultural labor force resulting from rural-urban migration of labor in many SE Asian countries. Food production has to be increasingly market-oriented as, clearly, subsistence agriculture cannot meet urban demands.

The shift to higher meat and fish consumption among higher-income and urban consumers will mean not only that there will be competing demand for use of land and water resources between the food and nonfood agricultural production (including the industrial crops as well as biofuels) but also that, within the food production sector, there will be shifting demands of the resources for crop, livestock and aquatic food production.

Increased food production can come from increased areas of production and/or increases in productivity. Overall food supply can also be increased by reducing postharvest wastage. Total postharvest food losses (as a result of processing, spoilage, pests, storage and distribution) are very large, estimated at 10-40%, though estimates vary widely for different crops and regions. Cutting postharvest losses could add significantly to food supplies both locally and globally, reducing the need to increase production (WRI 2009).

Expansion of Areas under Production

Pressure to produce more food inevitably raises the question of expanding the area under production, which can be achieved by:

- Opening up of new agricultural areas.

- Reclaiming previously productive lands which have moved out of production due to land degradation or been inaccessible due to conflict, landmines and unexploded ordnance (UXO).[14]
- Expanding aquacultural production in a range of environments.

Arable land per capita has declined since 1990 over the entire GMS, and is very low (less than 0.1 ha per capita) in Vietnam and Yunnan (see Table 5.1). Assuming no new land is brought into production, by 2050 arable land per capita would drop below 0.2 ha per capita for all countries except Thailand. Alternatively, to hold the current ratio of land per capita constant would require an additional 7.2 Mha of arable land, with 2.6 Mha in Vietnam alone. Such an expansion would place very serious pressures on ecosystems and biodiversity. Intuitively one can conclude that most of the best-quality farmland in the region is already under production (other than those areas that may have factors such as landmines that are restricting their use) which would suggest that further area expansion will be occur in marginal lands unlikely to sustain high yields and probably highly vulnerable to accelerated degradation.

The deltas and many coastal areas are already extensively settled and cultivated; Vietnam's relatively rapid increase in agricultural land area during the 1990s has now stabilized, while Thailand's agricultural land area has been falling since the early 1990s. Relatively low population density in the lowland plains of NE Cambodia and Lao PDR, the coastal zones of Cambodia and Myanmar and the more accessible parts of the Lao PDR uplands suggest that these areas are likely to be targeted for expansion of agricultural land—indeed, these are the areas where large economic land concessions have been granted over the last few years.

Much of the land not yet developed for agriculture is likely to be of relatively poor quality, steeply sloping, or suffering from constraints such as access to water or markets. An analysis by FAO (2000) indicates that less than 20% of land in SE Asia can be considered as free of physical constraints for agriculture; the majority of that is already under cultivation. The remaining forests in the region include areas of very high conservation value, and are also significant watersheds. Extensive clearance for agriculture could impact on biodiversity, and on both quantity and quality of water resources.

There is considerable scope to expand freshwater aquaculture in a range of environments over floodplain and plateau areas since it uses a diverse range of production practices (e.g., ponds, cages, pens, rice-fish culture, integrated agriculture-aquaculture). Some climate change impacts (e.g., increased salinization and prolonged flooding) may result in areas becoming less suitable for crops and livestock but more suited for fish production. Because the industry is mobile, it is adaptable: sites may be moved to more favorable locations; if areas become unsuitable for terrestrial agriculture with sea-level rise and salinity intrusion, a switch can be made to brackish water culture and freshwater fish could be moved further upstream.

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[14] It is estimated that around 4,500 km^2 of Cambodian land are contaminated with landmines and UXO. Demining operations are progressively bringing land back into agricultural production. (http://www.sac-na.org/ Cambodian National Level 1 Survey, 2008). UXO also limits access to land (mainly forests) in Lao PDR and Thailand (along the borders with Cambodia and Myanmar).

The widespread construction of reservoirs, especially in the Mekong River Basin, provides the opportunity for fish stocking and harvesting. Thailand has been able to increase freshwater fish production substantially to meet local needs, particularly in the Isan Plateau and even in the northern highlands, through reservoir stocking. While this does not adequately compensate for the biodiversity loss resulting from development of built structures (including dams), it nevertheless supplies an affordable protein source for the rural poor.

Any large-scale program of agricultural expansion requires a thorough assessment of land capability/suitability, taking into account the value of existing ecosystem services than could be lost or compromised by agricultural development.

Table 5.1. Area of arable land per capita and as a percentage of total land area (1990-2050). (FAOSTAT Terrastat 2009; World Bank 2009b; World Gazetteer 2009.)

	1990 Arable land			2007 Arable land			2050 Arable land	
							Area of arable land kept constant	*Area per capita kept constant*
	1,000 ha	*Per capita (ha)*	*Total land area (%)*	*1,000 ha*	*Per capita (ha)*	*Total land area (%)*	*Per capita (ha)*	*1,000 ha*
Cambodia	3,695	0.38	20	3,800	0.26	21	0.15	6,606
Lao PDR	799	0.20	3	1,170	0.20	5	0.13	1,855
Myanmar	9,567	0.24	14	10,577	0.22	16	0.18	12,729
Thailand	17,494	0.32	34	15,200	0.24	30	0.23	16,044
Vietnam	5,339	0.08	16	6,350	0.07	19	0.05	8,948
Yunnan				2,381*	0.05	6	0.05	2,541
China	123,726	0.11	13	140,630	0.11	14	0.10	150,097

*Assumes 6% of Yunnan is arable (ADB 2004).

Increasing Productivity

A wide range of technological solutions to increase agricultural productivity have been developed and are being implemented with varying levels of success across SE Asia. These include improvements in:

- *Crop, livestock and cultured fish varieties* (higher-yielding, drought- and pest-resistant) and matching crops to prevailing conditions.
- *Crop, livestock and fish nutrition* (chemical and nonchemical fertilizers, mulching, legume rotations, improved feed formulations).
- *Control of pests and diseases* (pesticides, herbicides, biological controls, integrated pest management).

- *Land management* (crop rotations, erosion control, conservation farming techniques).
- *Irrigation* (increase in irrigated area, increased efficiency, drip irrigation, supplementary irrigation of rain-fed crops, water reuse, wastewater irrigation).
- *Water management in rain-fed systems* (water harvesting, diversified storage, conservation agriculture, multiple water use for diversified farming).
- *Intensification* (double cropping, intensive livestock systems and aquaculture).

These are the technologies that underpinned the Green Revolution of the 1960s-1980s, and there is little doubt that, applied appropriately, they could provide very large increases in food production (IRRI 2008). For example, there are large potential gains to be made in closing the yield gap: average provincial rice yield in Cambodia's highest-yielding province of Kandal at 3.6 t/ha is more than double that of Siem Reap province (1.7 t/ha); but well below the yields of 5 to 6 t/ha achieved in the Mekong Delta in Vietnam (MAFF 2009b).

Singh et al. (2009) analyzed yield gaps for rain-fed crops for South and SE Asia, and concluded that the actual yields of many food crops are much below the potential yields that can be obtained in experimental plots with improved management techniques. For example, in NE Thailand they found that there is a potential to increase productivity of maize by 35-200% and soybean by 50-95%; potential yield gains for upland rice were lower (around 20%) and significant increases in rice yield may require a shift to irrigated cropping.

The prospects of achieving yield increases comparable to those of the past 40 years are unclear (Tilman et al. 2002; Ruttan 1999; Barnett et al. 1995). In many regions in SE Asia, the rate of increase in rice yields is declining as actual crop yields approach a ceiling of maximal yield potential (Cassman 2001). Further, continuous cereal crop production systems, including systems with two or three crops a year commonly observed in the Mekong Delta and the Chao Phraya Basin, may become progressively susceptible to diseases and insect attack due to a reduction in diversity or lack of crop rotations. The fact that there would appear to be a lack of a larger exploitable 'yield gap' in the major rice producing regions of the GMS highlights the need to steadily increase the yield potential ceiling. Areas where there are still large yield gaps lend themselves to the introduction of appropriate technologies and should therefore become the target of efforts to increase productivity. Identifying these regions and understanding the impediments to achieving potential yields should become a priority in establishing adaptation strategies in the face of a large number of drivers.

Closing the Nutrient Cycle

High-yielding agricultural production systems are dependent on the addition of synthetic fertilizers, in particular industrially produced nitrogen (NH_4 and NO_3) and phosphorus requiring significant energy in their production. Without the use of industrially produced fertilizers, world food production could not have kept pace with demand and if this was not the case a greater proportion of natural ecosystems would have had to be converted to agriculture. What is clear is that further increases in the application of nitrogen and phosphorus are unlikely to be as effective at increasing yields (Tilman et al. 2002). Yield response curves of crops to nitrogen fertilizer clearly indicate that the highest efficiency is achieved at the lower increments added with efficiencies declining at higher levels of addition. Consequently, a significant amount of the applied nitrogen added to crops is lost from agricultural fields. This explains why rice paddy agriculture along with livestock production systems is the most important source of the GHG methane (Prather et al. 2001).

The key to addressing issues associated with the use of industrialized fertilizers is to increase nutrient use efficiencies; in effect, increasing grain yields per unit of nitrogen, phosphorus or water added. Clearly, there are lessons to be learnt from developed economies as for example in the USA where over the past 26 years nitrogen fertilizer efficiency has increased by 36% (Frink et al. 1999). These improvements are a result of significant investments in research and extension education, soil testing and timing of fertilizer applications. Other strategies that could be implemented to increase nutrient efficiencies in cropping systems are the use of crop varieties bred for higher nutrient use efficiencies; cover crops or reduced tillage to reduce losses associated with leaching, volatilization and erosion; and closing the nitrogen and phosphorus cycles through the application of livestock and human wastes.

