Cambodia's
Second National Communication

Submitted under the United Nations Framework Convention on Climate Change

Ministry of Environment
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Foreword

Cambodia has been a Party to the United Nations Framework Convention on Climate Change (UNFCCC) since the ratification in December 1995. Its membership became official on 17 March 1996. Cambodia ratified the Kyoto Protocol in 2002, which entered into force in February 2005. The signing and ratification of the UNFCCC and the Kyoto Protocol by the Royal Government of Cambodia is testament to our commitment to fulfilling our obligations under the Convention. It also signifies that Cambodia is concerned about the impacts of climate change on its people and on their survival and development.

The most important objective of both treaties (UNFCCC and Kyoto Protocol) is to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system. An important pillar of the Climate Convention is the commitment of the Parties to take action to ensure a comprehensive response to climate change, taking into consideration their 'common but differentiated responsibilities' in line with the respective capabilities of countries. This is strengthened and reflected by the commitment of all Parties to submit to the Conference of the Parties (COP) National Communications under Articles 4 and 12 of the Convention.

Cambodia has taken relevant national measures: building our institutional capacity, formulating and implementing our Climate Change Strategic Plan for the next 10 years, mainstreaming climate change into planning and budgetary processes. Cambodia conducts pioneering work to build climate change financing and monitoring and evaluation frameworks, and implement actual measures to build community resilience and sustainable livelihoods.

Cambodia is one of the countries that has contributed the least to causing climate change; it is however one of the most vulnerable to climate change. Hence, Cambodia takes climate change seriously in its development agenda to support building a greener, low-carbon and climate-resilient, equitable, sustainable and knowledge-based society, while contributing to the global efforts to address climate change.

The Initial National Communication was submitted in October 2002. This Second National Communication has been prepared to fulfil Cambodia's commitments to the Convention. It contains the necessary information about the country's major sources of greenhouse gas emissions and sinks, vulnerability and adaptation options, together with the necessary mitigation measures that Cambodia has implemented, and will continue to implement, to adapt to climate change impacts and to further contribute to global efforts to reduce greenhouse gas emissions.

SAY Samal

Minister of Environment

Chair of the National Council for Sustainable Development

Table of Contents

List of Figures

List of Tables

Acronyms, Chemical Symbols and Scientific Units

ADB	Asian Development Bank
AFOLU	Agriculture, Forestry and Other Land Use
AR-CDM	Afforestation and Reforestation - Clean Development Mechanism
ASEAN	Association of Southeast Asian Nations
AWGCC	ASEAN Working Group on Climate Change
AWMS	Animal Waste Management System
BAU	Business as Usual
CAMCONTROL	Cambodia Import Export Inspection and Fraud Repression Department of the Ministry of Commerce
CCCA	Cambodia Climate Change Alliance
CCCO	Cambodia Climate Change Office
CCIM	Cambodian Centre for Independent Media
CCSR	Centre for Climate System Research
CCTT	Climate Change Technical Team
CCVI	Cambodian Climate Vulnerability Index
CD4CDM	Capacity Development for the Clean Development Mechanism
CDC	Council for the Development of Cambodia
CDHS	Cambodia Demographic and Health Survey
CDM	Clean Development Mechanism
CDRI	Cambodia Development Resource Institute
CER	Certified Emission Reduction
CGG	Cambodian Genocide Group
CH_4	Methane
CIPS	Cambodia Inter-censal Population Survey
CMDG	Cambodia Millennium Development Goal
CNMC	Cambodia National Mekong Committee
CO_2	Carbon Dioxide
CO_2-eq	Carbon Dioxide Equivalent
COP	Conference of the Parties
CRC	Cambodian Red Cross
CSIRO	Commonwealth Scientific and Industrial Research Organization
Danida	Danish International Development Agency
DAP	Diammonium phosphate
DAPH	Department of Animal Production and Health

DCC	Department of Climate Change
DNA	Designated National Authority
DoM	Department of Meteorology
DSSAT	Decision Support System for Agro-Technology Transfer
EDC	Electricité du Cambodge (Electricity of Cambodia)
EEZ	Exclusive Economic Zone
EIC	Economic Institute of Cambodia
ENCOFOR	Environmental and community-based framework for designing afforestation, reforestation and re-vegetation projects in the CDM
EU	European Union
FA	Forestry Administration
FAO	Food and Agriculture Organization of the UN
FAOSTAT	FAO Statistics
FCPF	Forest Carbon Partnership Facility
GCM	General Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GERES	Group for the Environment, Renewable Energy and Solidarity
Gg	Gigagram
GGGI	Global Green Growth Institute
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Organization for International Cooperation)
GMAC	Garment Manufacturers Association in Cambodia
GPG	Good Practice Guidance
GTZ	German Technical Cooperation Agency (GIZ)
GWh	Gigawatt hour
HDI	Human Development Index
HFP	Heavy Fuel Oil
HVAC	Heating, Ventilation and Air Conditioning
ICEM	International Centre for Environment Management
IFPRI	International Food Policy Research Institute
IGES	Institute for Global Environmental Strategies
ILO	International Labour Organization
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
ITC	Institute of Technology Cambodia

JICA	Japan International Cooperation Agency
JWRF	Japanese Waste Research Foundation
kton	kiloton
kWp	kilowatt peak
LGP	Length of Growing Period
LU	Livestock Unit
LUCF	Land Use Change and Forestry
LULUCF	Land Use, Land Use Change and Forestry
MAFF	Ministry of Agriculture, Forestry and Fisheries
MAGICC	Model for the Assessment of Greenhouse-gas Induced Climate Change
MEF	Ministry of Economy and Finance
Mha	Million hectare
MIME	Ministry of Industry, Mines and Energy
MoE	Ministry of Environment
MoH	Ministry of Health
MoP	Ministry of Planning
MoT	Ministry of Tourism
MoWRAM	Ministry of Water Resources and Meteorology
MPWT	Ministry of Public Works and Transport
MRC	Mekong River Commission
MRD	Ministry of Rural Development
MW	Megawatt
NAPA	National Adaptation Programme of Action
NBP	National Biodigester Programme
NCCC	National Climate Change Committee
NCDM	National Committee for Disaster Management
NCSD	National Council for Sustainable Development
NCSP	National Communications Support Programme of UNDP, UNEP and GEF
NEDO	New Energy and Industrial Technology Development Organization
NGO	Non-Governmental Organization
NIES	National Institute for Environmental Studies
NIS	National Institute of Statistics
NMVOC	Non-Methane Volatile Organic Compound
NO_2	Nitrous Oxide
NPK	Nitrate, Phosphate, Potassium

NPRS	National Poverty Reduction Strategy
NSDP	National Strategic Development Plan
ODA	Official Development Assistance
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PES	Payment for Environmental Services
PRECIS	Providing Regional Climates for Impacts Studies
REDD	Reducing Emissions from Deforestation and Forest Degradation
RGC	Royal Government of Cambodia
RTAVIS	Road Traffic Accident and Victim Information System
RUA	Royal University of Agriculture
RUPP	Royal University of Phnom Penh
SCENGEN	Scenario Generator
SEDP	Socio-Economic Development Plan
SHS	Solar Home Systems
SNAP	Strategic National Action Plan for Disaster Risk Reduction
SNC	Second National Communication
SRES	Special Report on Emission Scenarios
SRI	System of Rice Intensification
TSR	Technically Specified Rubber
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
US	United States
USA	United States of America
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VER	Voluntary Emission Reduction
WB	World Bank
WFP	World Food Programme
WGIA	Workshop on Greenhouse Gas Inventories in Asia
WRI	World Resources Institute
WTO	World Trade Organization

Executive Summary

Introduction

The Kingdom of Cambodia ratified, as a Non-Annex I Party, the UN Framework Convention on Climate Change (UNFCCC) in 1995 and acceded to the Kyoto Protocol in 2002. The Initial National Communication (INC) was officially submitted to the UNFCCC in 2002.

In 2006, the Royal Government of Cambodia (RGC) established the National Climate Change Committee (NCCC), a cross-sectoral and multi-disciplinary body with the mandate to prepare, coordinate and monitor the implementation of policies, strategies, legal instruments, plans and programmes related to climate change. With an amendment in 2014, the NCCC has functioned since its establishment as the inter-ministerial mechanism for coordination of climate change response in Cambodia. Its functions have recently been taken over by the establishment, in May 2015, of the National Council for Sustainable Development (NCSD). The Council comprises high-level representatives (Secretaries and Under-Secretaries of State) of concerned government ministries and agencies, with the Prime Minister as its Honorary Chair and the Minister of Environment as its Chair. Council membership has increased compared to NCCC, covering a greater number of ministries and agencies, and including provincial governors.

The RGC appointed the Ministry of Environment (MoE) as the Designated National Authority (DNA) for the Clean Development Mechanism (CDM) in July 2003, and established that same year, within MoE, the Cambodia Climate Change Office (CCCO), responsible for a wide range of climate change related activities: formulation of a draft climate change plan and policy, implementation of the UNFCCC, assessment of new technologies to adapt to the adverse effects of climate change or to mitigate greenhouse gas (GHG) emissions, capacity building and awareness raising. The office also served as the Secretariat of the UNFCCC, the Intergovernmental Panel on Climate Change (IPCC), the Kyoto Protocol and the CDM Focal Points for Cambodia. The RGC upgraded the status of CCCO from office to department (Department of Climate Change (DCC)) in October 2009 – a strong indication of the Government's commitment to strengthen climate change institutions in the country. The DCC, in addition to serving as part of the Secretariat for the NCCC, and currently the NCSD, acts as the Secretariat of the Cambodian DNA and has been actively promoting CDM projects in Cambodia.

The Second National Communication, presented herein, is organized in eight chapters, in accordance with articles 4 and 12 of the Convention, and presents information on the following aspects: national circumstances; national GHG inventory for the year 2000 and GHG emission projections; impacts and vulnerability to climate change; the situation with respect to the implementation of climate change response in the country, including measures to mitigate and adapt to climate change and related plans, programmes and projects in these areas; financial commitments, technology transfer and international cooperation; systematic research and observation; education, training and public awareness; and constraints, gaps and related financial, technical and capacity needs. The preparation of the report has been made possible by funding support from the Global Environment Facility (GEF).

National Circumstances

Geography

Cambodia occupies a total area of 181,035 km^2 and shares borders with Thailand, Lao PDR and Vietnam. The country's topography broadly consists of the central plains surrounded by mountainous and highland regions, and a 435 km coastline to the south. Phnom Penh, the capital city, is located in south-central Cambodia, at the confluence of the Mekong, Tonle Sap and Bassac Rivers. The Mekong River and its tributaries dominate the hydrology. The Tonle Sap Lake, an outlet of the Mekong during the rainy season, covers an area of up to 10,400 km^2 in the northwest.

Climate

Cambodia's tropical monsoon climate is characterized by a rainy season and a dry season. The rainy season, which lasts from May to early October, accounts for 90% of annual precipitation. The dry season, from November to April, brings drier and cooler air from November to March, and then hotter air in April and early May. The maximum mean temperature is about 28^{o}C and the minimum mean temperature about 22^{o}C. Maximum temperatures are common before the start of the rainy season and may rise to more than 38^{o}C. The average annual rainfall from 1994 to 2004 varied between 1,400 mm and 1,970 mm.

The geographical incidence of extreme weather events such as droughts and floods varies, and while floods affect lowlands areas, the geographical distribution of droughts is widespread. Though there are some actual benefits from the seasonal flooding experienced in the central plains, providing fish as well as nutrients to the soil, the frequency of severe floods has increased over the last decade. Storms occur more frequently between August and November, with the highest frequency in October. The country is rarely exposed to the full force of tropical cyclones and typhoons as it is surrounded by mountain chains, which dissipate a typhoon's force.

Population

The Cambodian population increased from 11.4 million in 1998 to 14.7 million in 2013. This corresponds to an annual growth rate of 1.46% in 2013 (NSDP 2014), which is among the highest in Southeast Asia. However, the population growth rate has been gradually declining from an estimated rate of 4% between 1981 and 1993 to the current rate of 1.46%. Between 1975 and 1979, an estimated 1.7 million Cambodians, out of a population of 8 million, lost their lives during the Khmer Rouge regime. The Cambodian population is young, with about 61% of people under 24 years of age in 2005. The sex ratio (number of males per 100 females) was very low (86) in 1980 due to male casualties during the Khmer Rouge regime, but this ratio has been increasing in later years, reaching 94.2 in 2008. More than 80% of Cambodians live in rural areas while 19.5% live in urban areas. Approximately 52% of the population live in the central plains, 30% around the Tonle Sap Lake, 11% in the highlands and mountainous areas, and 7% in coastal areas. In 2005, the national average population density was 75 people per square kilometre.

Poverty remains a serious social issue in Cambodia. Although poverty reduction continues to be a national imperative, Cambodia has made remarkable progress in the last two decades. It is set to achieve its Millennium Development Goal (MDG) poverty rate target of 19.5% by 2015, despite the upward revision of the poverty line in 2011, thus having succeeded in reducing by half the proportion of its people living below the poverty line.

As Cambodia has a tropical monsoon climate with marked rainy and dry seasons, the impacts of climate on human health are significant. Malaria and dengue fever are the prevailing mosquito-borne diseases. Malaria is a public health concern in Cambodia, while outbreaks of dengue fever have occurred from time to time, and it remains a major cause of childhood morbidity and mortality.

Economy and development

Cambodia's economy has grown steadily since the liberalization of its markets; the annual GDP growth rate from 1993 to 2004 averaged 9.7%, while per capita GDP averaged 6.5%. Based on a 2011 Economic Review of Cambodia, agriculture, fisheries and forestry accounted for 32% of GDP, industry 22%, services 38% and taxes on product 8%.

Industry has been a fastest growing sector in Cambodia's economy since early 1990s, increasing from 12.6% of GDP in 1993 to 26.2% in 2006, with an average annual growth rate of more than 15% over this period. Though suffering a short decline in late 2000s, industry growth rebounded and remained steady at approximately

22% of GDP. In terms of gross value added by sector in 2004 the textiles and manufacturing sub-sectors made significant contributions. Industry employs 8% of the labor force, far below agriculture, which employs 75%. The challenge for Cambodia's economy is to broaden the opportunities available to its increasing population, while diversifying beyond agriculture and the garment sector.

Tourism is the fastest growing sub-sector in services, and accounted for about 12% of GDP in 2011. International visitor arrivals have grown from about 118,000 people in 1993 to about 2.88 million people in 2011. Tourism expenditures have similarly increased from an estimated US$100 million in 1995 to US$1,912 million in 2011, and provide approximately 350,000 direct jobs.

Energy

Cambodia currently imports its entire consumption of petroleum products, which steadily increased from US$549 million in 1998 to US$691 million in 2004. Cambodia's first significant petroleum discovery was announced in January 2005. Oil and gas lie offshore within Cambodia's Exclusive Economic Zone. Oil and gas production have the potential to drastically transform Cambodia's economy, society and GHG emission characteristics.

Cambodia's renewable energy sources are abundant, however they remain largely untapped for electricity production. Biomass, the main cooking fuel for households, accounts for more than 80% of total national energy consumption. Commercial size hydropower projects have been in operation in Cambodia since 1968. In 2002, total installed capacity was about 14 MW, while Cambodia's technical potential for hydropower has been estimated at 8,600 to 10,000 MW for the Mekong River, the Mekong tributaries and the coastal provinces. Some recent studies pointed to even greater potential. At present, total installed hydropower capacity is more than 500 MW, with solar and wind power remaining limited in Cambodia.

Total electricity production in Cambodia amounted to 1,858 GWh in 2008, up from 107 GWh in 1991. Electricity imports from Thailand and Vietnam have rapidly increased, from 1.7 GWh in 1998 to 57 GWh in 2004. In 2004, only 14% of households had access to electricity, while 64% and 16% of households used kerosene and battery lighting respectively.

Agriculture

Cambodia's agriculture is predominantly rain-fed and characterized by low input, and moderate or low fertility land, thus making it dependent on weather conditions and changing climate. Rice is Cambodia's primary staple and provides approximately 70% of nutritional needs. Rice crops occupied 83% of the 3.22 Mha of harvested area. Four other food crops, namely corn, cassava, soybean and mung bean, occupy approximately 13%. The remaining 4% is used for growing vegetables, sesame, peanut, sugarcane, potato, tobacco and jute.

Animal husbandry has been traditionally practised at the household level in Cambodia. Cattle and buffalo provide most of the agricultural draught and manure for fertilizing crops, and constitute essential household assets. Many rural families raise pigs and chickens at the household level.

Low yields, coupled with natural disasters, contribute to temporary food shortages. Based on food availability, food access and food absorption, a mapping of food security has been conducted for the country. Seven of Cambodia 25 provinces (including Phnom Penh capital city), are classified as severely to extremely food insecure, and an additional seven moderately insecure.

Forestry

The Forest sector's contribution to GDP reached 5.4% in 1998, but declined to 1.9% in 2006. Forests play a significant role in traditional rural livelihoods, providing construction wood, fuel wood, food and medicine, as well as ensuring ecosystem functions such as watersheds, storm and coastline protection. Firewood remains the main source of energy for cooking for 91% of rural people. Cambodia's forest cover was estimated at 10.8 Mha or around 60% of the country's land area in 2006, down from 67% in 1985/87.

Some 25% of Cambodia's forests lie within a system of 23 protected areas. The 3.2 Mha of protected areas, including national parks, wildlife sanctuaries, protected landscapes, and multiple use areas, was established to conserve the country's biodiversity. Cambodia's protected areas have been under pressure from logging, forest conversion, illegal wildlife trade and mining. The system suffers from a lack of financial and technical resources, and inadequate law enforcement. The loss of dry land forest is mainly due to agricultural expansion, illegal logging and over-exploitation. Cambodia has set up a Cambodian forest carbon credit system through the implementation of a number of feasibility studies in protected areas and community forestry.

Fisheries

Cambodia's inland fisheries are among the most productive in the world and have traditionally played a significant role in rural livelihoods. Fish are an essential source of protein for rural people. Fish also supplements rice cultivation in terms of income generation. An estimated one million Cambodians depend on inland fisheries for their livelihoods. Cambodia's inland fisheries are directly affected by seasonal patterns of floods and droughts, and thus vulnerable to changing climate conditions. Despite its extensive coastline and exclusive economic zone, Cambodia's marine fisheries have traditionally not been as commercially exploited as inland fisheries.

Greenhouse gas inventory

The greenhouse gas inventory (GHG inventory) has been prepared using the IPCC guidelines, default emission factors and activity data from various sources. UNFCCC software was used to harmonize data, calculate emissions and compile tabular information. Many governmental and non-governmental organizations, as well as individual experts, took part in the GHG inventory process.

Cambodia's GHG emissions were estimated at 47,709 GgCO_2-eq in 2000, and removal at 48,383 GgCO_2-eq. The net removal was estimated at 674 GgCO_2-eq. Hence, Cambodia remained a net sink in the year 2000. In 1994, Cambodia was a net sink country able to offset approximately 5,142 GgCO_2-eq.

Energy

Based on the sectoral approach, total emissions are estimated at 2,767 GgCO_2-eq, in which Carbon Dioxide (CO_2) contributes approximately 74% of the total emissions, Methane (CH_4) contributes approximately 21% and Nitrous Dioxide (N_2O) contributes approximately 5% for this sector.

In terms of emission in CO_2 equivalent, the main source of GHG emission from the energy sector is the residential sub-sector, which accounts for 31%. This is due to the high use of biomass as fuel for cooking in households. The second contributor to national GHG emissions from fuel combustion is transportation (26%, mainly road transportation), followed by energy industries (14%) and manufacturing industries (12%).

Agriculture

In 2000, total emissions of the two main GHGs (CH_4 and N_2O) from this sector reached 21,112 GgCO_2-eq. CH_4 contributed to approximately 99% of total emissions, while N_2O contributed only 1%. Rice cultivation accounted for 68%, enteric fermentation for 16% and agricultural soils for 11%.

Land use change and forestry

The total emission of CO_2-eq from Forest and Grassland Conversion by burning above-ground biomass on-site and off-site is estimated at 22,859 Gg. However, at the same time, changes in forest and other woody biomass stocks and abandonment of managed lands absorbed 27,208 GgCO_2 and 20,958 GgCO_2 respectively, which resulted in a net sink of about 25,307 GgCO_2-eq in Land Use Change and Forestry (LUCF).

Waste

In Cambodia, solid waste disposal and wastewater handling are the main sources of methane emission, while human sewage is the main source of nitrous oxide. Total net emissions from the waste sector in the year 2000 were estimated at 229.24 $GgCO_2$-eq, of which methane contributed approximately 93% from solid waste disposal on land and wastewater handling, while N_2O contributed about 7%.

Programmes with measures to facilitate mitigation of climate change

Mitigation options

For each sector and fuel type a list of mitigation options was formulated based on previously successful projects, pilot projects, feasibility studies, literature reviews and expert opinion. These mitigation options were screened based on UNFCCC documentation (UNFCCC 2004) to determine the most viable options for Cambodia. The total amount of savings of emissions (in CO_2-eq) adds up to around 26% (from 2025 onwards); about 60% to be realized in the energy industry sector, with increasing energy efficiency as the most important measure.

Strategies and policy

Four short- to long-term strategies were developed to guide the implementation of mitigation options.

In the *short-term win-win strategy,* mitigation options include connecting battery charging stations, offices and companies to the national grid; and pico-hydro for which the costs are very low, but there are few suitable streams in Cambodia. The private sector can implement these options profitably but may not do so due to low awareness or limited investment finance. Dissemination of information and the linking of banks with the private sector are therefore required to facilitate uptake. Under this strategy it is estimated that 573 $GgCO_2$-eq can be saved per year in 2050.

The *extended short-term win-win carbon finance strategy* includes carbon finance. Several projects can apply for funds from the CDM. With carbon finance it is likely that the private sector will be incentivized to implement mitigation options such as solar grid power, rice husk for electricity generation, methane recovery, cement heat and power systems, combined electricity and cooling (HVAC) projects. The total saving in year 2050 could be 588 $GgCO_2$-eq per year or 2% compared to the baseline emissions.

In the *medium-term green growth support strategy*, options include solar home systems (SHS), mini and micro hydro, efficiency and technology improvement in main industrial sectors, fuel wood efficient technologies, solar lanterns, wind water pumping and charcoal briquettes from agricultural waste. The private sector is often reluctant to experiment with new technologies, but donor funding can provide information, training and funding for pilot projects that can trigger market acceptance. The medium-term green growth support strategy requires donor financing to drive the private sector towards investing in sustainable energy development or green growth. The total savings can add up to 1,385 $GgCO_2$-eq, or 6% compared to baseline emissions.

The *long-term green growth planning strategy* requires a mix of government planning, donor support, private sector involvement and carbon finance. The mitigation options include national grid extension planning and implementation, energy efficiency, methane recovery from hydro dams, efficient charcoal production, biofuel and transport mitigation options. Savings are not calculated for all mitigation options due to a lack of data. However, the options assessed can save 4,548 $GgCO_2$-eq per year in 2050 or an 18% reduction compared to the baseline.

Vulnerability and adaptation to climate change

For the Second National Communication (SNC), climate change impact and vulnerability were assessed for four sectors, namely agriculture (including water resources and focusing on rice production), forestry, coastal zones and human health. Adaptation options of each sector were proposed to address climate vulnerabilities.

Impact and vulnerability assessment

Under future climate conditions (2025 and 2050), most of Cambodia's agricultural areas will be exposed to higher drought risks. The growing period for most agricultural areas will be less than five months (between two and three months). Efforts to increase the planting index of more than 1.0 may be impossible without the development of irrigation facilities.

Based on data from the past 20 years, losses in production were mainly due to flooding (about 62%) and drought (about 36%). Most flooding occurs due to increased water levels in the Mekong River and Tonle Sap Lake between early July and early October. These two water bodies are linked to each other, and the increase in water levels in the Mekong River is closely related to rainfall throughout the basin. Therefore a study to investigate the relationship between regional rainfall and its impact on the Mekong River may be required.

The impact of climate change on yield is quite significant. Under the high emission scenario (SRES-A2), wet season rice yield (rain-fed) will continuously decrease until 2080, and could fall by up to 70% of current yield levels. Similarly for dry season rice (irrigated rice), yields for crops planted in November and December could decrease by 40%. Under the low emission scenario (SRES-B1), the yield decrease is much less — ranging from 60% to about 20%. This suggests that achieving global reductions in emissions is important to Cambodia's agriculture.

Under emission scenarios SRES-B1 and SRES-A2, until 2050 most of the lowland forest will be exposed to a longer dry period, particularly forest areas located in the northeast and southwest. More than 4 Mha of lowland forest, which currently has a water deficit period of between four and six months, will become exposed to a water deficit period of between six and eight months or more.

Rising sea levels will potentially impact coastal systems in a number of ways, including inundation, flood and storm damage, loss of wetlands, erosion, saltwater intrusion and rising water tables. Analysis of the impact of sea-level rises on coastal areas suggests that a total area of about 25,000 ha will be permanently inundated by a sea level rise of one metre, increasing to 38,000 ha at a sea level rise of two metres.

From the spatial analysis of malaria transmission risk, it was found that the spatial pattern of malaria risk in Cambodia changes as rainfall and temperature change in the future. Though the spatial pattern of the malaria risk transmission in the future under the high and low scenario is similar, the area under high transmission risk is larger in SRES-A2 (high emission) than in SRES-B1 (low emission). In both emission scenarios, the transmission risk tends to increase until 2050, and then decreases again in 2080.

Adaptation measures

In the context of adaptation, in the short term it is the intention of the RGC to focus on increasing its capacity to cope with current climate risks through improving climate risk management and community livelihood. Using climate information, increasing water use efficiency and creating additional sources of income for farmers are among the measures identified.

Long-term efforts will be directed at increasing the resilience of the agriculture system to future climate risks through the revitalization of long-term policies and planning that take into account climate change. Measures include information use, infrastructural interventions, expanding to other areas with lower risks, insurance, better varieties of crops and long-term research.

For forests, the focus will be on more and better-protected forests, especially in the northeast and southwest of the country, where longer dry periods are expected. For coastal zones, long-life climate-proof infrastructural developments are needed. Protection and improvement of mangrove forests and planting windbreakers are also considered.

In general, adaptation programmes for climate related health issues are aimed at reducing: (i) the number of malaria cases, and (ii) deaths caused by malaria. Reducing the transmission risk can reduce malaria cases. Improving access to health facilities can reduce death cases due to malaria.

Other issues relevant for the achievement of the objectives of the Convention

Integration of climate change into relevant policies

A key initiative is the Pilot Programme on Climate Resilience (PPCR). This programme is designed to pilot and demonstrate ways to integrate climate risk and resilience into developing countries' core development policies and planning (with the World Bank (WB), the Asian Development Bank (ADB) and the International Finance Corporation (IFC)). Other national initiatives and projects, such as the Cambodia Climate Change Alliance (CCCA), have been designed to deliver this type of support and are contributing to strengthening Cambodia´s policy framework. Key guidance has already been developed and is now guiding the country´s response, namely the Cambodia Climate Change Strategic Plan and the Strategic National Action Plan for Disaster Risk Reduction (SNAP) 2008-2013. A number of sectoral climate change action plans have been developed.

Technology transfer

In Cambodia, most transfer of technologies related to climate change occurs through the implementation of CDM projects. As of 2015, the Cambodian DNA for CDM has approved 11 projects. In addition to North-South cooperation, South-South cooperation should be given due attention to ensure transfer of appropriate and least-cost technologies. In March 2013, Cambodia submitted its Technology Needs Assessment and action plan on mitigation and adaptation to the UNFCCC. The transfer of adaptation technologies to Cambodia is even more important than the transfer of mitigation technologies, given Cambodia's high vulnerability to the impacts of climate change.

Systematic observations and research

In Cambodia, meteorological data collection is still limited. Data is recorded manually at twenty stations and sent to Phnom Penh periodically for inclusion in the database. The former nine automated stations are out of operation. The Mekong Secretariat, in cooperation with the Ministry of Agriculture, Forestry and Fisheries (MAFF), with financial support from the United Nations Development Programme (UNDP) and the Food and Agriculture Organization (FAO), prepared the first-ever Cambodia Land Cover Atlas 1985/87-1992/93. Remote sensing/geographic information system (GIS) units have been established in several ministries, mainly under technical assistance of donor projects. MAFF has recorded the most detailed data relating to agriculture in Cambodia, in cooperation with FAO, the World Food Programme (WFP) and the Cambodian Agricultural Research and Development Institute (CARDI). With the support of the United Nations Population Fund (UNFPA), the National Institute of Statistics carried out the national census in 1998.

The key higher education institutions in Cambodia are the Royal University of Phnom Penh (RUPP), the Institute of Technology Cambodia (ITC), the Royal University of Agriculture (RUA), the Prek Leab School of Agriculture and the National Institute of Public Health. Research on climate change issues at these institutions is limited.