There are possible advantages of improving efficiencies and minimizing losses through combinations of organic and inorganic fertilizer use. Organic matter effectively acts as a slow release form of nutrients, but the problem that confronts agronomists and soil scientists is the synchronization of releases that meet crop demand. There are significant research opportunities to investigate these aspects particularly with respect to the concept of 'fortification' of waste materials that would meet crop demand. The advantage of such an approach would be a dramatic decrease in the need for inorganic nutrients that would have significant positive implications with respect to energy saving in the manufacture of inorganic fertilizers. Needless to say, the fertilizer industry would resist any such approach and to date it has been against the concept of 'fortification.' It is also pertinent to note that we are still using the same fertilizer technology developed four decades ago in our current production systems, clearly indicating a resistance by the fertilizer sector for change. There are certainly innovative fertilizer delivery platforms that supply nutrients in a far more efficient and sustainable manner.

Strategic spatiotemporal applications of inorganic fertilizers to meet crop demand will significantly improve nutrient efficiencies from these sources as well as the amounts applied. It is interesting to note that investment in on-farm nutrient management research and in extension activities that promote such practices have occurred as yet (Dobermann et al. 2002). Without the implementation of these practices this technology should be viewed as inappropriate for many developing countries as it has continued, and will continue, to have significant off-site impacts.

Multiple cropping, using crop rotations or intercropping, will increase nutrient and water use efficiencies as well as reduce damage from pests. The concepts implicit in agroforestry systems have significant merit with respect to increasing nutrient and water use efficiencies. The spatiotemporal attributes associated with root systems in these mixed systems, in effect, mimic, to a certain degree, natural ecosystems and the services they provide. In addition, there is the potential benefit of increased carbon sequestration in these systems, particularly with the deep-rooted nature of these systems. The concepts implicit in 'mixed' production systems of exploring efficient resource utilization have not been explored to a great degree within the context of farming systems in the region. Integrated farming systems have been promoted in certain areas in the region; however, their adoption as a sustainable and efficient production system has not been widely acknowledged or accepted. There is a need to undertake further studies of such systems in order to quantify the ecosystem services provided by these mixed systems and implications in delivering productivity gains both from a yield and input perspective.

Livestock production will become an increasingly important regional component in the agriculture sector as per capita incomes rise. Whilst industrial scale production of livestock in the region is still in its infancy (i.e., chicken and pork production for global markets) this trend will increase rapidly. The safe handling and sustainable disposal of animal wastes from high-density animal confinement facilities are a challenge but could be viewed as an opportunity. The composting of animal waste to create crop fertilizers and soil amendments offers an opportunity to closing the nutrient cycle and improving the quality of soils. The closing of the nutrient cycle will decrease dependence on synthetic fertilizer production. Further fortification of these products as described previously offers an opportunity to enhance the nutrient content of these materials. Contrasting this, pastoral livestock production systems make extensive use of ecosystem services and eliminate many of the problems associated with confined animal production systems. This does require a high level of management to prevent a decline in the vital ecosystem services of rangelands. When appropriately stocked and managed, grassland-ruminant ecosystems are an efficient, sustainable method of producing high-quality protein with minimal environmental impacts (Tilman et al. 2002).

Nutrient management may take on new urgency as global supplies of phosphorus are depleted. Most of the world's farms do not have or do not receive adequate amounts of phosphate and the demand for P fertilizer is increasing. Projections of the life span of remaining P reserves range from 60 to 130 years (Dery and Anderson 2007); in 2007-2008, the price of phosphate rose 250% (Jung 2008). The key response to "peak phosphorus" is to recreate a cycle of nutrients by returning animal and human wastes to the soil.

Nutrient management is also significant in the context of mitigation of GHG emissions from agriculture. Agriculture is the major driver of changes in the nitrogen cycle. Increased use of nitrogen fertilizers results in N_2O flux to the atmosphere, as well as nitrogen pollution of aquatic ecosystems from agricultural fields and from animal wastes (Galloway et al. 2004). Nitrous oxide from soils is one of the main sources of GHG emissions from the agriculture sector in the developing countries of East Asia (including SE Asia), mainly associated with N fertilizers and manure (Smith et al. 2007). Recent studies (quoted in Howarth et al. 2009) indicate that approximately 4% of the nitrogen that human activity has introduced into the environment ends up as N_2O in the atmosphere. The IPCC assessment approach assumes that of nitrogen fertilizer inputs only 1% is emitted as N_2O, and may be significantly underestimating the contribution of N_2O to global warming.

Improvements in Water Management

Water and its efficient use are the key to future food security and economic growth in the region. Whilst the region may not be seen as suffering from water scarcity, difficulties in access and dry-season shortages already induce economic water scarcity and water use conflicts in some areas. Increasing demands from agriculture, urbanization and industrialization will place great pressure on maintaining river flow regimes that are essential for the maintenance of aquatic habitats. Agriculture will be required to play a role in improving efficiencies. Within the agriculture sector there are a range of approaches that would improve water use efficiencies and reduce the risks associated with drought stress (CA 2007; de Fraiture et al. 2007).

In devising strategies to improve future water management in the GMS, there are three important issues to be addressed. The first is to define and quantify the water resource, to understand the physical, social, political and economic drivers that determine water availability and access (including transboundary constraints) and the ways in which changing water availability and access affect food production, livelihoods and the environment. The second is to improve understanding of the impacts of climate change on runoff, infiltration and water availability. The third is to identify adaptive management strategies and trade-offs to balance changing water availability against increasing demands, in order to cope with uncertainty and change. Key components of adaptive management are water allocation strategies, development of appropriate water storage, and adoption of key policy instruments providing incentives to use water differently. Clearly, all of the above will require significant financial investments and a commitment by policymakers to change. This will not occur until water is valued and priced at an appropriate level.

The proportion of irrigated land varies from 7% of total cropland in Cambodia to 31% in Vietnam (World Bank 2009b) and all national governments see expansion of irrigation as an important priority for both for securing current production and reducing risks from climate change. For example, government programs in Myanmar have doubled the area under irrigation over the last 20 years to 1.4 Mha (UNDP 2006); and the Government of Cambodia aims to expand irrigated area by 20,000 ha per year to 25% of cropped area (MAFF and MOWRAM 2007). Irrigated agriculture predominates in the deltas and government policies generally aim to extend irrigation coverage to the plains and upland valleys.

However, significant areas of the plains and uplands may never be irrigable because of topographic, hydrologic or soil constraints: for example, FAO estimates that only 20% of total potential cropland in Cambodia is irrigable (MAFF and MOWRAM 2007). Thus a large proportion of croplands is likely to remain rain-fed, and it is essential that water management options for rain-fed agriculture are not neglected. According to MAFF and MOWRAM 2007, the Cambodian Strategy for Agriculture and Water (2006-2010) concluded that the

> "*introduction of improved water management technology for rain-fed agriculture would be more cost effective, more easily managed, and have more widespread benefits in the long run. It is not a question of one or the other approach, but of choosing where different technologies are appropriate, how their relative monetary and social benefits compare, and how to achieve equitable investments that benefit the whole rural population.*"

Improvement in Water Management in Rain-fed Systems

Rain-fed agriculture dominates production in the GMS. The majority of the wet-season rice crop is either rain-fed or has only limited supplementary irrigation (Mainuddin et al. 2008). Drought is the major risk in the plains and uplands, but rain-fed production in the deltas and floodplains is prone to risks from both floods and droughts: in the major Mekong floods of 2000, it is estimated that over 400,000 ha of rice were destroyed in Cambodia (MAFF 2009b) and 93,000 ha in Vietnam.[15]

[15] http://kaigan.civil.tohoku.ac.jp/~kazama/research/APD02.pdf

A range of technologies and practices for improving water management at the farm scale are loosely grouped as "agricultural water management (AWM)" technologies. These range from traditional techniques to modern innovations, and include (IWMI 2006):

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

Conservation farming approaches can increase production by reducing the risk of intermittent drought stress that is common to rain-fed production systems. Simple approaches to improving the quality of soils through the application of organic matter (waste materials) and/or inorganic natural minerals (clays) will have a positive impact on the water-holding capacity of soils and their nutrient-holding ability. Noble and Suzuki (2005) report typical yield increases of 30-100% in rain-fed, lowland and organically grown rice when soils were treated with bentonite clays in farmer-initiated field studies in Northeast Thailand. Reduced tillage, stubble mulching and other soil conservation practices that reduce evaporation from the soil surface also have a positive impact on the water storage capacity of soils. .

Water harvesting and small-scale water storage for supplementary irrigation in dry spells during flowering or grain-filling can significantly improve yield and reduce risk of crop failure (CA 2007). Small-scale water storage and irrigation systems permit flexibility for farmers to select diverse cropping systems with staggered planting dates that better suit the uncertainties in water availability from season to season, while the water storage ponds can provide additional income from fish culture (van der Mheen 1999). Small-scale water harvesting using on-farm storage has been successfully implemented in NE Thailand as part of the "integrated farming system" promoted by King Bhumipol (Setboonsarng and Gilman 2009) where ideally 30% of farm area is set aside for ponds for water storage used for irrigation and fish culture. In a study in Tamil Nadu, Jayanthi et al. (2000) found that integrated farming requires less water per unit of production than monocropping systems. IWMI (2006) reviewed a wide range of small-scale AWM technologies available for southern Africa, and concluded that when used appropriately they can provide substantial improvements in household food security and incomes, in a cost-effective manner. They stressed, however, that these approaches are highly specific for particular systems, and must be targeted to suit agroecosystem, soil, microclimate and social contexts.