Capacity building

Since 2000, there have been at least 80 training sessions, workshops, public awareness activities and other capacity building activities related to climate change conducted in Cambodia. Most capacity building activities were supported by Japan, Korea, the Netherlands, Denmark, UNDP, UNEP, ADB, EU, WB and NGOs. From 2003 to 2005, Cambodia participated in the implementation of a global project entitled "Capacity Development for the Clean Development Mechanism" (CD4CDM). In October 2003, the Institute for Global Environmental Strategies (IGES) of Japan supported the capacity building programme for the CDM. In 2009, Danida and Oxfam America provided support to the Climate Change Capacity Strengthening and Awareness Raising Programme in Cambodia.

Information and public awareness

A national survey of climate change perceptions and awareness undertaken in 2007 found that 85% of respondents believed that Cambodia's climate is changing, but only 59% of respondents (including 82% of farmers) had heard of the term 'climate change' and associated the change with human practices. The young and educated had higher levels of awareness, and men had higher levels of awareness than women. Television and radio were found to be the most common sources of receiving information on health and the environment. The Cambodian Centre for Independent Media (CCIM) in 2007, with funding from the British Embassy, undertook a nine-month project to raise public awareness on climate change. The project mobilized more than 100 students to participate in writing a climate change radio drama. In 2010, a study targeting ministries, committees, academic institutions and the media indicated that 60% of interviewees could explain the links between their institutional mandates and climate change.

At the national level, the Department of Climate Change (DCC), the national focal point of UNFCCC, plays an important role as the coordinating body for climate change activities, including information and networking. The Climate Change website (www.camclimate.org.kh) was established in 2001 and is regularly updated by DCC to disseminate climate change related information.

Constraints, gaps and needs

Reporting process

Insufficient technical and financial resources continually constrain the preparation of national communication. Development and implementation of effective climate change strategies is constrained by limited human capacity, the lack of reliable and comprehensive data sets, and research to support GHG inventory, mitigation analysis and vulnerability assessments. Other constraints include a lack of awareness and availability of appropriate technology options, and significant financial, policy and institutional limitations.

National greenhouse gas inventory

The following are examples of some of the challenges encountered in preparing the GHG inventory:

1. Lack of activity data and local emission factors (the general IPCC default values were used);
2. Data classification is different from IPCC Guideline categories, in particular for LUCF;
3. Lack of a sustainable GHG inventory system;
4. Insufficient financial support for regular inventory preparation.

To address these issues, a better understanding of IPCC guidelines is necessary, including training on uncertainty analysis and quality assurance. Better and disaggregated information about the most important emission sectors (energy and agriculture) is needed, including soil classification and fertilizer use. Energy balance sheets, which illustrate consumption in economic sectors, are crucial to improve future inventory in this sector. Forest cover and land use classification must be comprehensively updated, based on IPCC and Good Practice Guidance (GPG) Land Use, Land Use Change and Forestry (LULUCF) categories. Data on waste generation and its composition must be collected.

Vulnerability and adaptation assessment

Climate risk projections and modelling are still limited in Cambodia due to insufficient data, information and capacity. Vulnerability assessments need more technical and scientific capacity as well as financial resources.

GHG mitigation measures

Planning information is often lacking, as well as technical expertise and financial resources to perform analyses of mitigation options. More detailed studies on mitigation opportunities and the costing of mitigation measures are also lacking. This makes it difficult to carry out financial and economic studies to demonstrate the benefits of mitigation options. Available data for many economic sectors are very limited.

Technology development and transfer

One barrier to technology transfer is the weak coordination and sharing of information between stakeholders. There is a need to strengthen relevant stakeholders to coordinate and share information on activities, projects and other information related to climate-friendly technology development and transfer. Advanced technologies are manufactured outside Cambodia and are expensive, often requiring the training of experts so they can verify the technical and environmental soundness of the equipment and processes. These experts would need the proper incentives, job security and motivation to remain in their jobs.

In the area of renewable energy, Cambodia is still highly underdeveloped. It requires technology initiatives and training of experts to tap into the potential for solar, hydropower, biomass gasification and wind power. In adaptation technology, especially, water resources need much more attention.

Finances

Cambodia has limited financial means to address constraints and gaps, as well as limited adaptive capacity to the adverse effects of climate change. It does not have adequate financial resources to independently implement the adaptation and mitigation options highlighted in this SNC. Therefore, international community support is needed to support the implementation of adaptation and mitigation options highlighted here.

Enabling environment

Sound policies and institutions underpin successful climate change strategies. The general integration of climate change risks into policy, plans and strategies at the national and sub-national levels needs strengthening. Cambodia’s efforts focus on the Cambodia Climate Change Strategic Plan, the National Policy on Green Growth and the National Green Growth Strategy, in which future developments are strategically planned toward low-carbon development and climate resilience.

1. Introduction

The Kingdom of Cambodia ratified, as a Non-Annex I Party, the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and acceded to the Kyoto Protocol in 2002. The Initial National Communication (INC) was officially submitted after the ratification in 2002.

Preparing a comprehensive Second National Communication (SNC) in Cambodia is still a challenging task. Many functions and data are not available yet and had to be developed in the process. Additional studies had to be conducted to produce some essential information about the country's present and future emissions, vulnerabilities and options for adaptation and mitigation.

Chapter 2 describes Cambodia's circumstances, which include information about the Government structure, policy, geography, climate, demography and economy. Chapter 3 provides information on the national greenhouse gas (GHG) inventory, which updates the amount of GHG emissions and removals from economic sectors. The results of a comprehensive study about vulnerabilities to climate change, including a scenario analysis for future situations, are provided in Chapter 4. Chapter 5 deals with mitigation of GHG emissions in the energy sector, while Chapter 6 describes the contributions to mitigation from the agriculture, land use and forestry sectors. Some additional information is presented in Chapter 7, including information on the integration of climate change into relevant policies, and information related to technology transfer, research, systematic observations, education, awareness raising and capacity building. Chapter 8 provides information on existing gaps and constraints, with an indication of how these will be covered in future reporting under the UNFCCC obligations and commitments.

The preparation of this National Communication has been made possible by funding support from the Global Environment Facility (GEF) and the Cambodia Climate Change Alliance (CCCA), with the active participation of relevant line ministries and agencies, as well as support from the National Climate Change Committee (NCCC)[1].

[1] At the time of publication of this National Communication, and as part of the institutional reforms taking place in Cambodia, the role of the NCCC has been taken over by the National Council for Sustainable Development (NCSD), which was officially established in May 2015.

2. National Circumstances

2.1 Government structure

Cambodia is a parliamentary monarchy. The King is the Head of State and a symbol of unity for the nation, but does not govern. The 1993 Constitution established a liberal democracy and a market economy as the foundations of the country's political regime.

The Government consists of three separate branches: Legislative, Executive and Judiciary. The Parliament, which holds primary legislative power, is composed of the National Assembly and the Senate. Members of the National Assembly are directly elected through a proportional representation system. The Royal Government of Cambodia (RGC) consists of 25 ministries and two secretariats of state. The King appoints the Prime Minister and the Council of Ministers upon submission from the National Assembly. The Constitution establishes the judiciary as an independent branch of government and guarantees its independence from the Legislative and Executive. Cambodia is divided into 24 provinces and one municipality.

2.2 National and regional development priorities

The first and second Socio-Economic Development Plans (SEDP) set out five-year development goals for the periods 1996-2000 and 2001-2005, respectively. The National Poverty Reduction Strategy (NPRS) was adopted in 2002 and Cambodia's Millennium Development Goals (CMDGs) were agreed in 2003. The goals and strategies of these documents have been incorporated into the first (2014) and subsequent Rectangular Strategies for Growth, Employment, Equity and Efficiency (Rectangular Strategies I, II, III), which set out an agenda of institutional reforms for the country, focusing on the achievement of sustainable development and poverty reduction objectives. National Strategic Development Plans (NSDP) provide a broad framework aimed at harmonizing development efforts and the effectiveness of aid to implement these strategies. The last NSDP (2009-2013), which implemented the Rectangular Strategy II, already identified climate change as a priority development issues due to its major threat to the country's economic and growth prospects. NSDP 2014-2018, which supports the implementation of the Rectangular Strategy III (Figure 2.1), included climate change indicators as part of its mechanism for the Monitoring and Evaluation of the Results Framework, setting the responsibility of line ministries and agencies within each angle of the Rectangular Strategy.

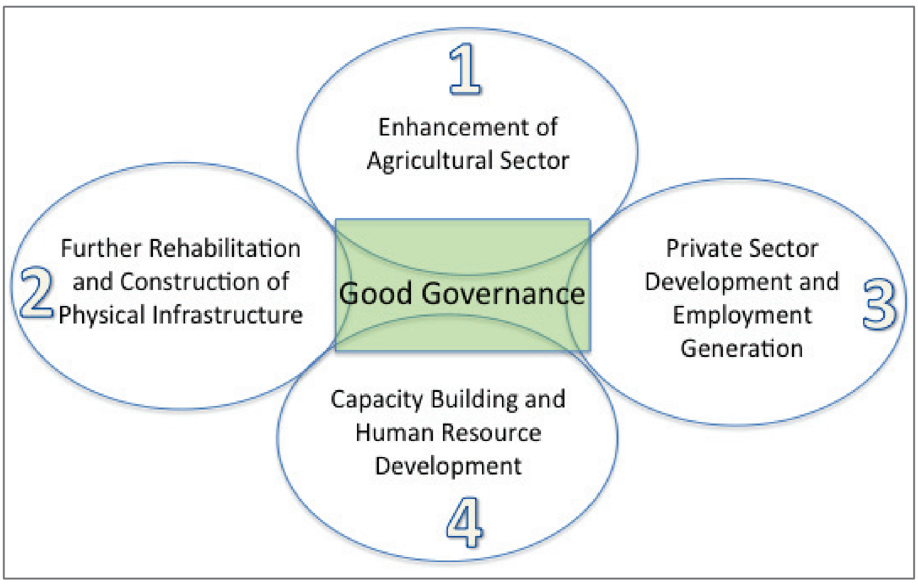


Figure 2.1: Third Rectangular Strategy (NSDP 2014-2018)

2.3 Geographical characteristics

The Kingdom of Cambodia is located in mainland Southeast Asia between latitudes 10° and 15° N and longitudes 102° and 108° E. Cambodia occupies a total area of 181,035 km^2 and shares borders with Thailand to the west and northwest, Laos to the northeast, Vietnam to the east, and the Gulf of Thailand to the southwest. The country's topography broadly consists of the central plains surrounded by mountainous and highland regions, and a 435 km coastline to the south. Phnom Penh, the capital city, is located in south-central Cambodia, at the confluence of the Mekong, Tonle Sap and Bassac Rivers. The Mekong River and its tributaries dominate the hydrology. The Tonle Sap Lake, an outlet of the Mekong during the rainy season, covers an area of up to 10,400 km^2 in the northwest. Phnom Aural, culminating at 1,813 meters, constitutes the highest point. Figure 2.2 presents a map of Cambodia.

Figure 2.2: Map of Cambodia

2.4 Climate

Cambodia's tropical monsoon climate is characterized by a rainy season and a dry season. During the rainy season, which lasts from May to early October, winds from the southwest carry heavy rains and account for 90% of annual precipitation. The dry season, from November to April, is associated with the northeast monsoon, which brings drier and cooler air from November to March, and then hotter air in April and early May. The maximum mean temperature is about 28^oC and the minimum mean temperature about 22^oC. Maximum temperatures in excess of 32^oC are common before the start of the rainy season and may rise to more than 38^oC. The average annual rainfall from 1994 to 2004 has fluctuated between 1,400 mm and 1,970 mm per year. Annual rainfall varies considerably across the country. In lowland areas, annual rainfall ranges from 1,000 mm to 1,700 mm, while in the highlands it ranges from 1,000 mm to 2,700 mm, and in coastal areas from 1,000 mm to 3,000 mm. However, over the past decade, some inland provinces have experienced less than 600 mm of rainfall annually, while precipitation has reached 3,800 mm in coastal areas.

2.5 Extreme climate events

The central plains experience seasonal flooding that provides fish and soil nutrients. However, the frequency of severe floods has increased over the last decade. The 2000 floods were the worst to hit Cambodia in 70 years, while severe floods also occurred in 1991, 1996, 2000, 2001, 2002 and 2011 (NCDM 2011).

In 2000, for example, heavy floods killed 362 people, most of them children. The cost of the damage caused by the 2000 floods reached US$157 million. In 2001, floods killed 62 people and resulted in economic losses of about US$30 million, and in 2002 the Mekong floods killed 29 people and caused more than US$12 million in damage (CRC 2008). In 2011, Cambodia experienced severe floods again, which affected approximately 1.5 million people, killing 250 people and causing damage to more than 400,000 hectares of crops (NCDM 2011).

While floods affect lowlands areas, the geographical distribution of droughts is widespread (MoP 2005). The 1998 drought led to crop failure, while an estimated 2.5 million people per year were affected in the droughts of 1995, 1996 and 2002.

Storms occur more frequently between August and November, with the highest frequency in October. The country is rarely exposed to the full force of tropical cyclones and typhoons as it is surrounded by mountain chains, which dissipate the typhoon’s force. In 2009 however, Typhoon Ketsana caused more than 40 deaths; more than 66,000 families had to leave their houses and the storm damaged significant agricultural crops and road infrastructure.

2.6 Population

2.6.1 Demography

Cambodia’s demographic and population statistics are based on the 1962 and 1998 General Population Censuses of Cambodia, the 2004 Cambodian Inter-censal Population Survey (CIPS), and the 2008 General Population Census.

The Cambodian population increased from 11.4 million in 1998 to 14.7 million in 2013 (NSDP 2014). The annual growth rate of the population registered a decline of 0.58 percentage points from 2.12% to 1.54% during the 1980s.

Between 1975 and 1979, an estimated 1.7 million Cambodians, out of a population of 8 million, lost their lives during the Khmer Rouge regime (CGG 2006). This has caused imbalances in Cambodia’s demographic characteristics. The Cambodian population is young, with about 61% of people under 24 years of age in 2005. The sex ratio (number of males per 100 females) was very low (86) in 1980 due to male casualties during the Khmer Rouge regime. It has been showing gradual improvements in later years, reaching a 94.2 ratio in 2008 (Figure 2.3).

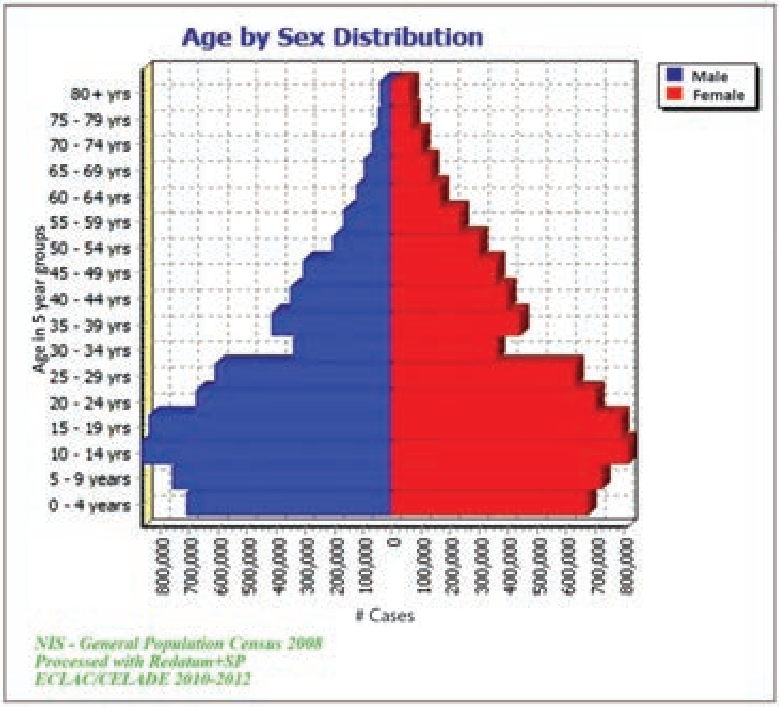


Figure 2.3: Population pyramid in 2008

More than 80% of Cambodians live in rural areas, while 19.5% live in urban areas. Approximately 52% of the population lives in the central plains, 30% around the Tonle Sap Lake, 11% in the highlands and mountainous areas and 7% in coastal areas. Cambodia's population and population densities are much lower than that of its neighbours. While population densities reach 235 persons per square kilometre in the central plains, it is less than 17 persons per square kilometre in the highlands. In 2005, the national average population density was 75 people per square kilometre.

2.6.2 Poverty

Poverty remains a serious social issue in Cambodia, although the country has been registering significant progress in terms of its poverty reduction efforts. According to the poverty line drawn in the 1990s, the country had achieved its previously set MDG target in 2009, with a poverty rate of 14.6% (lower than half of the 39% poverty rate registered in 1993-1994). In 2011, the Government set the bar higher, defining a new poverty line[2] while maintaining the MDG goal of halving the poverty rate registered in 1993-1994. Recent trends indicate that Cambodia will achieve its MDG target of 19.5% in 2015, despite the upward revision of the poverty line, thus having effectively managed to reduce to half the proportion of its people living below the poverty line. Trends also show a steady reduction in the rural poverty rates in Cambodia, from about 53% in 2007 to 21% in 2011 (NDSP 2014).

Households engaged in agricultural activities have the highest incidence of poverty. Constraints in terms of access to land, forests, fisheries and other natural resources, as well as few opportunities in the industry and service sectors, further perpetuate the cycle of poverty. Poor health, combined with high healthcare expenditures is the major cause of household impoverishment.

2.6.3 Health

As Cambodia has a tropical monsoon climate with marked rainy and dry seasons, the impacts of climate on human health are significant. Malaria and dengue fever are the prevailing mosquito-borne diseases. Malaria is a public health concern in Cambodia, while outbreaks of dengue fever have occurred from time

[2] The new poverty line, established in 2011, is based on the cost of a food basket providing 2,200 kilocalories per day (up from 2,100 kilocalories per day) and a revised allowance for non-food items, including a small token for clean water.

to time, and it remains a major cause of childhood morbidity and mortality. In 2004, more than 95,000 malaria cases were treated, with about 400 fatalities. A high level of drug resistance has been documented in Cambodia.

Cambodia's medical facilities are inadequate. There are more than 5,200 inhabitants per doctor, and only about 7,700 medical beds for the whole country. Personal savings and borrowed money are the main means by which households pay for healthcare (CDHS 2000, 2005). Despite improvements in infant mortality, under-five mortality and life expectancy at birth, the health status of Cambodians is still among the lowest in the region.

2.7 Economy

2.7.1 Overview

Cambodia's economy has grown steadily since the liberalization of its markets; the annual Gross Domestic Product (GDP) growth rate from 1993 to 2004 averaged 9.7%, while per capita GDP averaged 6.5% (NIS 2005).

In 2006, agriculture, fisheries and forestry accounted for 28% of GDP, industry 28% and services 40% (Table 2.1). Due to a high reliance on agriculture, climate has a significant impact on GDP from one year to another. The contribution of industry to GDP has more than doubled since 1990, but is concentrated in the textiles, apparel and footwear sectors. The challenge for Cambodia's economy is to broaden the opportunities available to its increasing population, while diversifying beyond agriculture and the garment sector.

Table 2.1: GDP at current prices by economic activity, 1990-2006

Sectors	1990[a] (%)	1994[a] (%)	1998[b] (%)	1999[c] (%)	2000[c] (%)	2001[c] (%)	2002[c] (%)	2003[c] (%)	2004[c] (%)	2005[c] (%)	2006[c] (%)
Agriculture, Fisheries & Forestry	51.5	45.2	45.2	41.0	35.9	34.8	32.2	32.6	30.9	27.0	27.9
Industry	11.6	18.3	17.2	18.0	21.8	22.5	24.4	25.6	26.2	25.3	27.6
Services	36.9	36.5	33.6	35.4	37.1	37.7	38.1	36.9	37.5	37.0	38.9

Source: a) MoE 2002; b) NIS 2003a; and c) MEF 2006

Note: % refers to share of GDP

Cambodia is still dependent on Official Development Assistance (ODA), which includes grants, loans and technical assistance. ODA has grown from US$500 million in 1993 to US$700 million in 2008. Between 1993 and 2007, disbursements were at the US$7.6 billion level, or US$507 million per year on average, with the following breakdown: 45% for technical assistance; 40% for investment projects; 8% for budget support; and 7% for food aid and emergency relief (CDC 2007).

From 1994 to 2004, cumulated foreign direct investment in Cambodia amounted to US$1.2 billion, principally in infrastructure/services (45%), industry (25%) and tourism (26%). Total foreign direct investment amounted to US$229 million in 2004, of which 43% was from China, 22% from other ASEAN members, 10% from Hong Kong and 10% from the European Union. Garment exports expanded rapidly following preferential access to the United States and European Union markets in 1996 and 1997 respectively, from 10% of domestic exports in 1995 to 93% in 2000 (MoP 2002). Cambodia's membership of the World Trade Organization (WTO), granted in 2004, provides access to other members' markets on a most-favoured nation basis, but will also intensify competition with foreign enterprises.

2.7.2 Agriculture

Cambodia's agriculture is predominantly rain-fed and characterized by low input and moderate or low fertility land, thus making it dependent on weather conditions and changing climate. The development of agriculture is essential to poverty reduction, as this sector constitutes around 30% of GDP and employed more than 70% of the workforce in 2007 (EIC 2008). Cambodia's total agricultural land is about 5.3 Mha, of which 3.7 Mha is arable land.

Rice is Cambodia's primary staple and provides approximately 70% of nutritional needs (MoE 2004a). Rice crop cultivated area was 2.58 Mha (NIS 2008). Some 80% of rice production stems from local varieties cultivated during the rainy season. High yielding varieties are mainly planted during the dry season, and account for the remaining 20% of rice production. Rice productivity is highly dependent on weather conditions, for instance, the severe floods of 2000 reduced the harvested area to 1.9 Mha (NIS 2002), and yields decreased from 2.10 t/ha in 2003 to 1.98 t/ha in 2004 due to drought. Yields have gradually increased over the last decade but remain among the lowest in Asia.

Four other food crops, namely corn, cassava, soybean and mung bean, occupy approximately 14% of the crop area. The remaining 3% is used for growing vegetables, sesame, peanut, sugarcane, sweet potato, potato, tobacco and jute (NIS 2008). Animal husbandry has been traditionally practised at the household level in Cambodia. Cattle and buffalo provide most of the agricultural draught and manure for fertilizing crops, and constitute essential household assets (MoE 2004a, b and 2005). Many rural families raise pigs and chickens at the household level.

Instability in agricultural yields is considered to be higher in Cambodia than in most other Asian countries, and Cambodian agriculture is extremely vulnerable to unexpected and changing patterns of floods and drought. Low yields coupled with natural disasters contribute to temporary food shortages. Based on food availability, food access and food absorption, a mapping of food security has been conducted for the country. Seven of Cambodia's 25 provinces (including Phnom Penh capital city) are classified as severely to extremely food insecure, and an additional seven moderately insecure. Phnom Penh is the only area considered secure in terms of food (MoP 2005).

2.7.3 Forestry

The Forest sector's contribution to GDP reached 5.4% in 1998, but declined to 1.9% in 2006 (MEF 2006). Forests play a significant role in traditional rural livelihoods, providing construction wood, fuelwood, food and medicine, as well as ensuring ecosystem functions such as watersheds, storm and coastline protection. As a complement to farming and fishing, forest foraging constitutes a safety net for rural people. Without any commercially viable alternative firewood remains the main source of energy for cooking for 91% of rural people (CIPS 2004).

Cambodia's forest cover was estimated at 10.8 Mha or around 60% of the country's land area in 2006, down from 67% in 1985/87 (FA 2003, 2005 and 2007, and MoE 2005). These estimates were determined using satellite imagery, with limited ground verification, and therefore do not provide details on the quality of forests (MoE 2005) (Table 2.2). The CMDG target is 60%. The most significant forest loss occurred in the northwest of the country (Banteay Meanchey, Battambang, Siem Reap, Otdar Meanchey and Pailin Provinces) (CDC 2007).

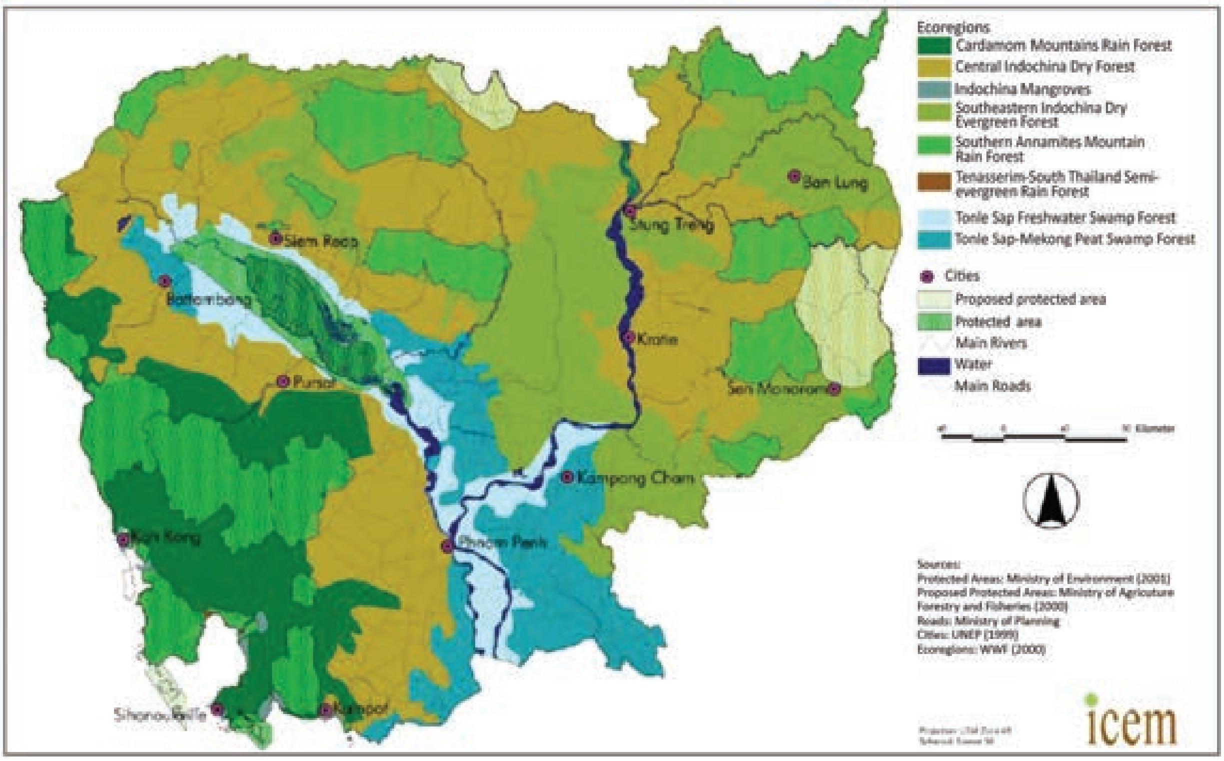
Cambodia's forests are classified into five groups: evergreen, semi-evergreen, deciduous, mangrove and other types (MAFF 2004) as seen in Figure 2.4. Some 25% of Cambodia's forests lie within a system of 23 protected areas (MoE 2005). The 3.2 Mha protected area network, consisting of national parks, wildlife sanctuaries, protected landscapes and multiple use areas, was established to conserve the country's biodiversity, including at least 212 species of mammals, 720 species of birds and 2,308 species of vascular plants (MoE 2005). Cambodia's protected areas have been under pressure from logging, forest conversion, illegal wildlife trade and mining. The system suffers from a lack of financial and technical resources, and inadequate law enforcement.

Table 2.2: Changes in forest cover 1960s to 2006

Year	1960s[2]	1973/76[3]	1985/87[3]	1992/93[3]	1992/93[4]	1996/97[4]	2002/03	2006
Total land area[1] (thousand ha)	18,153	18,153	18,153	18,153	18,153	18,153	18,161	18,161
Forest area (thousand ha)	13,277	12,711	11,852	11,284	10,860	10,638	11,392	10,864
Forest cover (%)	75.2	71.9	67.4	63.6	61.3	60.2	62.7	59.8

Source: FA 2003, 2005, 2007 and MoE 2005

Note: [1] Including flooded land area;
[2] Total land, Land area (Forest information system (2003), FAO, 2010)
[3] From MRC 2004; Cambodia Land Cover Atlas (1985/87; and 1993/95)
[4] DFW 1998. Forest Cover Assessment



Source: MEF and MoE 2003

Figure 2.4: Forest types of Cambodia

The loss of dry land forest is mainly due to agricultural expansion, illegal logging and over-exploitation. Forest fires have not historically been a serious threat to forest cover, however there are indications that they may become so in the near future, particularly in the event of an extended dry season as a result of climate change.