Breeding drought-tolerant crop varieties that have high water use efficiencies will also contribute to yield increases in water-limiting environments. Trials of drought-tolerant rice varieties in Kampong Cham and Siem Reap in Cambodia increased yields from farmers' fields by 1.0 to1.6 t/ha (from 1.9 t/ha to 3.5 t/ha) compared to currently used varieties (CURE 2009). Similarly, submergence-tolerant varieties currently being introduced in India and the Philippines can significantly reduce crop losses due to flooding.[16]

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[16] http://www.irri.org/flood-proof-rice/

Improvement in Water Management in Irrigated Systems

A recent FAO study found that large- to medium-scale public irrigation systems are generally performing well below their potential (Mukherji et al. 2009; Facon 2007). Problems stem mainly from inappropriate design, operation and maintenance. Given the high level of existing and planned investment in irrigation infrastructure, improving the performance of these systems must be a high priority.

In many older irrigation systems in the GMS, water use is highly inefficient due to poor design of conveyance and application systems combined with a tendency to over-irrigate. Increased water use efficiencies can be achieved through upgrading distribution systems (channel lining, use of pipes) and the adoption of improved technologies such as drip and pivot irrigation, deficit irrigation and the production of wet-dry (aerobic) rice.

Intensification of cropping systems through both full and supplementary irrigation in the dry season is needed to realize the full value of irrigation infrastructure. Many systems were initially designed around rice production (e.g., low drainage requirements, inflexible scheduling), making it difficult for farmers to diversify into higher-value dry-season crops (MRC 2002). More flexible systems are needed to allow farmers greater control and autonomy of irrigation scheduling, thereby encouraging diversification of farming activities. In South Asia and China, there has been a massive shift to farmer-managed small-scale pumping, even in areas where public irrigation previously dominated—the "atomization" of irrigation (Mukherji et al. 2009). There is evidence of a similar shift in SE Asia with a rapid increase in the number of small pumps installed in Vietnam (>800,000 by 1999), Thailand (> 3 million by 1999) and even more recently in Cambodia (120,000 in 2006).[17]

Small-scale pumping often relies on groundwater sources, and there is a significant risk of unregulated overexploitation of groundwater, with potential impacts on linked surface water, particularly in the deltas and floodplains with highly connected groundwater and surface water which must be managed conjunctively to be sustainable. Groundwater currently accounts for only a small proportion of irrigation in the GMS, but its use is increasing and little is known about the size and sustainability of groundwater resources. Overpumping has already significantly degraded groundwater resources in several areas in Vietnam.[18] A comprehensive assessment of groundwater potential and use in the region is urgently needed.

If the risk of flooding of lowland areas increases as a result of climate change, it may be appropriate to shift the main cropping season to the dry season. This trend can already be seen in the Mekong Delta, where the traditional wet-season rice crop accounts for only 10% of total production, which is now dominated by two irrigated crops in spring and autumn.[19] Such a shift would require major investment in irrigation, but it may be an opportunity to implement new, more flexible approaches. In Bangladesh, tracts of flooded rice lands in low-lying areas that are no longer cultivated with deep-water rice, in favor of dry-season irrigated rice, are now under community-based management for floodplain fisheries during the monsoonal season (WorldFish Center 2007).

The inefficiency and low utilization of large- to medium-scale irrigation schemes are frequently attributed to failures in operation and management (Facon 2007; World Bank

[17] MAFF statistics 2006-07

[18] http://www.monre.gov.vn/MONRENET/default.aspx?tabid=255&idmid=&ItemID=66584

[19] http://www.gso.gov.vn/

2006; Mukherji et al. 2009). This is due to inadequate funding, training and technical support for agencies managing irrigation schemes, and to institutional failures where central bureaucracies and public-sector irrigation institutions have often lacked the structure and incentives to optimize productivity. The response has been for donors to encourage governments to hand over responsibility for managing irrigation back to farmers through Participatory Irrigation Management/Irrigation Management Transfer (PIM/IMT). However, based on a major review, Mukherji et al. (2009) concluded that "*In most of Asia, transferring management from bureaucratic irrigation systems to farmers' groups has neither significantly improved productivity, operation and management, nor has it produced other net benefits…. many experts now believe there is a need to look beyond conventional PIM/IMT.*" Suggested approaches include public-private partnerships for irrigation management, contracting out of management services, and unbundling of system management into smaller components.

In all surface water irrigated systems there is significant return flow that needs to be managed in a sustainable manner to prevent long-term negative impacts, as is evident in parts of Northeast Thailand. This water often contains high levels of dissolved salts, pesticides and minerals. There are a number of innovative approaches that include sequential biological concentration (SBC) that could be used to effectively utilize this otherwise problematic water thereby increasing water use efficiencies and adding an economic value to wastewater.

With the rapid urbanization in GMS countries, the role of urban wastewater within the agriculture sector in the region could hold significant potential in increasing water use efficiencies. This is an area that has not been promoted and one that holds significant implications for closing the nutrient cycle, reducing the costs associated with wastewater treatment plants and increasing water use efficiencies.

Environmental Flow Management

The significance of freshwater fisheries to both food security and the economies of the GMS countries means that maintaining the health of freshwater ecosystems which support the fisheries is a very important priority. River ecosystem health and associated environmental services deteriorate when natural flows of water, sediments and organic materials are substantially disrupted or modified, for example by damming or diversion. Hydropower development (see section on Hydropower Development) and diversion of water for agriculture (see section on *Improvement in Water Management in Irrigated Systems*) are placing increasing pressure on the riverine ecosystems of the GMS.

Definition of the magnitude and timing of flows needed to maintain a river in an ecologically acceptable condition (environmental flows or environmental water demand) has been the subject of extensive debate and study internationally (Arthington et al. 2006; Richter et al. 2006). A preliminary assessment of the environmental impacts of flow modification has been conducted for the Mekong (MRCS/IBFM 2006), but few studies have been carried out elsewhere in the GMS. However, methods have been developed for assessing and managing environmental flows where detailed hydroecological data are not available (Arthington et al. 2009; Smakhtin et al. 2007) and these methods can provide the basis for adaptive management programs until more comprehensive studies are available. There is an urgent need to incorporate these approaches into water resources planning before extensive developments are undertaken to prevent degradation of fisheries and other environmental services observed in other parts of the world (World Commission on Dams 2000).

Protecting and Restoring Ecosystem Services

Agriculture is essentially a means of concentrating and enhancing provisioning aspects of ecosystem services but this can often come at the cost of other functions, particularly regulating services which are intimately related to land cover. For example, deforestation reduces the ability to regulate erosion; loss of wetlands reduces the ability of streams to regulate floods and water quality; clearance of mangroves reduces the ability to regulate storm impacts. Landscapes can be modified to protect or enhance a specific ecosystem service, for example, afforestation in watersheds to prevent erosion and improve water quality; man-made wetlands for sewage treatment; restoring environmental flows in rivers to preserve aquatic ecosystems (see previous section on *Environmental Flow Management*); and construction of man-made reefs and replanting of mangroves to mitigate storm damage in coastal zones.

The challenge is to create productive agroecosystems that maintain and enhance a range of ecosystem services. Traditional agricultural systems provide some remarkable examples of high-functioning agroecosystems, including the subak system of rice cultivation in Bali, where coordination of planting and irrigation in a district maximizes water use efficiency, improves pest control, and provides important social and cultural values; and the dehesa/montado savannah grasslands of Portugal and southern Spain which combine grazing of cattle and cultivation of cork oaks in a drought-resistant system, which supports very high levels of biodiversity.

In many cases, this can best be achieved by mimicking aspects of natural systems (LeFroy et al. 1999); Paddy fields mimic the water retention of natural wetlands to provide multiple benefits including rice and fish production, flood mitigation, groundwater recharge, soil erosion control and water purification (Foley et al. 2005; CA 2007). Plantations can mimic natural forests, with a well-developed understory to prevent soil erosion, provide habitats and promote biodiversity.

Landscape management of food-producing systems as an integrated unit holds significant potential in addressing some of the negative consequences of our current production systems. For example, the strategic establishment of buffer strips of trees and shrubs within the landscape (watershed) will reduce erosion and nutrient losses from production fields; buffer zones of natural vegetation along streams and rivers will decrease sediment discharge and provide habitats for a range of important fauna and flora. There is an urgent need to develop functional planning approaches to watershed management that will deliver ecosystem services along with sustainable food production.

It is important that actions to preserve and improve the quality of ecosystem services enhance, rather than compete with, livelihoods of the rural poor either directly, through improvements in local environments and production, or indirectly through financial compensation or payments for ecosystem services.

Mitigation of GHG Emissions from Agriculture

At the national to local level the focus of responses to climate change in the agriculture sector is primarily on adaptation to protect productive capacity and livelihoods by building more resilient systems. In contrast, at the international level, much of the focus has been on mitigation of climate change using natural systems to reduce emissions or increase storage of GHG. These two are not directly aligned, but neither are they necessarily in conflict, and finding synergies between the two should be a priority.

Mitigation of climate change through agriculture and land management represents a particular—and very important—case of ecosystem service provision. Carbon sequestration and regulation of nutrient fluxes have been compromised by agricultural development, with resulting large increases in GHG emissions, so that agriculture is a major contributor of GHG emissions in many developing economies. Agriculture and land management could thus play a correspondingly large part in mitigation efforts (Smith et al. 2007; World Bank 2008; ADB 2009a). The section on Responding to Climate Change outlines changes in land use and agricultural management that could restore and enhance the capacity of agroecosystems to regulate GHGs and mitigate climate change. In many cases, there is a high degree of synergy: adoption of mitigation practices will enhance adaptation and other environmental outcomes, and vice versa (Table 3.3).