Mangrove forest loss is relatively low in Cambodia, however there are some trends that threaten mangrove habitats and local livelihoods (FAO 2010). These include woodcutting for charcoal production and fuelwood, as well as the conversion of mangroves to shrimp farms and salt farms. Charcoal production in particular is increasing, with much of the charcoal produced being illegally exported.

Reforestation/tree planting, community forestry establishment, forest boundary demarcation, wildlife and forest research and conservation, and the development of the National Forest Programme were actively carried out by the RGC. Cambodia set up a forest carbon credit pilot project through the implementation of a number of feasibility studies in protected and community forestry areas (NSDP update 2009-2013).

2.7.4 Fisheries

Cambodia's inland fisheries are among the most productive fisheries in the world and have traditionally played a significant role in rural livelihoods. Fish are an essential source of protein for rural people. Average annual fish consumption is 67 kg per person and represents 40% to 60% of protein intake (WRI 2000). Fish also supplements rice cultivation in terms of income generation. An estimated one million Cambodians depend on inland fisheries for their livelihoods, either as fishermen or workers employed in inland fishing activities.

The Tonle Sap Lake, the Mekong River and its tributaries, constitute a rich and diverse ecosystem that supports some 500 fish species (Rainboth 1996). During the rainy season, flooding of the rivers and lakes creates an extensive wetland across the central plains where fish have access to food and breeding grounds. The Great Lake expands to four to six times its size and covers an area of 15,000 km^2. In terms of yield, Cambodia ranks fourth in the world (140 to 190 kg/ha), with an estimated 250,000 tons in 2004 and an economic value of US$300 million (MoE 2005). Cambodia's inland fisheries are directly affected by seasonal patterns of floods and droughts, and thus are vulnerable to changing climate conditions.

Despite its extensive coastline and exclusive economic zone, Cambodia's marine fisheries have traditionally not been as commercially exploited as inland fisheries. Domestic demand for freshwater fish is higher. The marine fish catch was estimated at about 50,000 tons in 2004 (NIS 2004).

2.7.5 Energy

Cambodia currently imports its entire consumption of petroleum products, which has steadily increased in cost from US$549 million in 1998 to US$691 million in 2004 (NIS 2005).

Cambodia's renewable energy sources are abundant, however they remain largely untapped for electricity production.

Biomass, the main cooking fuel for households, accounts for more than 80% of total national energy consumption, and includes forests products, agricultural crops and residues, and municipal waste and sewage. The technical potential for electricity generation from biomass has been estimated at 18,852 GWh per year (Williamson et al. 2004). However, applications have been limited to small-scale or demonstration projects, with total installed capacity at some 2 MW.

Commercial-size **hydropower** projects have been in operation in Cambodia since 1968. Cambodia's technical potential for hydropower has been estimated at 8,600 to 10,000 MW of installed capacity for the Mekong River, the Mekong tributaries and the coastal provinces (Mekong Secretariat 1991, 1973, MRC 2013).

Despite a relatively high level of solar radiation, Cambodia's use of **solar** photovoltaic and solar thermal technologies has been restricted by high investment costs and low awareness. Total solar photovoltaic installed capacity amounted to 205 kWp in 2002, with the bulk on communication towers (NEDO 2002, MIME 2003, Williamson et al. 2002). Cambodia's **wind power** resources are located on its plateaus and mountain ranges, with an estimated technical potential of 1,380 MW (World Bank 2001). To date, only a limited number of small wind turbines have been installed for household and community use.

Oil and gas exploration began in the early 1970s in Cambodia, with confirmation of gas in 1972. However, exploration by international companies did not resume until 1992 when political stability returned. Cambodia's first significant petroleum discovery was announced in January 2005. Oil and gas lie offshore within Cambodia's exclusive economic zone. Oil and gas production has the potential to drastically transform Cambodia's economy, society and GHG emission characteristics (World Bank 2009).

Energy production and consumption: Diesel and Heavy Fuel Oil (HFO) are the main fuels used to generate electricity in Cambodia. Biomass use is limited to micro-generation installations and captive systems.

Independent Power Producers (IPP) accounted for 64% of total electricity produced in 2004, while the remainder was provided by Electricité du Cambodge (EDC), the state electric utility and the Ministry of Industry, Mines and Energy (MIME)[3]. Total electricity production in Cambodia amounted to 1,858.364 million kWh in 2008, up from 107 GWh in 1991. Electricity imports from Thailand and Vietnam have rapidly increased, from 1.7 GWh in 1998 to 57 GWh in 2004.

Kerosene is the main source of household lighting in Cambodia. In 2004, only 14% of households had access to grid electricity, while 64% and 16% of households used kerosene and battery lighting respectively.

In 2004, some 86% of households used fuelwood for cooking. While charcoal and Liquid Petroleum Gas (LPG) are more accessible in urban areas (23% and 20% of households respectively), they are only marginally used nationwide as cooking fuel (5% and 2% respectively). These statistics have remained broadly unchanged since the 1998 General Population Census (CIPS 2004).

Cambodia's energy sector is facing major challenges. The national per capita energy consumption in 2010 was just 153 kWh (NSDP update 2009-2013). Despite considerable progress in expanding the capacity and coverage of electricity supply in recent years, electricity costs remain among the highest in the world, and the electrification rate, one of the lowest in Asia. Cambodia's power supply relies heavily on imported fuels; a new challenge is emerging due to the general increase of international fuel prices. The Government is exploring new sources of energy, including hydropower, offshore and onshore oil and gas, and some sources of renewable energy (World Bank 2006).

2.7.6 Transport

Land transport

Cambodia's road network consists of 38,870 km of national roads (11%), provincial roads (9%) and rural roads (80%). The national roads connect Phnom Penh to the main provincial capitals and border crossings. The national road network was built in the 1920s and 1930s, and has fallen into disrepair due to lack of maintenance. Rehabilitation of this network is a priority for the Government. Less than 16% of the entire road network is paved (NIS 2005, MoP 2005, SEDP II). Much of the provincial network is impassable during the rainy season, when floods isolate parts of the country.

The number of registered motor vehicles (cars, minibuses, pick-ups, buses, trucks, motorcycles) increased by 79% between 1994 and 2004 to 918,130 vehicles, which corresponds to an annual rate of increase of almost 7%. Motorcycles represent 70% of vehicles, followed by cars (26%) and trucks (3%) (NIS 2005). The increase in road transport has been accompanied by an increase in traffic accidents. Between 2000 and 2004 the number of road traffic accidents increased by 15% annually, with a daily average of 3 fatalities and 20 injuries (RTAVIS 2005).

Cambodia's rail network was built between 1929 and 1942 (385 km Northern Line), and in the 1960s (266 km Southern Line). The network is in a dilapidated state and not usable along large sections. Both freight and passenger transport by rail have decreased over the past decade, with the rehabilitation of the national road network. Table 2.3 presents the volume of rail transport for the period 1999-2006.

[3] The Ministry of Industry, Mines and Energy has been restructured and there are currently two ministries - the Ministry of Industry and Handicrafts and the Ministry of Mining and Energy.

Table 2.3: Traffic volumes - rail transport 1999-2006

Traffic Volume	Unit	1999	2000	2001	2003	2004	2005	2006
Goods	kton	268	340	410	433	298	269	316
	ton-km	77,386	91,956	105,025	100,486	77,702	20,002	92,500
Passenger	passenger (thousands)	429	335	223	94	82	48	11
	passenger-km (thousands)	50,209	45,419	32,415	13,450	10,378	5,173	5,173
Equipment	ton	415	3,283	1,806	713	523	350	73
	ton-km (thousands)	573	461.39	281	109	83	66	17

Sources: CNMC 2003; MPWT 2007, 2009

Water Transport

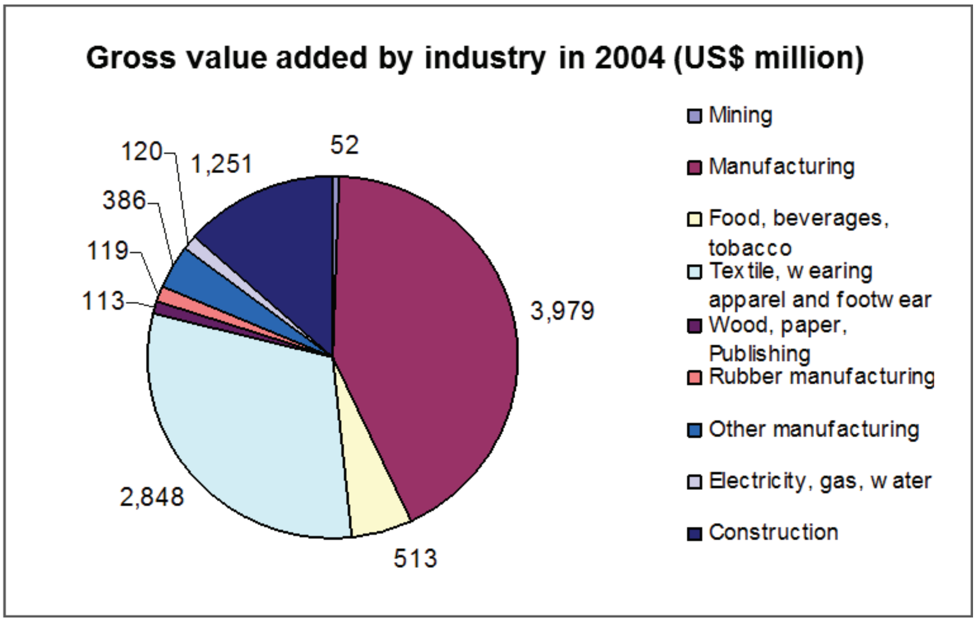
Both marine and river transport play significant roles in linking Cambodia's economy to international markets. Sihanoukville Autonomous Port, the country's only deep-sea port, has seen its quantities of cargo, containers and vessels steadily increase since 1996. Some 3.9 million tons of cargo were expected to be handled through the port by 2010, up from 1.6 million tons in 1999. At the confluence of the Bassac, Mekong and Tonle Sap Rivers, the port of Phnom Penh occupies a central position in river transportation. The throughput of the port peaked in 1997 at 658,000 tons (75% of which was imported fuel), with a switch from river to road transport. In addition, lack of dredging prevents the use of large vessels in the navigable waterways.

Air transport

Cambodia's open sky policy has resulted in a substantial increase in air travel in the last decade. The country has two international airports: one in Phnom Penh and one in Siem Reap, gateway to the temples of Angkor, the country's primary tourist destination. Visitor arrivals by air to Cambodia have increased from 28,525 in 1999 to 309,373 in 2004.

2.7.7 Industry

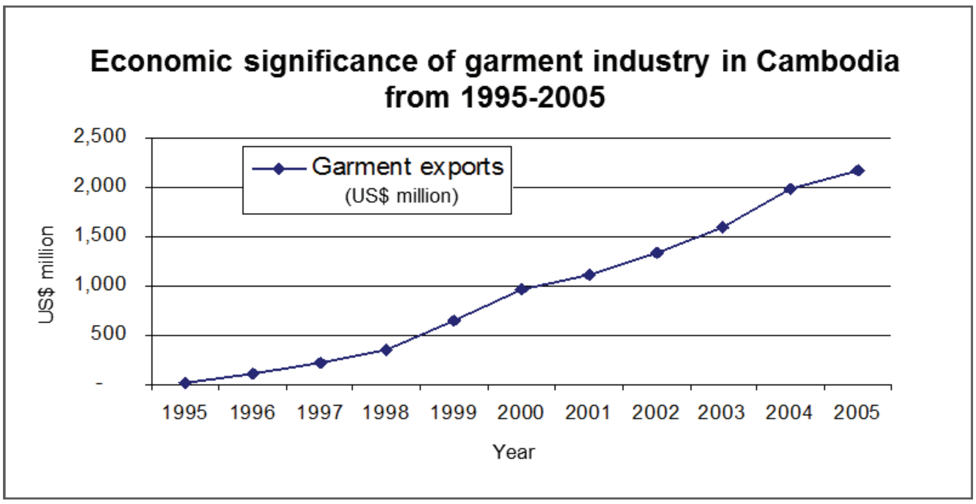
Industry has been a fastest growing sector in Cambodia's economy since early 1990s, increasing from 12.6% of GDP in 1993 to 26.2% in 2006, with an average annual growth rate of more than 15% over this period. In terms of gross value added by sector in 2004 the textiles and manufacturing sub-sectors made significant contributions (see Figure 2.5). Though industry growth decreased for a short period during the late 2000s, it quickly recovered and remained steady at approximately 22%, with the industry sector representing approximately 24% of GDP in 2013. Industry employs 8% of the labor force, far below agriculture, which employs 75% (NIS 2007, World Bank 2006).



Source: Revised from NIS 2005

Figure 2.5: Gross value added by industry, 2004

The textiles, clothing and footwear sub-sector has been the fastest growing sub-sector, with an average annual increase of 41% over the period, totalling 89% of Cambodia's exports in 2004 (Figure 2.6). The economic significance of the garment sector is presented in Table 2.4.



Source: Revised from USAID, USAID 2005 and 2006

Figure 2.6: Garment exports from 1995-2005

As of August 2007, there were 305 companies in the Garment Manufacturers Association in Cambodia (GMAC). Factories are located in and around Phnom Penh, and ship their production overseas through the port of Preah Sihanouk Province. About three-quarters of factories are entirely owned by investors from China, Hong Kong, Taiwan, South Korea, Malaysia and Singapore. The remainder are joint ventures between Cambodian owners and international partners.

Table 2.4: Economic significance of the garment industry in Cambodia

Indicator	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Factories (number)	20	24	67	129	152	**190**	186	188	197	219	247
Total employment (thousand)	18.7	24.0	51.6	79.2	96.6	**122.6**	188.1	210.4	234.0	259.8	283.9
Garment exports (US$ million)	26.2	106.4	223.9	355.3	653.0	**965.0**	1,119.8	1,338.4	1,601	1,979	2,169
New Investment (US$ million)	30	46	97	123.6	66.5	**37.2**	19.5	36.3	29	85	118
Nominal GDP (US$ million)	3,099	3,172	3,387	3,105	3,515	**3,651**	3,787	4,079	4,355	4,888	5,391

Source: USAID 2005 and 2006

Preferential access to the EU and US markets, the absence of restrictive quotas and lower production costs all contributed to the emergence of Cambodia's export-oriented garment manufacturing in the mid-1990s. Cambodia has managed to take advantage of a corporate social responsibility niche, whereby factories are independently monitored by the International Labour Organization's *Better Factories Cambodia* programme. The project grew out of a trade agreement between the USA and Cambodia, whereby Cambodia was promised access to US markets in exchange for improved working conditions in the garment sector (ILO 2007). As a least-developed country, Cambodia has access to EU markets without quotas or duties. The USA and the EU represented 64% and 29% respectively of Cambodia's total garment exports in 2005.