The Kyoto Protocol and the Clean Development Mechanism (CDM) formalized the agreement that the developed world would provide financial incentives for mitigation in the developing world, to promote sustainable development. While agriculture (excluding agroforestry) is not currently considered under the CDM, there is increasing recognition that similar financial mechanisms are required to drive change in land use. The World Development Report 2008: Agriculture for Development (World Bank 2008) concluded that

> *"As a major source of greenhouse gas (GHG) emissions, agriculture also has much untapped potential to reduce emissions through reduced deforestation and changes in land use and agricultural practices. But for this to be achieved, the current global carbon financing mechanism needs to change."*

Improving Livelihoods for the Rural Poor

A key component of building resilience in agricultural systems is improving livelihoods for small-scale farmers and fishers who make up the bulk of rural communities and constitute the majority of rural producers. Rural communities are operating in a rapidly changing environment, described by Rauch (2009) as the "new rurality," characterized by the following:

- Changing-markets, driven by the global economy.
- Changing-livelihoods, with increasing opportunities and need for off-farm income.
- Increased production risks due to changing climate.
- Changing-institutions, with decentralization of government roles and increasing importance of community organizations and the private sector.
- Depletion of natural resources and insecurity of tenure/access.

While there is considerable uncertainty about the impacts of climate change, there is little doubt that its effects will be felt most strongly by the poor. Impacts of climate change on the habitats that marginal producers depend on will further exacerbate their livelihood insecurity stemming from historical neglect and discrimination. This underscores the gravity of their vulnerability to the cumulative impacts of climate and other anthropogenic activities that degrade the natural resources.

Most smallholders have limited capital and assets, and so are vulnerable to extreme events such as droughts and floods; and their level of food insecurity is high. As a result, their strategies to deal with change tend to be risk-averse: diversification, low input production, and reliance on social networks (Friend et al. 2006). Key components for improving rural livelihoods are focused on reducing risk, with particular attention given to disadvantaged groups such as women, children and the elderly (Brody et al. 2008), and include the following (Rauch 2009; Resurreccion et al; 2008):

- Secure access to natural resources: security of tenure for land, water rights, and common property access rights for forests, wetlands, rivers and lakes.
- Diversification of production systems to spread risk of losses (mixed crop-livestock-aquacultural systems).
- Improved agricultural technologies to boost production.
- Access to transparent and competitive markets.
- Rural off-farm employment and enterprise development to supplement agricultural income.
- Financial safety nets to mitigate risk: access to credit; crop insurance and crop mortgages.
- Emergency food and nutrition programs.
- Disaster-preparedness programs to mitigate risks from floods, cyclones and droughts.

Fish have particular advantages in coping with climatic and market uncertainty, since they have the unique feature of being amenable to intermittent harvesting. Fish do not age or over-ripen in the sense that they have to be harvested before they get too old or decay. Although an aquacultural enterprise may have its peak in the production cycle, fish may be left to live until there is need for food, or prices are high enough; hence, a fish farmer is not forced to sell his crop. This flexibility provides an advantage in the case of transitory food insecurity as well as market timing to boost household income during lean months. Increased flood events in low-lying riverine and deltaic plains make wild fish populations available as a common resource which, if judiciously managed, can provide access of the rural poor to an important protein source using a range of fish capture to culture activities including traditional fish-aggregating devices and floating beds that the landless can cultivate on while aggregating fish below (such as the *dhap* system practiced in Bangladesh). Different modes of community-based floodplain fisheries management that empower the poor and landless, successfully implemented elsewhere such as in Bangladesh, can be adapted for the specific conditions in the target region.

At the national level, promoting economic growth from agriculture must remain an important component of rural poverty-reduction strategies. The World Development Report (World Bank 2008) reported that economic growth in agriculture benefits the poor proportionally more than growth in other sectors. In addition, agriculture serves as an employment safety net in absorbing surplus urban labor in a reverse urban-rural migration at times of regional and global economic downturns (e.g., the Asian financial crisis in the late 1990s, and presently). Economic growth in rural areas can be promoted by the following:

- *Investing in rural infrastructure* including roads, markets, electrification/energy supply, aquacultural production systems and irrigation.
- Promotion of *agroindustries* such as food processing, to increase the value of agricultural production and providing alternative rural employment.
- Improving the capacity of the rural populations to *diversify their livelihoods* and providing opportunities for different needs groups.
- *Improving access to markets*.

6. Implementing Change in Agriculture

The goal of sustainable agriculture is to maximize both the net benefits that society receives from agricultural production and the services provided by ecosystems. Current production in the region does not meet these goals and hence there is a need to reengineer agricultural systems to deliver greater social and environmental benefits as well as meeting demands for food security and production. At the technical level, a great deal is already known about how agricultural systems need to change to achieve this (See sections on Other Drivers of Agricultural Change and Rethinking Agriculture in the GMS). The difficulty lies not in what should be done, but in how to do it, and who will do it.

Mechanisms for Change

Much of the change required to reengineer agricultural production can only be effected at the farm scale by individual producers. Thus it is essential to find ways to enhance the ability of individuals and communities to adopt more sustainable practices. Mechanisms for promoting changes in land management have been the subject of much debate (see, for example, Rauch 2009; Wunder 2008) and range from direct "command and control" approaches to market mechanisms and education, including the following:

Government interventions

- Policies (e.g., policies in all countries to eradicate shifting cultivation).
- Legislation (e.g., mandating environmental impact assessments for changes in land use).
- Zoning of land use (e.g., zone around Bangkok where intensive poultry farming is forbidden; protection of water supply catchments).
- Regulations mandating or prohibiting particular practices (e.g., prohibition on cultivating land at slopes above 20 degrees in Yunnan).

Financial mechanisms

- Tariffs and taxes (e.g., tariffs on pesticide use to discourage unnecessary use).
- Subsidies (e.g., the Thai government subsidies for irrigation of sugarcane and for fertilizers or irrigation to encourage uptake).
- Access to finance (e.g., micro-credit, community banks).
- Contributions in cash or kind for initial costs for adopting new practices (e.g., Yunnan government provided materials and labor to establish terracing for upland rice).
- Incentive payments such as payment for ecosystem services and benefit sharing (e.g., payments for tree planting in water supply catchments in Yunnan and to reestablish forests in Vietnam).
- Trade mechanisms such as quality standards (e.g., limits on pesticides in aquacultural products) and certification and ecolabeling programs (e.g., sustainable timber) (Shaw et al. 2007).
- Market mechanisms and consumer demand (e.g., organic produce).
- Insurance schemes to decrease risk on uptake of new practices.

Information

- Agricultural extension and advisory services, and demonstration projects for new techniques.
- Participatory implementation, farmer to farmer education programs.
- Incorporation of local knowledge into research findings.
- Improving access to information, e.g., real-time climate data for early warning and agronomic planning.

Noble et al. (2006) examined factors affecting adoption of new sustainable agricultural practices and technologies and found that the most important drivers were quick and tangible outcomes, innovative and appropriate technology and a participatory approach to implementation. In addition, they identified the need for an external priming agent, to facilitate new technologies through financial and nonfinancial contributions.

Consumer preferences and market forces can also be significant drivers of agricultural production: for example, increasing demand for meat and dairy products in the region has resulted in a rapid increase in livestock herds. These forces can be harnessed to lead change in production systems. This approach has been widely adopted in the forestry sector using certification and ecolabeling programs and marketing campaigns for sustainably harvested timber (Rosander 2008), but success depends on building market demand. Experience with timber suggests that "certified timber products are only successful in certain environmentally conscious markets."[20] So building consumer awareness is essential and different approaches are required for domestic and export markets. In Cambodia, the Centre for Study and Development in Agriculture (CEDAC) is working with farmers to establish and certify organic production and to develop domestic and export markets for Cambodian organic rice.[21,22] Products such as Cambodian pepper and Lao PDR coffee are establishing niche export markets, capitalizing on the "green" image of low-input traditional farming systems. In the short term, consumer pressure for more sustainable production methods is more likely to come from the international consumer movements than from local demand in GMS countries (where the focus is on producing more food at affordable prices). An example is international pressure from export markets for more environmentally friendly shrimp farming in Thailand and Vietnam, forcing the adoption of international codes of practice.

In many cases, governments can only play a facilitating and enabling role in adaptation at the local level (Resurreccion et al. 2008). It is critical to build adaptive capacity in communities by creating the information, social structures and supportive governance needed to support effective adaptation and reduce vulnerability to unpredictable or unforeseen impacts and changes (UKCIP 2009; Daw et al. 2009).

Under the UNFCCC, the main focus in promoting adaptation to climate change has been on policy, and the formulation of National Plans for Adaptation (NAPAs; see below). In relation to mitigation, the Clean Development Mechanism of the Kyoto Protocol, and more recently the REDD scheme, are establishing markets for carbon credits from land use changes relating to forestry (Angelsen 2008). However, agriculture (apart from agroforestry) is excluded from the CDM and REDD.

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[20] http://rainforests.mongabay.com/1010.htm
[21] http://www.phnompenhpost.com/index.php/2009062926772/Business/CEDAC-due-to-ship-its-first-batch-of-organic-brown-rice.html
[22] http://www.avantageventures.com/avcatalogue/sv-cedac-social-enterprise

The World Bank is currently funding a program on the economics of adaptation to climate change (EACC), using case studies in nine countries including Vietnam. In addition to helping decision makers in developing countries to integrate adaptation strategies into their development plans and budgets, the program aims to develop a global estimate of adaptation costs to inform the international community's efforts, including UNFCCC and the Bali Action Plan, to provide access to adequate, predictable, and sustainable support, and to provide new and additional resources to help the most vulnerable developing countries meet adaptation costs (World Bank 2009c).

There is increasing recognition that land and water management are critical elements of both adaptation and mitigation to climate change, and that agricultural and other land and water management practices that provide mitigation and/or adaptation benefits should be eligible for financial support in the same way that forest-related changes are promoted through REDD and the CDM.[23] This is a particularly important principle in a context where changes in land use practice are sought from poor farmers whose livelihood options are limited.

This principle applies beyond climate change; clearly, there is a need for appropriate incentives for adoption of sustainable farming practices and provision of ecosystem services other than carbon sequestration. There are numerous examples in developed countries of incentives and policies that can lead to adoption of sustainable farming practices. For example, in the United States, the Conservation Reserve Program (CRP) pays farmers to take land out of production for a specified period. Innovative approaches to financing are needed, drawing on the experience gained with payment for environmental services (Wunder 2008;; Planchon et al. 2008), benefit sharing (White et al. 2008; Noble 2009) and other pro-poor conservation financing. Many of the environmental problems and ecosystem services desired are difficult to monitor and quantify. Rather than basing incentive payments on environmental performance itself, proxies for performance such as the adoption of auditable practices may be more appropriate.

Making the right decision is becoming an increasingly knowledge-intensive task at both policy and farm levels. Governments and farmers will need to rely on a rapidly expanding base of context-specific biological and agronomic knowledge and good practices. Producers in the region have always lived with climate variability, and innovations that build upon local and indigenous practices, combining modern knowledge with sound ecological principles, need to be researched as a means to enhance adaptive capacity. Information for local adaptation, including real-time climate data for early warning and agronomic planning, must be considered a public good to be shared at all levels. Information needs to be effectively communicated and deployed through communities of knowledge formed among local universities, local/meso-level government units, NGOs involved in rural development, civil society and the private sector in order to reach and benefit larger numbers of people.

Agriculture in the National Climate Change Adaptation Strategies

Food security is usually presented as the preeminent issue in the country adaptation strategies. The way the NAPA was formulated for climate change by the Governments of Cambodia (MoE 2005), Lao PDR (WREA 2008), and Vietnam (MoNRE 2008) with a strong focus on agriculture and water resources brings into light the way countries view food

[23] Draft Guiding Principles, Dialogue on Adaptation to Climate Change for Land and Water Management, Danish Ministry of Foreign Affairs and Partners,

security, primarily from the perspective of food production (Ludi and Bird 2007). Thailand does not have a formal NAPA but, its research focus on the climate-change adaptation strategy at national, provincial and village levels put strong emphasis on food production, namely how climate change will impact rice production. In this context, the strategy to ensure food security is focused on increasing adaptive capacity of agroecological zones significant for the country's rice production.

The question remains whether focusing on adaptive capacity of agroecological zones is enough to sustain long-term food availability in relation to impacts of climate change. Put differently, to what extent can the countries improve their resilience and thus better adapt to climate change by fine-tuning their focus on food production with other dimensions of food security in terms of equal distribution of food, reliable food supply, and effective food utilization (consumption pattern) in their adaptation strategy? Theoretically, countries can reduce the maximum level of their food production target if they can recalculate the actual amount of food demands through introduction of measures to change the existing pattern of food consumption. Similarly, in theory, countries can encourage farmers to produce food more effectively, if they can change the actual pattern of food distribution through reformulation of food price mechanisms.

The extent to which countries can link the different dimensions of food security as their means to reduce the possibility of further environment degradation due to pressures to increase food production is an issue that needs to be addressed in the overall formulation and implementation of the adaptation strategy at the country level. There is a need to align environmental strategies with agriculture and water resources policies. While these strategies (such as payment for environmental services and other incentives) are defined to protect the environment, such an attempt can only have optimum impact if it is linked and incorporated into the overall government agriculture and water resources national policies. This incorporation plays an important role not only for possible upscaling of these strategies from local to national level, but also for synergizing strategies of national governments at the regional level.

While the issue of food security is not new in the development context, the global focus on climate change has opened up opportunities and mechanisms for long-term planning and management which can potentially promote sectoral integration. Opportunities for sectoral integration emerge with the fact that there are no defined boundaries between climate-specific and non-climate-specific adaptations. Regardless of its global scale and coverage, climate change is only one of the factors challenging the agricultural development pattern of countries. At the country level, opportunities for sectoral integration become evident in the way measures to cope with climate change involve and relate almost all sectors in the country's development. In Cambodia and Vietnam, government attempts to promote sectoral integration through their NAPA to climate change is most evidenced from the way they propose to combine both sectoral and agroecological parameters in the formulation of their adaptation strategy. In Lao PDR, government promotes sectoral integration through the formulation of cross-sectoral priority projects. In addition, all these three countries attempt to mainstream climate change programs into the countries' existing development plans. In Vietnam, the government's attempt to use climate change as its cross-sectoral umbrella program is most apparent from the way the NAPA strategy involves different sectoral ministries for both program formulation and implementation.

However, whether this planned sectoral integration is feasible operationally remains uncertain. The proposed sectoral integration challenges the very existence of government ministries with regard to their sectoral importance in relation to their decision-making authority and access to funding. With reference to the formulated NAPA, the countries still do not have a clear idea of how they will integrate their sectoral development activities in relation to climate change despite their concerted attempt to promote sectoral integration.

The Vietnamese NAPA (MoNRE 2008) appoints some government ministries to be in charge of each proposed project. For instance, MoNRE is responsible for the development and application of action plans to respond to climate change, in coordination with the Ministry of Planning and Investment (MPI). Yet, it is unclear how the action plans will be translated or mainstreamed into the different sectoral ministries. Besides, it was stated in the NAPA that all ministries are responsible for further international cooperation. Yet, it is unclear how each ministry's role and connection in international cooperation will result in integrated climate change adaptation programs. Similarly, the way the defined action plans for sectoral integration will shape each sector's relation in international cooperation remains opaque.

At the project level, the NAPA, defined by the Government of Cambodia (MoE 2005), does not clarify how it will link the proposed cross-sectoral and sectoral-focused activities. It is also unclear from the NAPA report whether sectoral project activities are supposed to be incorporated into the cross-sectoral projects. The high level of generality in the proposed cross-sectoral projects disconnects these projects with potential and actual problems related to climate change as encountered by sectoral agencies, and thus to a certain extent to the reality on the ground. For instance, the way the proposed project on vegetation planting for flood and windstorm protection will be able to uniformly address problems faced by the different sector agencies due to increased variability in the occurrence of floods and droughts remains questionable. Similarly, the way the proposed cross-sectoral project on strengthening of community disaster preparedness and response capacity is going to be conducted in relation to sectoral importance and its development linkages remains obscure. Consequently, the five proposed cross-sectoral projects on climate change lack the potential to promote interministerial, cross-sectoral cooperation on climate change. In theory, the proposed cross-sectoral projects can be implemented without necessarily integrating the relevant sector agencies.

Nevertheless, the way the Government of Lao PDR (WREA 2008) has transformed the country's strategy from climate change adaptation to disaster management highlights the potential of climate change programs in ensuring sectoral cooperation and coordination both horizontally (between ministries) and vertically (between different administrative levels). Yet, whether this potential can be translated into the country's long-term adaptation plan to climate change prior to the occurrence of natural hazards or whether such potential can be developed towards sectoral integration remains highly speculative.

An essential element in building the potential for sectoral integration is the way national- and local-level adaptation strategies can be linked as means to improve the resilience of countries towards climate change. The prevailing view of adaptation to climate change as a linear process linking a specific impact with a planned response is oversimplistic and unrealistic, as adaptive responses are formulated in the context of a whole range of impacts and drivers at different administrative levels. Hence, instead of choosing to downscale or upscale current strategies to cope with climate change should focus more on the possibility to jump-scale. In this context, local adaptation strategies can be used as a point of reference and starting point to initiate sectoral integration or revise the defined national strategy.

With reference to the current high level of uncertainty and limited knowledge on climate change in general and effective adaptation strategy in particular, recent endeavors to cope with climate change should put equal value and importance to both the role of science and technology and the role played by local communities in identifying local adaptation strategies at the farming system level. For instance, the identification of the local-level adaptation strategy is particularly useful in addressing the present ambiguity between climate change impact and non-climate-change impact. At the institutional level, the farming system level can be defined as the starting point to formulate the cross-sectoral adaptation strategy, focusing on the different typologies and characteristics of farming systems, rather than endlessly finding alternative way to promote sectoral integration from the national level.

Adaptation strategies will rely more on autonomous than planned adaptation due to the high level of uncertainty with regard to potential and actual impacts of climate change. In this context, the defined national strategy should be treated as the starting point for exploration, rather than a formal guideline for the countries to adapt to climate change. In this way, the question is not whether to upscale or downscale, but rather how to adapt relying on local, national, and regional (global) adaptive capacity. Put differently, instead of focusing on the uncertainty of climate change impact, we can take a step forward in assessing the local, national, and regional resilience to climate change.

Assuming that the local-national-regional linkages are decisive in shaping the actual significance of the climate change adaptation strategy, the challenge lies in the identification of key elements for the desired interconnection, and thus the creation of analogical space. For instance, the success of upscaling farmers' adaptation strategy lies primarily in the ability to find common characteristic between their particular farming system and the agroecological area, context, and sector where upscaling is desirable. Hence, the effectiveness of upscaling farmers' adaptation strategy to national-level policy formulation lies in the ability to connect their development interests (in relation to their farming ecosystems) with the country's development interest (in relation to its developmental carrying capacity).

In addition, the formulation of current adaptation strategies should link both public- and private-sectors organizations. The identified mechanisms for change require horizontal (inter-sectoral) and vertical integration (between the different administrative/agroecological levels), and also urge a stronger tie of cooperation between public- and private-sectors.

Sida/SENSA's Role in Climate Change and Agriculture in the Region

Sida/SENSA Policies and Programs in the GMS Region

Swedish development cooperation is guided by the 2003 Policy for Global Development, which has an overall goal "to contribute to an equitable and sustainable global development," with two perspectives permeating all actions: a rights perspective and a perspective of the poor. Historically, Sida's involvement in development assistance in the GMS dates back to the mid-1980s and it has always had a strong focus on poverty reduction, democratic governance and human rights, with an increasing emphasis on the environment and natural resources management in recent years. Over the last 10 years, bilateral programs with GMS countries included strong components on rural development, including rural roads (in Lao

PDR and Cambodia); local government in rural areas (Seila program in Cambodia); land titling (Cambodia and Vietnam); and sustainable land use and forestry in upland areas of Lao PDR and Vietnam. Sida has worked with governments to improve monitoring and research capabilities relating to environment and natural resources: Sida helped develop the Lao National Agriculture and Forestry Research Institute and has collaborative programs with the Environment Protection Agencies in Vietnam and China. While Sida's involvement in Myanmar is currently limited to humanitarian efforts and measures to combat HIV/AIDS, it is poised to intensify cooperation should the political situation improve, and has determined that a UNDP-sponsored rural development program would fall within the category of permissible interventions.