2.7.8 Tourism

Cambodia's main tourist destination is the temples of Angkor, a World Heritage site built between the 9th and 15th centuries and covering an area of 400 km^2. Cultural and historical tourism, and to a lesser extent nature-based tourism, are the main attractions for international visitors.

Tourism is the fastest growing sub-sector in services, and accounted for about 12% of GDP in 2011. International visitor arrivals in Cambodia have grown from about 118,000 people in 1993 to about 2.88 million people in 2011. Tourism expenditures have similarly increased, from an estimated US$100 million in 1995 to US$1,912 million in 2011 and provide approximately 350,000 direct jobs (MoT 2011). Despite its rapid growth, the Cambodian tourism sub-sector remains dependent on international visitors and is vulnerable to external shocks, including rising oil prices, epidemics and recurring natural disasters.

2.8 Climate change institutional arrangements

In 2006, the RGC established the NCCC, a cross-sectoral and multi-disciplinary body with the mandate to prepare, coordinate and monitor the implementation of policies, strategies, legal instruments, plans and programmes related to climate change. With an amendment in 2014, the NCCC has functioned since its establishment as the inter-ministerial mechanism for coordination of climate change response in the country. Its functions have recently been taken over by the National Council for Sustainable Development (NCSD) since its establishment in May 2015. The Council comprises high-level representatives (Secretaries and Under-Secretaries of State) of concerned government ministries and agencies, with the Prime Minister as its Honorary Chair and the Minister of Environment as its Chair. Council membership has increased compared to the NCCC, covering a greater number of ministries and agencies, including provincial governors.

Currently, NCSD has made efforts to improve the coordination of climate change activities in Cambodia and to promote a stronger, comprehensive and effective climate change response, including the preparation of the Cambodian Climate Change Strategic Plan 2014-2023, the Sectoral Climate Change Action Plans and the Climate Change Financing Framework.

The Cambodia Climate Change Office (CCCO) of MoE was established in 2003 to be responsible for a wide range of climate change related activities: formulation of draft climate change plans and policies, implementation of the UNFCCC, assessment of new technologies to adapt to the adverse effects of climate change or to mitigate GHG emissions, and capacity building and awareness raising. The Office also serves as the Secretariat of the UNFCCC, the Intergovernmental Panel on Climate Change (IPCC), the Kyoto Protocol and the Clean Development Mechanism (CDM) Focal Points for Cambodia. The CCCO coordinates inter-ministerial technical working groups specialized in sectors (energy and forestry), and along climate change themes (GHG inventory, mitigation, vulnerability and adaptation, and UNFCCC implementation). The Government upgraded the status of CCCO from office to department (Climate Change Department) in October 2009 – a strong indication of its commitment to strengthen climate change institutions in the country.

The MoE was appointed as the Designated National Authority (DNA) for the CDM in July 2003. The DCC, acting as the Secretariat of the Cambodian DNA, has been actively promoting CDM projects in Cambodia, with technical and financial support from the Institute for Global Environmental Strategies (IGES) of Japan, the Government of the Netherlands via the United Nations Environment Programme (UNEP) and the European Union (EU). The activities include technical and institutional capacity strengthening, CDM awareness raising, CDM project identification and facilitation of host country approvals in accordance with the requirements of the Kyoto Protocol of the UNFCCC.

2.8.1 Obligations under the UNFCCC and the Kyoto Protocol

Cambodia has accepted obligations as a signatory party of both the Climate Convention and the Kyoto Protocol. Under Articles 4 and 12 of the UNFCCC, subject to availability of support, Cambodia must report its emissions by sources and removals by sinks (GHG inventory), national mitigation and adaptation measures, and any other relevant achievements towards the objective of the Climate Convention. Under the Kyoto Protocol, Cambodia must set up institutional arrangements for the national approval of CDM activities.

As described above, the NCSD and the DCC were explicitly established with the primary roles and responsibilities of assisting the Government in dealing with national climate change issues and assisting Cambodia in fulfilling its international obligations.

The formulation of national communications under the UNFCCC falls under the purview of the NCSD and the DCC, and provides the basis for institutional continuity at both the policy-making and technical levels, across a comprehensive range of government stakeholders. The DCC acts as the Secretariat of Cambodia’s DNA for the CDM, while a selection of members of the Climate Change Technical Team (CCTT) relevant to mitigation activities forms the Board of the Cambodian DNA.

2.9 Overview of national circumstances

Table 2.5 shows the most important data about the national circumstances.

Table 2.5 Cambodia's national circumstances

	Unit	Year 2000	Year 2005	Year 2010	Year 2013
Area	km^2	181,035	181,035	181,035	181,035
Population	Million	12.6	13.8	14.9	14.7
Urban population	%	16	15	19.5 (Census 2008)	21.4
Rural population	%	84	85	80.5 (Census 2008)	78.6
Annual average growth rate	%	1.8	2.06	1.77	1.46
National average population density	$Person/km^2$	70	75	83	82
Population below poverty line	%	-	34.7 (2004)	25	17.9
Life expectancy	Years	M: 54; F: 58	M: 61; F: 65	M: 64; F: 68	M:67.1 ; F:71
Literacy rate	%	68.9 (1999)	73.6 (2004)	87	(Age:15-24) 91.5
GDP per Capita	US$	288	357 (2004)	795	1,036
Share of informal sector in GDP:					
- **Share of agriculture in GDP**	%	35.9	30.9 (2004)	25.5	4.2
- **Share of industry in GDP**	%	21.8	28.9 (2004)	29.8	9.8
- **Share of services in GDP**	%	37.1	34.4 (2004)	38.9	8.8
Cultivated area for short-term food crop	thousand ha	2,413.70	2,468.2 (2004)	2,650	3,993
Cultivated area for wet season rice	thousand ha	2,060.60	2,048.4 (2004)	2,315	2,567
Cultivated area for dry season rice	thousand ha	262.3	283.6 (2004)	335	484
National average paddy rice yield	ton/ha	1.9	2.0 (2004)	2.8	3.1
Wet season paddy rice yield	ton/ha	1.81	1.7 (2004)	2.23	2.92
Dry season paddy rice yield	ton/ha	3	3.4 (2004)	4.01	4.38
Livestock :					
- **Non-dairy cattle "cow"**	thousand heads	2,992.70	3,039.9 (2004)	3,368.4 (2007)	3,430.90
- **Buffalo**	thousand heads	693.7	710.1 (2004)	772.8 (2007)	619.1
- **Swine**	thousand heads	1,838.30	2,428.6 (2004)	2,389.4 (2007)	2,436.70
- **Poultry**	thousand heads	15,249.80	12,990.6 (2004)	15,825.3 (2007)	27,316.40
Forest coverage of total land area	%	58	59.09 (2005/2006)	57.61	59.19

Source: NSDP Update 2009-2013 & NSDP 2014-2018; MAFF 2014

3. National Greenhouse Gas Inventory for 2000

3.1 Introduction

The national GHG inventory for the year 2000 is the second national inventory submitted by Cambodia to the UNFCCC. The first national GHG inventory was prepared in 1994. Cambodia's Inventory of Greenhouse Gas for the Year 2000 was developed following the Revised 1996 IPCC Guidelines and the UNFCCC software for use in calculating and estimating emissions (Version 1.3.2, 28 January 2007). This was complemented by the IPCC Good Practice Guidance (GPG) and Uncertainty Management in National Greenhouse Gas Inventories and the IPCC Good Practice Guidance on Land-Use, Land-Use Change and Forestry (GPG LULUCF).

In accordance with the IPCC Guidelines, Parties may use different methods, also known as *tiers*. Tier 1 represents the minimum or default methodology, while Tiers 2 and 3 require more detailed data and involve more elaborate methods. Cambodia's inventory for 2000 adopted a Tier 1 approach. However, gaps in specific national data, necessary for the application of even Tier 1 methods, have created significant difficulties in many areas, for example, in the energy module where disaggregate information is not available. There is currently no national methodology for GHG inventory in Cambodia. Thus, this inventory has made extensive use of IPCC default emission factors, and in some cases, default activity data[4]. Despite these limitations, every effort was taken to make this inventory as complete and representative as possible.

To the extent possible, the national inventory for the year 2000 presents estimates of anthropogenic emissions for the following three gases by sources and removals by sinks: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Due to data limitations, information on other gases not controlled by the Montreal Protocol has not been reported.

The following sectors are covered in the inventory: Energy, Agriculture, Land Use Change and Forestry, and Waste. In its INC, Cambodia reported emissions from cement manufacturing for the year 1994. However, the company has since ceased its activities, and was not in operation in the year 2000. Cambodia does not currently process or produce minerals, chemicals or metals. Thus for the purpose of reporting, Cambodia's emissions are not reported for industrial processes. The Solvent and Other Product Use sector is only a significant source of non-methane volatile organic compounds (NMVOCs). As no other GHGs are emitted in significant amounts from the use of solvents and data are not available in Cambodia, their emissions are not reported here.

3.2 National GHG emission and removal in 2000

3.2.1 Overview of GHG emissions

Cambodia's GHG emission was estimated at 47,709.06 GgCO_2-eq in 2000 and removal was 48,165.86 GgCO_2-eq. The net emission after accounting for the removal was -456.81 GgCO_2-eq. Hence, Cambodia remained a net sink country in the year 2000. In 1994 Cambodia was able to offset approximately 5,142 GgCO_2-eq of global GHG emissions (MoE 2002).

The estimated emissions in 2000 for the three main GHGs were 24,911.32 Gg for CO_2, 945.95 Gg for CH_4, and 9.46 Gg for N_2O. The contributions of sectors towards these totals can be seen below (Table 3.1).

[4] The cases where default emission data have not been used are noted in the text. In all other cases, default data have been adopted.

Table 3.1: Total emissions and removals by sector for the year 2000 (Gg)

GHG source and sink categories	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	Total CO_2-eq
Energy	2,052.59		28.19	0.40	2,767.30
Agriculture			875.52	8.79	21,112.16
Land Use Change & Forestry	22,858.73	-48,165.86	32.06	0.22	-24,565.50
Waste			10.18	0.05	229.24
Total	**24,911.32**	**-48,165.86**	**945.95**	**9.46**	**-456.81**

The highest contributor was Land Use Change and Forestry (LUCF), which accounted for about 49% of total national emissions, followed by agriculture with 44%, energy (6%) and waste (less than 1%). See Figure 3.1.

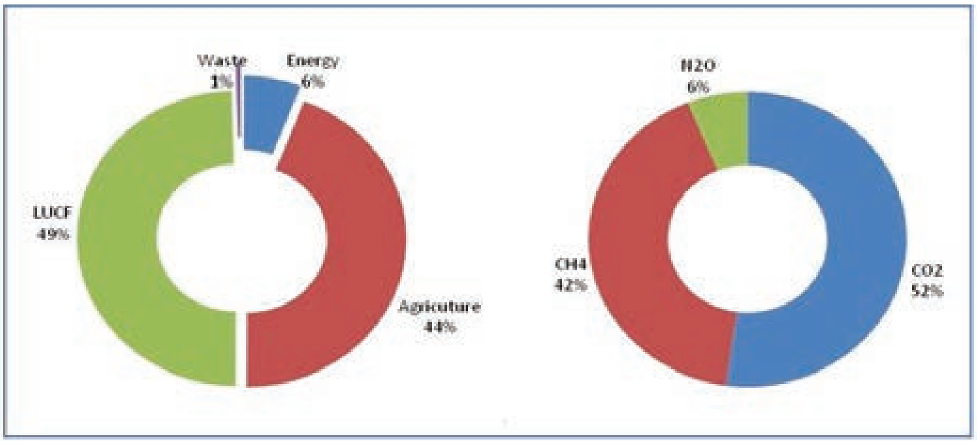


Figure 3.1: Percentage of emissions by sector and gases for the year 2000 (in CO_2-eq)

Forest and grassland conversion plays an important role in CO_2 emission in the Land Use Change and Forestry sector, accounting for 22,858.73 GgCO_2-eq or 95% of the sector's emissions. However, changes in forest and other woody biomass stocks and abandonment of managed lands removed 48,165.86 GgCO_2-eq.

The residential sub-sector is the main source of GHG emission within the energy sector, which accounted for 883.66 GgCO_2-eq (or approximately 31%) followed by the transport sub-sector and energy production. In agriculture, rice cultivation was the highest contributor of methane emissions, followed by enteric fermentation from domestic livestock. Methane emissions from the waste sector remained minimal. Table 3.2 provides a more detailed sectoral overview of Cambodia's 2000 GHG inventory.