Bilateral country programs are currently being wound back in all countries except Cambodia, and the focus is shifting to a regional approach in areas where Sida can act as a catalyst and where Swedish aims and experience are particularly relevant. Environment and natural resource preservation have been identified as priority areas in the GMS, and climate change is emerging as an important area for regional cooperation. High priority is given to research, technical cooperation and dissemination of information (Sida 2005).

Sida actively pursues opportunities for cooperation and cofinancing with other donor countries, the UN system and the multilateral development banks through strategic alliances. Sweden's strengthened partnership with the ADB-GMS program is an important example.

Sida's strategy on climate change is for climate considerations to be integrated in all development cooperations, focusing on two primary aspects: contributing to a development that reduces GHG emissions, and mitigating the negative effects of climate change. In the agriculture sector, Sida's strategy is to improve and share knowledge on how climate change affects agriculture with particular emphasis on the links between water, agriculture, food security and overexploitation of natural resources (Sida 2008).

The Stockholm Environment Institute (SEI) has recently completed a scoping study for Sida on a Swedish International Agricultural Network Initiative (SIANI) (Larsen et al. 2009), which aims to promote effective development cooperation in the area of poverty reduction through sustainable agricultural production. SIANI will implement activities through strategic initiatives, dialogues on sustainable agriculture and network communication. The inception study identified four key issues for the network:

- Agricultural systems for the twenty-first century.
- Trade, markets and agricultural development.
- Reconciling multiple agendas in land use conflicts.
- Food safety and security.

SENSA's role is to monitor the environmental situation in the SE Asia region and disseminate information on regional environmental initiatives, trends and policies, to better understand how issues of key importance in Sweden's international commitment, such as climate change, consumption and production patterns, public participation and chemicals can be promoted (Sida-SENSA 2006). SENSA's main responsibility is to provide strategic advice to Sida and to support Sweden's involvement in the region, and to identify possibilities for transfer of Swedish experiences and expertise to meet the challenges in SE Asia. Geographically, SENSA covers all the countries of SE Asia plus the Chinese provinces of Yunnan and Guangxi, since these are included within the GMS. Priority themes (Sida-SENSA 2009) are the following:

- *Sustainable Mekong region* (including cooperation with MRC, ADB-GMS, Lancang Mekong Dialogue, ADB's Poverty and Environment Trust Fund and SUMERNET.
- *Environment and health* (chemical and waste management).
- *Natural resources degradation and livelihoods.*
- *Climate change adaptation* **(**SEI-SENSA-UNEP Climate Change Adaptation Knowledge Platform in Asia [CCAKP []; REDD; Mangroves for the Future; and tsunami recovery.
- *Environmental policy* (trade and environment; sustainable production and UNESCAP's "Green Growth" initiative; and cooperation with ASEAN).

The CCAKP has been established jointly with UNEP and the Stockholm Environment Institute (SEI) to build national and regional capacity to respond to climate change, and to expand multilateral, regional and national cooperation to address its transboundary implications (Chiang and Tsering 2009).

Regional Actors in Agriculture and Climate Change

A range of international organizations, financial institutions, donors, research agencies and NGOs are involved in shaping the regional adaptive measures for climate change; a similarly diverse group is involved in agricultural and rural development. Key regional actors in climate change and agriculture/water management space are listed in Table 6.1, with their primary functions and areas of interest. There is a degree of overlap between the two domains, although there are a limited number of regional organizations with a primary focus on both climate change and agriculture. In general, regionally, climate change initiatives tend to be dominated by environmental agencies, and this is reflected in their programs and concerns. Water and forest management have received more attention, but agriculture has, to a large extent, been missing from proposed adaptation and mitigation programs. Agricultural adaptation to climate change has generally been subsumed into general rural development and disaster management programs; and mitigation programs and financing are dominated by energy and forestry sectors.

Both climate change and agriculture have a strong regional dimension, since the issues and problems are common across national borders. Important regional roles include:

- Research and knowledge generation.
- Sharing and dissemination of information..
- Policy formulation and planning.
- Coordination of programs to prevent duplication and promote synergies.
- Presenting regional issues and concerns in international fora.

Engaging Regional Actors and Stakeholders

Sida-SENSA is well positioned to act as a champion at the regional level for an approach that explicitly recognizes the interaction between agriculture, climate change and environmental sustainability, and seeks to implement this in three areas:

- Research (building on existing links with local research institutes).
- Policy dialogue (building on and linking existing networks under SIANI and CCAKNP).
- Promoting investment in agricultural development to achieve climate change objectives.

Implementing mechanisms identified by Larsen et al. (2009) for SIANI are relevant to engaging partners in the GMS:

- Strategic initiatives: e.g., through targeted research and pilot programs.
- Policy dialogues.
- Network communication: through the CCAKP and SIANI.

Key research partners are the CGIAR centers, SEI and the MRC Climate Change Adaptation Initiative, all with strong existing programs in the areas of both agriculture/water and climate change.

Key target groups for policy discussions are the agencies funding major programs in agriculture and/or climate change in the region: The ADB, World Bank, FAO, International Fund for Agricultural Development (IFAD), ASEAN. Although ASEAN is involved in agriculture only peripherally, it could act as a very important platform for promoting agricultural change at the regional level, particularly through its involvement in agricultural trade.

Key implementation partners are agencies with significant investment in agricultural development in the region: FAO, IFAD and UNDP. The ADB-GMS Core Agriculture Support Program of ADB-GMS (CASP) program could be expanded, brought more into line with the ADB-GMS Core Environment Program and redesigned as a key agriculture-climate change program.

Table 6.1. Regional organizations involved in climate change and agriculture.

	Primary focus		Climate change strategy		Program component			
Organization	Climate change	Agriculture /water	Adaptation	Mitigation	Research	Policy	Programs	Outputs
Global Environmental Facility (GEF)/WB	√		√	√		√	√	NAPA preparation, monitoring and evaluation. Strong emphasis on food security issues and cross-sectoral development approach. US$500 million over 4 years, worldwide.
WB	√	√					√	Loans and grants for agricultural development: No active programs in Thailand or Myanmar. ~$180 m over 2004-2009 in Lao PDR, Cambodia and Vietnam.
MRC CCAI	√		√					Start in mid-2009. Tool development for climate adaptation planning for water, upscaling of local and national strategies, all stages in policy development process
MRC-START	√				√			Multiple climate scenarios for the region, downscaling of IPCC scenarios.
ADB-GMS Core Environment Program	√			√		√	√	Mainstreaming of climate change activities into the CEP's Biodiversity Conservation Corridors Initiative (BCI). Understanding of climate variability and its impact on adaptation strategies. Focus on measures to reduce emissions.
ADB-GMS CASP		√					√	Facilitating cross-border trade and investment in agriculture; agri-knowledge platforms; enhancing capacity in agricultural science and technology; mergency response mechanisms for agriculture. $25-35 million (2006-2010).
SEI-Asia	√	√	√	√	√			Range of agricultural and climate change research initiatives. Climate Change Platform, Water Evaluation and Planning System (WEAP) and the Climate Change Explorer.

	Primary focus		Climate change strategy		Program component			
Organization	Climate change	Agriculture /water	Adaptation	Mitigation	Research	Policy	Programs	Outputs
UNDP	√		√	√		√	√	Integrated climate change policies and action plans, linking climate change with poverty reduction; REDD (with FAP and UNEP). Sustainable energy systems, sustainable land use practices.
UNEP	√		√	√		√	√	Regional programs on clean energy, land use change (REDD); partner in Global Climate Change Adaptation Network.
WWF	√		√	√		√		Pilot climate vulnerability assessment; dialogue on climate change mitigation. WWF GMS is proposing to carry out climate change vulnerability assessment in the Greater Mekong.
IUCN	√		√		√	√		Research reports; establishment of climate change vulnerable community and adaptation initiative and task force (IUCN-IISD-SEI); development of planning tools and management strategies for climate change adaptation.
ACIAR		√	√		√			Research projects on agriculture for development. Proposed projects on climate change adaptation in Lao PDR and Thailand; food security in GMS.
CGIAR centers (IWMI, Worldfish, CIAT, Center for International Forestry Research [CIFOR])	√	√	√	√	√	√		Broadly based agricultural research and development programs. IWMI has worked with the ADAPT program: Water, Climate, Food and Environment under Climate Change: An Assessment of Global and Regional Impacts and the Formulation of Adaptation Strategies for River Basins. This global program had its regional focus on the Mekong basin countries assessing the impacts of climate variability and adaption strategies in each of the LMB countries.

	Primary focus		Climate change strategy		Program component			
Organization	Climate change	Agriculture /water	Adaptation	Mitigation	Research	Policy	Programs	Outputs
CGIAR Challenge Program on Climate Change	√	√	√	√	√	√		Challenge Program on Climate Change. Agriculture and Food Security Starts 2010. Aimed at overcoming the threats posed by a changing climate to achieving food security, enhancing livelihoods and improving environmental management in the developing world.
ASEAN						√	√	Climate change initiative under the Ministries of Environment. Singapore Declaration on Climate Change, Energy and the Environment (November 2007). Free trade agreements negotiated under ASEAN have had significant impacts on agricultural trade. Cooperation projects in the food, agriculture and forestry sectors.
FAO		√	√			√	√	FAO has between 30 and 45 projects active in each of the GMS countries. FAO promotes adaptation and mitigation in agriculture as an integral part of development. Implements the Special Program on Food Security (SPFS) to boost food production.
IFAD		√	√			√	√	Low-interest loans and direct assistance for projects on rural livelihoods and sustainable NRM ($328 m in Cambodia, Lao, Vietnam). No current projects in Thailand, Myanmar or Yunnan.