Table 3.2: Summary of Cambodia's national GHG inventory for the year 2000

National GHG inventory of anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol and GHG precursors								
GHG source and sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NOx (Gg)	CO (Gg)	NMVOCs (Gg)	SOx (Gg)
Total national emissions and removals	24,911.32	-48,165.86	945.95	9.46	33.04	925.58	62.71	0.00
1. Energy	2,052.59	0.00	28.19	0.40	22.80	522.80	62.71	0.00
A. Fuel combustion (sectoral approach)	2,052.59	-	28.19	0.40	22.80	522.80	62.71	0.00
1. Energy Industries	383.59	-	0.02	0.00	1.02	0.08	0.03	0.00
2. Manufacturing industries and construction	313.66	-	0.10	0.01	1.12	8.60	0.16	0.00
3. Transport	704.76	-	0.11	0.01	7.17	36.45	6.91	0.00
4. Other sectors	462.38	-	27.95	0.37	13.23	477.62	55.60	0.00
5. Other	188.19	-	0.03	0.00	0.26	0.05	0.01	0.00
B. Fugitive emissions from fuels	0.00	-	0.00	-	0.00	0.00	0.00	0.00
1. Solid fuels	-	-	0.00	-	0.00	0.00	0.00	0.00
2. Oil and natural gas	-	-	0.00	-	0.00	0.00	0.00	0.00
2. Industrial processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A. Mineral products	0.00	-	-	-	0.00	0.00	0.00	0.00
B. Chemical industry	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
C. Metal production	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
D. Other production	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
E. Production of halocarbons and Sulphur hexafluoride	-	-	-	-	-	-	-	-
F. Consumption of halocarbons and Sulphur hexafluoride	-	-	-	-	-	-	-	-
G. Other (please specify)	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
3. Solvent and other product use	0.00	-	-	0.00	-	-	0.00	-
4. Agriculture	-	-	875.52	8.79	2.27	122.24	0.00	0.00
A. Enteric fermentation	-	-	163.82	-	-	-	-	-
B. Manure management	-	-	22.37	1.11	-	-	0.00	-
C. Rice cultivation	-	-	684.05		-	-	0.00	-

D. Agricultural soils	-	-	-	7.62	-	-	0.00	-
E. Prescribed burning of savannahs	-	-	2.19	0.03	0.98	57.44	0.00	-
F. Field burning of agricultural residues	-	-	3.09	0.04	1.30	64.80	0.00	-
G. Other (please specify)	-	-	0.00	0.00	0.00	0.00	0.00	
5. Land-use change and forestry	22,858.73	-48,165.86	32.06	0.22	7.97	280.54	0.00	0.00
A. Changes in forest and other woody biomass stocks	0.00	-27,208.26	-	-	-	-	-	-
B. Forest and grassland conversion	22,858.73	0.00	32.06	0.22	7.97	280.54	-	-
C. Abandonment of managed lands	-	-20,957.60	-	-	-	-	-	-
D. CO_2 emissions and removals from soil	0.00	0.00	-	-	-	-	-	-
E. Other (please specify)	0.00	0.00	0.00	0.00	0.00	0.00	-	-
6. Waste	-	-	10.18	0.05	0.00	0.00	0.00	0.00
A. Solid waste disposal on land	-	-	9.69	-	0.00	-	0.00	-
B. Wastewater handling	-	-	0.49	0.05	0.00	0.00	0.00	-
C. Waste incineration	-	-	-	-	0.00	0.00	0.00	0.00
D. Other (please specify)	-	-	0.00	0.00	0.00	0.00	0.00	0.00
7. Other (please specify)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Memo items	-	-	-	-	-	-	-	-
International bunkers	55.55	-	0.00	0.00	0.00	0.00	0.00	0.00
Aviation	55.55	-	0.00	0.00	0.00	0.00	0.00	0.00
Marine	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
CO_2 emissions from biomass	9,193.33	-	-	-	-	-	-	-
Total national emissions and removals	24,911.32	-48,165.86	945.95	9.46	33.04	925.58	62.71	0.00
EQUIVALENT CO_2	24,911.32	-48,165.86	19,864.93	2,932.81				
NATIONAL CO_2-eq EMISSIONS/REMOVALS	-456.81							

Note: CO_2 emissions from biomass and international bunkers are excluded from the national emissions

3.2.2 Uncertainty analysis

Uncertainties may be broadly divided into uncertainties associated with emission factors and uncertainties associated with activity data. Because of the absence of specific national emission factors, the GHG inventory conducted for Cambodia for the year 2000 has made extensive use of IPCC default emission values. These factors have been measured under particular circumstances, which may not accurately reflect the Cambodian context. Activity data used in the Cambodian inventory have been collected by national and international agencies. However, for several sectors data are only irregularly collected or remain unavailable. Thus uncertainty levels are high for the source categories approach of the energy sector, as well as the LUCF sector. Table 3.3 summarizes the uncertainties in activity data.

Table 3.3: Summary of uncertainties associated with activity data

Sector	Uncertainty level	Availability of data
Energy - Reference approach	Medium	Fuel imports recorded annually Uncertainties regarding extent of smuggling of fuel across border
Energy – Source categories approach	High	No regular data collection and lack of data Assessment based on fuel consumption studies by international organizations and NGOs Energy consumption statistics by state electricity utility available, but little data on independent power producers and auto-generators (industry, commercial, residential) No national data on transport sector (air, road, boat), with the exception of rail
Agriculture	Medium	Data collected annually for most activities, including crops and livestock production Synthetic fertilizer use not comprehensively recorded
Land Use Change and Forestry	High	No regular data collection Inventory based on extrapolation of 1992/93 and 1996/97 forest assessment Concerns about reliability of harvesting/logging statistics due to illegal logging activities No existing soil classification (land use by mineral and organic soil types not available)
Waste	Medium	No regular data collection and lack of data Assessment based on urban population estimates and primary data for factory production

3.3 Emissions of greenhouse gases by sector

3.3.1 Energy

The calculation of CO_2 emissions in the energy sector applied both sectoral and reference approaches. Following the IPCC Reference Approach, emissions are estimated from the carbon content of fuels supplied to the country as a whole. The Cambodia Import Export Inspection and Fraud Repression Department (CAMCONTROL) of the Ministry of Commerce records imports of all fuels to Cambodia annually. Based on CAMCONTROL, in the year 2000, 630 kilotons of petroleum products with a value of US$162 million were imported. Total CO_2 emissions from fuel combustion using a reference approach accounted for 2,047.56 Gg, slightly lower than those using a sectoral approach, in terms of CO_2 emission.

In the IPCC sectoral approach, emissions are estimated from the carbon content of fuels supplied to the main fuel combustion activities. This approach requires data and emission factors that are not currently available in Cambodia.

Based on the sectoral approach, the total emissions from fuel combustion are the largest contributing source to energy sector emissions, and are estimated at 2,767.30 $GgCO_2$-eq, in which the emission of CO_2 contributes approximately 74% of total emissions, CH_4 only contributes approximately 21% and N_2O contributes approximately 5% for this category.

In terms of emissions in CO_2-eq, the main source of GHG emissions in the energy sector from fuel combustion activities is the residential sub-sector, which accounts for 883.66 $GgCO_2$-eq (or approximately 31%). This is due to biomass consumption for cooking in households. The second contributor to the national emissions from fuel combustion is transportation, which accounts for 708.82 CO_2-eq (approximately 26%), followed by energy industries, which account for 384.85 CO2-eq (approximately 14%). Sectors and sub-sectors without data are omitted from Table 3.4.

Table 3.4: Overview of emissions for energy sector

SECTORAL REPORT FOR NATIONAL GHG INVENTORIES (Gg)				
GHG SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**	**CO_2-eq**
Total Energy	2,052.59	28.19	0.40	2,767.30
Fuel Combustion Activities (Sectoral Approach)	2,052.59	28.19	0.40	2,767.30
1. Energy Industries	383.59	0.02	0.00	384.85
2. Manufacturing Industries and Construction	313.66	0.10	0.01	320.01
3. Transport	704.76	0.11	0.01	708.82
a. Civil Aviation	0.00	0.00	0.00	
b. Road Transportation	695.92	0.11	0.01	699.95
c. Railways	8.84	0.00	0.00	8.87
4. Other Sectors	462.38	27.95	0.37	1,164.41
a. Commercial/Institutional	61.64	0.30	0.00	68.50
b. Residential	189.34	27.63	0.37	883.66
c. Agriculture/Forestry/Fishing	211.40	0.01	0.00	212.24
5. Other (please specify)	188.19	0.03	0.00	189.21
Memo Items[1]				
International Bunkers	55.55	0.00	0.00	
Aviation	55.55	0.00	0.00	
Marine	0.00	0.00	0.00	0.00
CO2 Emissions from Biomass	9,193.33			

Note: [1] International Bunkers and CO_2 emission from biomass are excluded from the national emissions.

3.3.2 Agriculture

For the agriculture sector, GHG emissions are estimated from five sources:

1. Domestic Livestock: Enteric Fermentation and Domestic Livestock (CH_4 and N_2O emissions);
2. Rice Cultivation: Flooded Rice Fields (CH_4);
3. Prescribed Burning of Savannahs (CH_4, CO, N_2O, NO_x);
4. Field Burning of Agricultural Residues (CH_4, CO, N_2O, NO_x);
5. Agricultural Soils (CH_4, CO_2, N_2O).

Data used to estimate the emission from this sector were collected from statistics reported by the Ministry of Agriculture, Forestry and Fisheries (MAFF 2003). From the analysis it was found that in 2000, total emissions of the two main GHGs (CH_4, and N_2O) from this sector reached 21,112.16 GgCO_2-eq. Methane contributed approximately 99% of the total emissions, while N_2O contributed only 1%.

Domestic livestock. The common livestock of Cambodia are cattle, buffalo, swine and poultry. Ruminants, cattle and buffalo, emit high emissions, while swine and poultry (non-ruminants) have significantly lower methane emissions. Annual statistics on animal populations are provided by MAFF (2003). Three-year averages are estimated as follows: 2.8 million non-dairy cattle, 0.7 million buffalo, 2.1 million swine and 13.8 million poultry. Horse, sheep and goat populations are not recorded in Cambodia, however their numbers are presumed to be low. The total GHG emissions from enteric fermentation and manure management (non-dairy cattle, buffalo, swine, poultry) are estimated at 4,253.21 GgCO_2-eq, in which 3,440.31 GgCO_2-eq was emitted from enteric fermentation and 812.90 GgCO_2-eq from manure management (Table 3.5).

Rice cultivation. A total area of approximately 2.08 Mha of paddy was harvested in the year 2000, with 1.85 Mha harvested in the wet season and 233,000 ha in the dry season. Dry season paddy is irrigated (continuously flooded), while wet season is rain-fed and flood prone (MAFF 2003). Based on methodologies set by IPCC-GPG, the methane emission from rice production is estimated by multiplying the disaggregated harvested area by the appropriate emission factor under different ecosystems, water management regimes, soil and other conditions under which CH_4 will be affected. The emission from rice cultivation in Cambodia in 2000 was estimated at 14,365.01 GgCO_2-eq.

Prescribed burning of savannas. The area of grassland in Cambodia in 2000 was derived from forest cover assessments conducted in 1992/93 and in 1996/97 by the Forest Cover Monitoring Project MRC/GTZ. It was estimated at 497,000 ha. The total emission from prescribed burning of savannas was estimated at 54.34 GgCO_2-eq.

Field burning of agricultural residues. Production for the year 2000 of the following crops which produce residues burned in fields as recorded by MAFF were: maize/corn (101 Gg), rice (3,862 Gg), beans (13 Gg), soya (30 Gg) and peanuts (8 Gg). As there are no national statistics on crop residues, default values are used for the residue-to-crop ratio. Field burning of agricultural residues was estimated to have emitted 75.91 GgCO_2-eq in the year 2000.

Agricultural soils (estimating amount of N input). FAO statistics only report total fertilizer consumption in Cambodia for the years 1980 and 1990, without any data on nitrogen used. The Department of Agricultural Legislation of MAFF started recording fertilizer imports into Cambodia in 2003 (MAFF 2008). The total use of nitrogen can be estimated annually as MAFF reports the types, compositions and quantities of synthetic fertilizers imported. However, annual figures from 2003 to 2007 have fluctuated from year to year without any clear pattern. Thus, a conservative approach is to average the annual total amount of nitrogen imported, yielding a mean of 25,649 tons. Production levels of non-N fixing crops (maize/corn, rice, peanut) and production of pulses and soybeans for 2000 are recorded by MAFF.

Total N_2O emissions from agricultural soils were estimated at 7.62 Gg or 2363.69 GgCO_2-eq (Table 3.5).

Table 3.5: Emissions from agriculture sector

GHG source categories	CH_4 (Gg)	N_2O (Gg)	CO_2-eq
Enteric fermentation	163.82		3440.31
Manure management	22.37	1.11	812.90
Rice cultivation	684.05		14,365.01
Agricultural soils		7.62	2,363.69
Prescribed burning of savannahs	2.19	0.03	54.34
Field burning of agricultural residues	3.09	0.04	75.91
Total	**875.52**	**8.80**	**21,112.16**

3.3.3 Land use change and forestry

LUCF can be a source or a sink for CO_2. The GHG emissions from the LUCF sector occur mainly from human activities that affect the biosphere's capacity to absorb or release carbon into the atmosphere. Most of these anthropogenic interventions are in the form of land-use conversions and deforestation activities. The net release or uptake of GHG is a function of two basic biophysical processes:

1. Changes in forest/woody carbon stocks due to the net annual bio-mass growth of existing forest and non-forest stands, and possible biomass re-growth in abandoned lands;
2. Land-use and forest conversion practices, which affect the carbon chemistry of the atmosphere via biomass burning, decay and soil carbon release or removal.

Estimating carbon emissions and removals from LUCF is complicated due to the complexity of biological factors and a lack of reliable data. It requires accurate and reliable activity data, especially with regard to forest areas, the rate of annual change of land use, area of forests converted, the annual growth rate of biomass and the biomass density of forests.

Activity data, when available in Cambodia, are generally spatially coarse and need to be complemented by global estimates or secondary statistics. For this reason the 2000 inventory adopted the Tier 1 approach. The calculations of emissions from land-use change and forestry focus on three activities, which are sources or sinks of CO_2:

1. Changes in forest and other woody biomass stocks;
2. Forest and grassland conversion;
3. Abandonment of managed lands.

The IPCC guidelines point out that there are large uncertainties or errors associated with these calculations.

The total emission of CO_2 from forest and grassland conversion by burning aboveground biomass on-site and off-site is estimated at 22,858.73 Gg (Table 3.6). The estimate of nitrogen released from the on-site burning of forests is based on the quantity of carbon released from on-site burning. Thus, in 2000 land use change and the forestry sector emitted 22,858.73 CO_2-eq. At the same time, changes in forest and other woody biomass stocks and abandonment of managed lands absorbed CO_2 of 27,208.26 Gg and 20,957.60 Gg, respectively, which resulted in a net sink of about 25,307.13 GgCO_2-eq in LUCF.

Table 3.6: GHG emissions and removals from land use change and forestry in Gg[1]

LUCF GHG source and sink categories	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	Total CO_2-eq
Changes in forest and woody biomass stocks	0.00	-27208.26	-	-	-27,208.26
Forest and grassland conversion	22,858.73	0.00	32.06	0.22	23,600.36
Abandonment of managed lands	-	-20,957.60	-	-	-20,957.60
Total	22,858.73	-48,165.86	32.06	0.22	-24,565.50

Note: [1] The formula does not provide a total estimate of both CO_2 emissions and CO_2 removals. It estimates 'net' emissions of CO_2 and places a single number in either the CO_2 emissions or CO_2 removals column, as appropriate. Note that for the purposes of reporting, the sign for removals is always (-) and for emissions (+).

3.3.4 Waste

In Cambodia, solid waste disposal and wastewater handling are the main sources of methane, while human sewage is the main source of NO_2.