7. Knowledge Gaps, Conclusions and Recommendations

Knowledge Gaps and Research Priorities

The interactions between agricultural production, environment and climate change are complex and span a very wide range of scientific, social and economic issues. The knowledge gaps and priority areas for research presented are not comprehensive, but identify issues of particular relevance to the climate—agriculture—environment nexus. Thus we have not focused on production systems per se, but on production systems that provide environmental benefits; ecosystems that provide essential services for agriculture; and adaptation responses relevant to change from a range of drivers.

The key knowledge gaps identified during the study fall into four domains:

- *Improving climate change projections* to reduce the uncertainty around extent and direction of climate change and its impacts, and provide a sounder basis for adaptation planning.
- *Developing more productive agricultural systems* that are sustainable and resilient to change (both climate-related and others), and that retain and enhance the provision of ecosystem services including carbon sequestration.
- Building *resilient agricultural communities* capable of adapting to change.
- *Institutional and other mechanisms* for promoting uptake of sustainable production systems, and for ensuring that the links between agriculture, environment and climate change are acknowledged.

Across all these research domains, there are three important priorities. The first is that research should build from the regional knowledge base to provide locally specific solutions by optimizing existing techniques or refine information for particular agroecological zones or production systems. A considerable body of knowledge already exists from previous development programs in the region but one of the lessons from past experience is that although there are common themes and problems across the region, physical and cultural diversity is such that there are rarely "blanket" solutions. Scaling up and scaling out will require an understanding of regional diversity. This emphasizes the need to engage in, and build competence of, national research agencies and institutes as they are best positioned to carry out detailed local research and trials.

The second is that research should be adaptive, with a strong emphasis on monitoring and evaluation. New developments in information technology, physical and institutional infrastructure and the economic context mean that concepts and possibilities for agriculture and rural development are changing rapidly. As an example, planting of eucalypt for paper, promoted in Thailand and Vietnam in the 1980s, is now seen as an environmental issue rather than an option for promoting livelihoods. Ongoing adaptive research is essential to meet the needs of evolving communities.

The third priority is to ensure that the implications of research for policy and decision making are properly understood and that information is relevant and accessible at national and local/provincial scales. Policy dialogue networks such as CCAKP and

Swedish International Agricultural Network Initiative (SIANI) can play an important role in mediating and translating technical information for nontechnical audiences, and in assisting stakeholders to analyze the policy significance of emerging knowledge.

Improving Climate Change Projections

Improvements in our understanding of the extent, direction and impacts of climate change are critical to planning for all the dimensions of change. While other drivers may be more significant in the short term, changes in climate will be an important determinant of the long- term viability of planned responses. This is particularly important in the context of understanding the risks involved in investments to improve, extend or protect agricultural production systems (for example, establishment of long-term tree crops with a 20- to 30-year life span; or investment in flood protection works). The global focus on climate change has added a longer-term perspective to planning and investment but it is not possible to capitalize fully on this unless the degree of uncertainty in projections is improved.

Key issues for research include:

- Quantifying climate variability and its relation to climate change.
- Downscaling global/regional models to improve rainfall projections at the local level.
- Hydrological modeling to refine relationships between changes in rainfall and availability of surface water and distribution; this is particularly important in basins outside the Mekong, where very little information exists.
- Determining the interactions and cumulative effects of climate change and infrastructure (including hydropower) development on the Mekong hydrology and environmental flows affecting the flood pulse of the Tonle Sap and surrounding floodplains; and the ecological impacts on the flooded forests and native fish populations.
- Improving projections of impacts of flooding and sea-level rise in the deltas and other coastal areas.
- Synthesizing plausible future impact scenarios that identify the nature and extent of vulnerability of specific basins and coastal areas, to inform decision making and foster institutional planned adaptation within and across sectors.

Developing Productive Agricultural Systems

Future demands on agricultural systems in the region will require a radical reorientation with a stronger focus not only on production but also on sustainability and provision of ecosystem services, including carbon sequestration and other regulating services. This is essential if the productivity of agricultural systems is to be maintained and enhanced—degradation of the underlying ecosystems could seriously undermine agricultural productivity. Critical knowledge gaps and priorities for research include:

- Landscape approaches to inter-sectoral agricultural planning to sustain ecosystem services.

- Land suitability assessments (taking into account social, economic and equity issues as well as climate change) for land use changes, particularly opening up of new agricultural areas.
- Integration of environmental flow requirements into water resources development plans.
- Quantifying and enhancing carbon sequestration in agricultural systems.
- Minimizing the impacts of agricultural intensification, including closing the nitrogen cycle.
- Improving fish feed formulations and feeding practices to reduce dependence of aquaculture on, and polluting effects of, the use of trash fish.
- Promoting biogas technology at different scales—domestic, community to municipal—as a means of harnessing methane from livestock wastes and reducing dependence on firewood and other fuels.
- Irrigation—hydropower interactions: opportunities, risks, and planning requirements.
- Assessment of extent and sustainability of groundwater resources and the degree of connectivity with surface water.
- Assessment of water management options in the plains—irrigation vs. rain-fed production, diversified storage.
- Improving water productivity through:
    - multiple water-use agricultural systems—integration of crop, livestock and fish production, which also serves to hedge farmers against uncertainty and risk.
    - enhancing fish stocks of water bodies and innovating systems that span the capture-culture continuum based on indigenous species and practices.
- Urban and peri-urban agriculture: opportunities for wastewater reuse.

Building Resilient Agricultural Communities

The livelihood security of small-scale fishers and farmers, already operating in a rapidly changing social and economic context, is further threatened by climate change and other environmental stressors. Building the capacity of communities to adapt to change is an important priority for both climate change programs and rural development/poverty-alleviation efforts. In the long run, building adaptive capacity can reduce vulnerability to a wide variety of impacts, many of which are largely unpredictable or unforeseen.

A key role of the governments of the GMS countries is to provide the enabling conditions—through information and knowledge networks, appropriate governance structures and technical skills—for communities and individuals to enhance their adaptive capacity, with particular attention given to the most vulnerable—women, children and the elderly included. Research is needed to identify opportunities arising from the "new rurality" to diversify options, including strengthening the capacity to retain rural livelihoods, or strategies for enabling transition to alternatives.

- Diversified livelihoods—opportunities for off-farm income.
- Analysis of rural-urban interactions (goods, labor, capital) and impacts of urban development on rural communities.
- Disaster-preparedness programs targeted specifically at the agriculture sector.
    - Early weather warning systems that effectively communicate with, and promptly reach, rural communities.
    - Storm- and flood-proofing structures and installations used in agriculture, e.g., grain storage silos, fishing harbors and landing sites.
    - Crop/production insurance mechanisms for the poorest and most vulnerable to reduce risks associated with climate variability.
- Analysis of past and current adaptation by communities to provide feasible adaptations acceptable to local people.
- Participatory approaches to land and water management.
- Securing access and tenure to, and community-based management of, common property resources, particularly the water and fisheries resources of floodplains.

Institutions and Mechanisms for Change

In this region, where the majority of agricultural production is from semi-subsistence smallholders, change in agricultural systems must ultimately come through small-scale producers implementing different practices. This necessitates working across a range of scales: to inform and influence policy and governance that would enable both planned and autonomous adaptation; to develop and disseminate appropriate technologies and information; and to provide institutions at the local level to support and enhance adaptive responses of farmers or communities. Innovative financial and nonfinancial incentive mechanisms are essential to kick-start change, and to offset or redirect market pressures that encourage environmental degradation. These principles are already inherent in the climate change mitigation processes under the UNFCCC; equivalent measures for agriculture must be identified and implemented.

Key research areas include:

- Financial mechanisms for promoting sustainable land management (payment for environmental services and others).

- Harnessing trade and investment as a mechanism to promote sustainability; building on work underway in the International Institute for Sustainable Development (IISD).
- Investigation of market mechanisms for promoting sustainable agricultural production.
- Embedding agriculture in the UNFCCC process.
- Cross-sectoral assessment of adaptation and mitigation policies and strategies to ensure that strategies from one sector do not disadvantage vulnerable people in another.
- Seeking mechanisms (including incentives, technical assistance) that enable small-scale producers to comply with standards for food production and processing that are more environmentally friendly, such as the Code of Conduct

for Responsible Shrimp Aquacultural guidelines developed for Thailand and Vietnam and the *Hazard Analysis and Critical Control Points* (*HACCP*) standards for food safety.

- Promote market mechanisms and the role of the private sector in offering social protection, through microfinance (insurance, credit) to support agriculture-based livelihoods and buffer against sudden impoverishment in the face of increased extreme events and climate change. Particular attention should be given to how the poor and marginalized groups, including women, can benefit from such mechanisms.

Conclusions

Demographic, economic and social pressures have driven very rapid change in agricultural production systems over the last 20 years. Climate change is only one of a number of factors driving agricultural change, and in the next 20-30 years it is not likely to be the major driver; beyond that, major shifts in production may be required (although the level of uncertainty is very high). To a large extent, the degree to which countries, communities and production systems can adapt to more extreme climate changes beyond 2050 will be determined by how well they have learnt to adapt in the intervening period. The projected relatively slow pace of climate change in the region to 2050 provides an opportunity to reorient production systems to increase their resilience to more extreme climate-related changes beyond 2050, including sea-level rise in the highly productive deltas that currently supply the rice and fish for the majority of the regions.

The challenge facing agriculture in the region is how to produce more food, more sustainably in this context of rapid change; and how to build flexible, resilient production systems for the future. Global awareness of climate change has brought about an enhanced awareness of the fragility of natural systems and a new, longer-term perspective to national and regional planning, which presents an opportunity to radically rethink approaches to agricultural production.

The agriculture sector in the region is currently delivering food security and agricultural surpluses for export, but at high environmental cost and with limited impacts on alleviation of rural poverty. To meet future needs, it must be transformed to deliver not only food security under increasingly uncertain conditions but also environmental services (such as clean water and carbon sequestration) and economic security in rural areas from flexible, diverse systems able to withstand and respond to climate as well as other changes. At a technical level, a substantial amount is already known about how to bring about these changes. Conservation farming, improved water management, and improved agronomic and aquacultural practices have been demonstrated to alleviate the environmental degradation associated with current production, but effective application of these techniques is highly context-specific and adaptive research is needed to optimize production practices for particular agroecological systems. Opportunities exist for new landscape-based approaches to expand production while improving, rather than degrading, environmental services but these must also be tailored to specific land systems. A stronger focus is required on comprehensive land and water resources assessment, identifying critical habitats and ecosystem services, as the basis for planning and implementing change.

Implementing changes involves engaging both policymakers and producers. New mechanisms for promoting sustainable land use are needed, drawing on the experience from emerging financial models based on mitigation payments through schemes such as REDD, payment for environmental services and harnessing global trade to promote change. Reorienting agricultural production presents opportunities to work with rural producers to diversify and improve their livelihood options, and to build adaptive, resilient communities.

Recommendations

Sida-SENSA has positioned itself as a regional knowledge hub for environmentally sustainable development in the GMS region, with a particular focus on building institutional capacity and regional cooperation. There is a unique opportunity for Sida to promote a shift to more sustainable agricultural production systems, capitalizing on the current conjunction of rapidly changing, responsive agricultural economies; a new longer-term, regionally oriented planning perspective stemming from international awareness of climate change; and the "breathing space" of 20-30 years that projections suggest is available to the GMS region before radical changes in climate occur. By using this period to identify, pilot, implement and scale up measures to build more resilient communities, the GMS region will be well positioned to handle the more extreme changes predicted for the second half of the century—and more urgently, will alleviate current poverty and food insecurity. The commonality in agroecosystems and production issues across the region emphasize the importance of a regional approach, while the need for careful local targeting of measures provides an opportunity for Sida to increase dialogue internally between regional and country programs.

It is recommended that Sida-SENSA can contribute most effectively through targeted research programs leading to pilot implementation of new production modes; and by promoting understanding of the policy significance of emerging knowledge through regional dialogue and analysis. By working in close collaboration with national and regional research and management agencies to achieve these objectives, Sida can contribute to a third, equally important objective: building national and regional capacity to plan and manage sustainable agricultural production systems. Examples of priority projects in each arena are presented below.

Research and Pilot Implementation of New Agricultural Production Modes

a. *Provision of environmental services by agricultural systems: Regional options for mitigation of GHG emissions*

This major research program would focus on identifying and implementing approaches to mitigate GHG emissions from agriculture, as a working example of provision of environmental services by agricultural systems. The program would have three main dimensions:

- *A technical* dimension to identify land and water management options with significant potential to reduce GHG emissions, define the spatial domain in which they are relevant and quantify the potential mitigation gains (drawing on current research in CGIAR centers on options such as wet-dry rice; changes in livestock production to reduce methane; low-impact aquaculture, e.g., culture of mollusks, seaweed and spirulina; deep-rooted agroforestry [DROOPYS] and others).

- *Social/livelihoods* dimension to examine the changes in existing practices that would be needed to implement these approaches in existing systems, how this would impact on livelihoods and what incentives would be required to implement these changes, drawing on existing studies on incentives for adoption of sustainable practices (e.g., Payment for Environmental Services [PES] programs in CIFOR and CGIAR Challenge Program on Water and Food [CPWF]).
- *Institutional* dimension to assess and promote options for including agricultural systems under the UNFCCC processes, drawing on experience from the REDD program and from the current Dialogue on Adaptation to Climate Change for Land and Water Management.

The program would build from the very substantial body of research underway in the region in these areas, and would complement existing mitigation initiatives in the forestry sector. The first phase would identify agricultural production systems where mitigation of greenhouse gases can be validated and quantified. Pilot projects would be implemented based on these options, seeking external partners or markets to work with district or provincial authorities and communities to support changes in agricultural systems. By working initially in a context (mitigation of climate change) where the demand for environmental services is well established and there are at least some existing models for financing, it will be possible to identify mechanisms that can be used to promote environmental services from agriculture more broadly (outside the domain of climate change).

b. Redesign of rain-fed agriculture: Landscape approaches to agricultural planning

This project would develop landscape-scale approaches to agricultural land planning in the rain-fed areas, taking into account the interactions between agricultural production systems and environmental services.

Rain-fed production is both the largest agricultural system in the GMS in terms of area, and the system with the highest potential for productivity gains. Current levels of productivity are generally low, and research indicates that relatively simple measures (conservation farming, supplementary irrigation, crop diversification and managing soil fertility) could provide large gains in yields. Across the region, rapid change is already underway: new land is being brought into production, irrigated areas are expanding, and industrial crops and large-scale commercial agriculture are being adopted. These areas have high potential for agroindustries and agricultural employment, and their development will have important repercussions for economic growth and poverty reduction as well as for food security. But these are also areas where poor management in the past has resulted in serious degradation of land and water resources: soil erosion, fertility decline, deforestation and desertification. In many areas, small farm size, poor soils and uncertain rainfall constrain production options.

The objective is to optimize production systems based on existing land conditions and water availability while maintaining environmental integrity. Conventional land-suitability assessment would be extended to include landscape inventory identifying critical ecosystems and environmental services; and spatial analysis and mapping of water availability and demands, including environmental flow requirements and possible changes in availability due to climate change. Feasibility of options for water management (including both surface water and groundwater) in different zones will be assessed, drawing on methodologies currently being developed for South Asia and sub-Saharan Africa under a Gates Foundation project on "Agricultural Water Management Solutions."[24]

Pilot projects to implement inter-sectoral agricultural planning at the province or district level would be undertaken in collaboration with local authorities and research agencies, and would provide an opportunity to build local capacity in both research and planning. Pilot projects should target those areas where rapid land use change is either occurring or planned (for example, southern Lao PDR, northeast Cambodia, Myanmar's Dry Zone) and should encompass a range of rain-fed production systems, including extensive plantation agriculture as well as small-scale farming. This project could build on and complement current initiatives in land resource assessment and planning such as ADB's Lao PDR: Sustainable Natural Resources Management and Productivity Enhancement Project; [25] the Swiss Agency for Development and Corporation's major investment in agrobiodiversity in Lao PDR, "The Agrobiodiversity Initiative;"[26] and the proposed Cambodian government programs on land resource assessment and inventory under Program 4 of the Strategy on Agriculture and Water, coordinated by JICA and AFD (MAFF and MOWRAM 2007).

Policy Analysis and Dialogues

a. Roundtable on modeling the extent and direction of climate change in GMS

The very high degree of uncertainty around projections of climate change in the GMS region is a significant impediment to adaptation planning, and has resulted in the proliferation of reports addressing adaptation, which indiscriminately quote a range of sometimes contradictory worst-case projections as the basis for planning. This is particularly true for water availability, with projections ranging from significant increases to significant decreases in runoff and river flows, and hence in the incidence of floods and droughts. This information is critical to adaptation planning. The Sida-SEI-UNEP climate platform could very usefully initiate a technical roundtable on climate modeling in the region to provide a rigoros peer review and assessment of uncertainty in climate and related hydrological modeling in the region, and maintain (perhaps through the

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[24] http://awm-landscape.iwmi.org/
[25] http://www.adb.org/documents/dmfs/lao/37579-LAO-DMF.pdf
[26] http://www.swiss-cooperation.admin.ch/mekong/ressources/resource_en_172263.pdf

WEADAPT website http://www.weadapt.org/) an updated listing, review and assessment of regional studies as a resource for planners. IWMI is already undertaking aspects of such a review, and could provide technical capacity and support for this initiative. The recent Regional Technical Workshop on Application of Modelling Tools for Climate Change Impact and Vulnerability Assessment organized by MRC in Bangkok, Thailand on 8-9 September 2009 showed that the current models of impacts of climate change on the flow regime are not adequate, and more efforts in modeling are needed to expand the assessment to water use sectors, including agriculture.

b. Policy dialogue on agriculture in adaptation of climate change

A paradigm shift is needed in the way agricultural development is seen in the context of climate change in the GMS. Productive agricultural systems are the basis for reducing both poverty and vulnerability to climate change in rural areas: agricultural development should be seen as a proactive measure to increase adaptive capacity, not just a reactive measure to protect existing production systems. Agriculture needs a champion to bring it into the mainstream of the climate policy debate. Sida/SENSA, working through the CC Adaptive Knowledge Platform, could initiate a policy dialogue on agriculture and adaptation. This could draw on the resources of both the CCAKP and SIANI, and act as a catalyst for interaction between the two networks. The various CGIAR centers working with these sectors in the GMS can provide research support (for gathering information and evidence) and facilitator/"broker" roles. Consistent with the key issues identified for SIANI, the following policy-related elements could be included:

- A regional agricultural policy review focusing on building resilient food and agricultural systems for the twenty-first century that explicitly takes climate change impacts into consideration.
- A regional institutional assessment emphasizing new institutional configurations and governance arrangements that are more effectively multi-sectoral and inclusive, including an analysis of the role of ASEAN in promoting sustainable agriculture at the regional level.
- Institutionalizing a rights-based approach to climate change adaptation and mitigation in agriculture, with particular focus on rights of access to common resources.

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