The total annual municipal solid waste (MSW) channelled into solid waste disposal systems (SWDS) in Cambodia is estimated at 170 Gg. In the absence of national data, following IPCC Guidelines, it is assumed that all waste is disposed to unmanaged sites. The amount of recovered methane per year is zero. The Japan Waste Research Foundation conducted a feasibility and small-scale pilot project in 2003 on the Phnom Penh landfill waste site, but to date there has been no implementation of gas flaring or energy recovery schemes from waste in Cambodia (JWRF 2004, Williamson et al. 2004).

Only the urban population is used for estimating methane emissions from wastewater handling, as wastewater produced in rural Cambodia is assumed to receive little or no treatment.

There was no methane recovery or flaring facility in Cambodia in the year 2000. Thus, the amount of methane recovered/flared from industrial wastewater was zero. Net methane emissions from the selected industrial wastewater were negligible and amounted to less than one Gg in the year 2000.

For estimating the NO_2 from human sewage, the protein consumption in Cambodia has been estimated at 51 g/capita/day over the period 2001-2003 (FAOSTAT), or equivalent to 18.6 kg/capita/year.

Based on available data, the total net emissions from the waste sector in the year 2000 were estimated at 229.24 $GgCO_2$-eq, of which methane contributed approximately 93% from solid waste disposal on land and wastewater handling, while N_2O contributed about 7%. Table 3.7 provides an overview of GHG emissions from the waste sector.

Table 3.7: GHG emissions from waste sector

GHG source categories	CH_4	N_2O	Total CO_2-eq
Solid waste disposal on land	9.69		203.46
Wastewater handling	0.49	0.05	25.78
Waste incineration			0.00
Other (please specify)	0.00	0.00	0.00
Total	**10.18**	**0.05**	**229.24**

3.4 Key source category analysis

A *key source category* is one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct GHGs in terms of the absolute level of emissions, the trend in emissions, or both (IPCC GPG 2000). By identifying these key source categories, it is possible for national stakeholders to prioritize their efforts on a few categories in order to improve overall estimates.

The Tier 1 method to identify key source categories assesses the impacts of various source categories on the level and, if possible, the trend, of the national emissions inventory (IPCC GPG 2000). Cambodia conducted its GHG inventory for two different years, 1994 and 2000. Thus, level and trend assessment for key categories were conducted.

The source category level assessment determines a source's contribution to the total estimate (IPCC GPG 2000). Key source categories, when added together in descending order of magnitude, add up to more than 95% of total national GHG emissions (Table 3.8). The key sources of emissions are seen to be rice production and enteric fermentation in domestic livestock.

Table 3.8: Key source level assessment results

Inventory Categories	Base Year Estimate 1994 ($GgCO_2$-eq)	Current Year Estimate 2000 ($GgCO_2$-eq)	Total	Cumulative Sum
CH_4 emissions from rice production	3158.36	14365.01	57.9%	57.93%
CH_4 emissions from enteric fermentation in domestic livestock	3417.69	3440.31	13.9%	71.80%
N_2O (direct and indirect) Emissions from agricultural soils	2209.21	2363.69	9.5%	81.34%
Residential CH_4	713.37	1142.88	4.6%	85.94%
CO_2 Mobile combustion: road vehicles	825.25	774.39	3.1%	89.07%
CO_2 Emissions from energy industry	331.31	546.12	2.2%	91.27%
CH_4 Emissions from manure management	462.84	469.79	1.9%	93.16%
N_2O Emissions from manure management	1203.55	343.11	1.4%	94.55%
Residential N_2O	98.90	224.70	0.9%	95.45%

The source category trend assessment looks at the change in the source category emissions over time, computed by subtracting the base year (year 0) estimate for source category x from the current year (year t) estimate and dividing by the current year estimate. The Total Trend is the change in the total inventory emissions over time, computed by subtracting the base year (year 0) estimate for the total inventory from the current year (year t) estimate and dividing by the current year estimate. The trend assessment identifies source categories that have a different trend to the trend of the overall inventory. As differences in trends are more significant to the overall inventory level for larger source categories, the result of the trend difference is multiplied by the result of the level assessment to provide appropriate weighting. Thus, key source categories will be those where the source category trend diverges significantly from the total trend, weighted by the emission level of the source category. Based on the trend assessment, eight key sources were identified (Table 3.9).

Table 3.9: Key source trend assessment results

Trend Assessment Results	Base Year (1994) Estimate ($GgCO_2$-eq)	Trend Assessment (%)	Cumulative Sum (%)
CH_4 Emissions from rice production	3,158	46.99	46.99
CH_4 Emissions from enteric fermentation in domestic livestock	3,418	17.95	64.93
N_2O Emissions from manure management	1,204	11.26	76.19
N_2O (direct and indirect) Emissions from agricultural soils	2,209	10.81	86.99
CO_2 Mobile combustion: road vehicles	728	3.58	90.58
CH_4 Emissions from manure management	463	2.41	92.98
N_2O Emissions from wastewater handling	130	1.34	94.32
Other Sectors: Residential CH_4	713	1.33	95.66

4. Vulnerability and Adaptation to Climate Change

4.1 Introduction

As an agrarian country, Cambodia is highly vulnerable to the impacts of climate change and variability. The country's entire agricultural production system depends either on rainfall or on the annual flooding and recession of Tonle Sap Great Lake. It is therefore particularly sensitive to potential changes in local climate and monsoon regimes (MoE 2001). A recent study for Southeast Asia found Cambodia to be one of the most vulnerable countries in the region (Yusuf and Francisco 2009). Cambodia's 435 km coastline and large parts of the Mekong River flood plain could be severely affected by sea level rise. As a tropical country, Cambodia is vulnerable to a number of tropical diseases, such as malaria and dengue fever (MoE 2001). Weak health care systems, combined with poverty and a high illiteracy rate make people more vulnerable to diseases which might become more widespread due to climate change.

Extreme climatic events have caused serious damage to the welfare of the Cambodian people and to the economy, as discussed in section 2.4. Under a changing climate, these natural hazards may occur more frequently, and the poor are likely to be disproportionately affected.

4.2 Vulnerability assessment

4.2.1 Scope of assessment

A general vulnerability assessment was done using community data (section 4.2.1) along with an assessment of climate vulnerability at the provincial level (section 4.2.2). It includes a case study of Prey Veng, the province considered most vulnerable to climate change in Cambodia.

In its INC, Cambodia developed climate change scenarios and analysed their impact on sectors. The climate change scenarios were developed using MAGICC-SCENGEN (Hulme et al. 2000), a programme which links emission scenarios with global and regional climate change models. All the impact models used in the INC were statistically based (mostly based on regression analysis).

In the SNC, Cambodia has adopted a regional climate model (PRECIS) in combination with a number of General Circulation Models (GCM), run by the Climate Risk Assessment Division, the Centre for Global Environmental Research and the National Institute for Environmental Studies (NIES), with a resolution of 100 km x 100 km (Masutomi et al. 2009). To cope with the scarcity of historical climate data in evaluating the impact of current climate variability on sectors, long-term historical climate data have been reconstructed using PRECIS for the whole of Cambodia. A dynamic-based impact model was adopted for the agriculture sector.

The objectives of the vulnerability and adaptation assessment for Cambodia are to:

1. Assess historical and future climate change in Cambodia using reconstructed data from PRECIS and GCMs;
2. Assess the vulnerability of Cambodia to climate change and its capacity to manage climate risk;
3. Evaluate the historical and future socio-economic impact of extreme climate events on the Cambodian society;
4. Estimate the impact of climate change on the agriculture and forestry sector, water resources, human health and coastal zone;
5. Develop adaptation options in the agriculture and forestry sectors, water resources, human health and the coastal zone.

4.2.2 Vulnerability analysis at the community scale

In order to understand the variation in vulnerability between communities, a **Vulnerability Index** for Cambodia was developed as part of the analysis for the SNC. It was based on community data collected by UNDP in 2006 and 2008 (Rizaldi Boer et al. 2011). The main part of this chapter is based on this study, and the UNFCCC guidelines and manual for Non-Annex I parties (UNFCCC 2002).

The Vulnerability Index is based on three main indicators - socio-economic status, infrastructure and population (following methods outlined in UNFCCC, 2002). The socio-economic indicator is based on the condition of education facilities in the community, key occupations of the community, the source of household drinking water and access to drinking water. The infrastructure indicator is based on sanitation conditions, the availability of piped drinking water, electricity and housing facilities, as well as the distance of the community to the district office. The population indicator is based on population density and a dependency ratio, i.e. the ratio between the population aged under 15 or over 65 years old, to the population aged 15 to 65 years old.

The **socio-economic index** for Cambodia's communities ranges from 0.29 to 0.94, with a high index reflecting greater vulnerability. In 2006, only Poi Pet (Banteay Meanchey), Sla Kram (Siem Reap) and Kraek (Kampong Cham) communes had a socio-economic index of less than 0.5. Most of the communities located at a distance from the Tonle Sap Lake and Mekong River have a socio-economic index of more than 0.8, while communities in the immediate surroundings of the Tonle Sap Lake and Mekong River have a socio-economic index of between 0.5 and 0.8. Between 2006 and 2008 there was a slight improvement in the socio-economic condition, particularly in communities located near the Mekong River.

The **infrastructure index** is quite homogenous and poor across communities in Cambodia. Most communities have an infrastructure of more than 0.8, except for a few, such as Dangkor, Prek Pra and Teuk Thla in Phnom Penh capital city, with an index of 0.33, 0.29 and 0.20 respectively in 2006. In general, there was a slight improvement in the condition of infrastructure in Cambodia between 2006 and 2008.

The population index is also quite homogenous across communities. A higher population index is found in the communities surrounding the Tonle Sap Lake. One of the communities near the Mekong River, Cheung Thuek in Prey Veng Province, has a population index equal to 1. This means that it has the highest population density and dependency ratio, and hence a high level of exposure to climate hazards.

The population index could change quite rapidly in the future due to population growth. Between 2002 and 2008 for example, the population increased significantly, particularly in communities surrounding the Tonle Sap. If the population growth experienced between 2002 and 2008 (average of 1.54%) continues, most communities will have a population size of more than 30,000 people by 2050, thereby increasing the level of exposure to hazards.

The three indices (socio-economic, infrastructure and population) were combined to provide an overall vulnerability index. From 2006 to 2008, the number of communities categorized as very vulnerable decreased slightly. These communities are now vulnerable or less vulnerable (Figure 4.1).

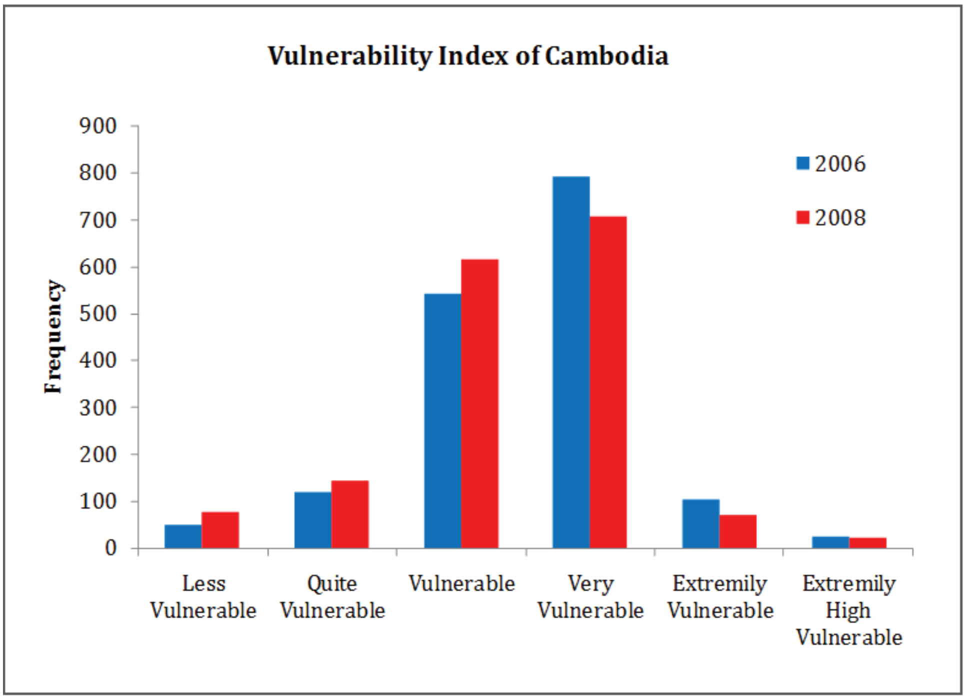


Figure 4.1: Number of communities according to vulnerability category

Most communities in Cambodia are categorized as vulnerable to extremely vulnerable. Phnom Penh, one of the most densely populated cities in Cambodia, is categorized as an extremely vulnerable area. The vulnerability index of communities surrounding the Mekong River and Tonle Sap Lake is increasing, mainly due to the rapid increase in population, while the index for those far from the Mekong River and the Tonle Sap Lake is decreasing. Overall, there is a tendency for lower vulnerability for the more vulnerable communities and a slight increase for the less vulnerable ones.

The analysis demonstrates that a high population growth rate, especially in more populated areas, unaccompanied by improvements in infrastructure and socio-economic conditions, might increase Cambodia's vulnerability. The approach developed for the SNC could potentially be used as a monitoring tool demonstrating changes in the socio-economic and infrastructure conditions in the communities over time. It could also be used to help local governments plan development.

4.2.3 Assessing the impacts of extreme climatic events

The impact of extreme climate events on the livelihoods of communities and sectors was further assessed through a survey in Prey Veng Province, considered to be most prone to climate risk. This province was selected based on a vulnerability assessment of all provinces using a **Cambodian Climate Vulnerability Index** (CCVI).

The CCVI was developed based on six indicators that, together, present a picture of the capacity of a society to cope with climate risk:

1. Infant mortality rates (deaths per 1,000 live births);
2. Percentage of residential structures classified as temporary;
3. Human Poverty Indices;
4. Population density;
5. Proportion of population having access to potable water;
6. Human Development Index (HDI).

Provincial data for all of these indicators are taken from the Cambodia Human Development Report (UNDP 2007). The province with the highest value for the first four indicators and lowest value for the last two indicators is considered the most vulnerable.

The climate vulnerability index of each province was combined with a **flood and drought index**. The flood and drought indices are taken from the NAPA Report (MoE 2006). The province with high flood and drought indices is the province where its rice growing areas are frequently and severely affected by flood and drought (the data were from 1982-2002; CRC 2003a and 2003b).

As floods and droughts are strongly influenced by the presence of forests, **forest cover** was added as an index to represent the level of risk of the province to current and future climate variability. These four indices were combined to present an overall CCVI. Figure 4.2 provides an example for Prey Veng Province.

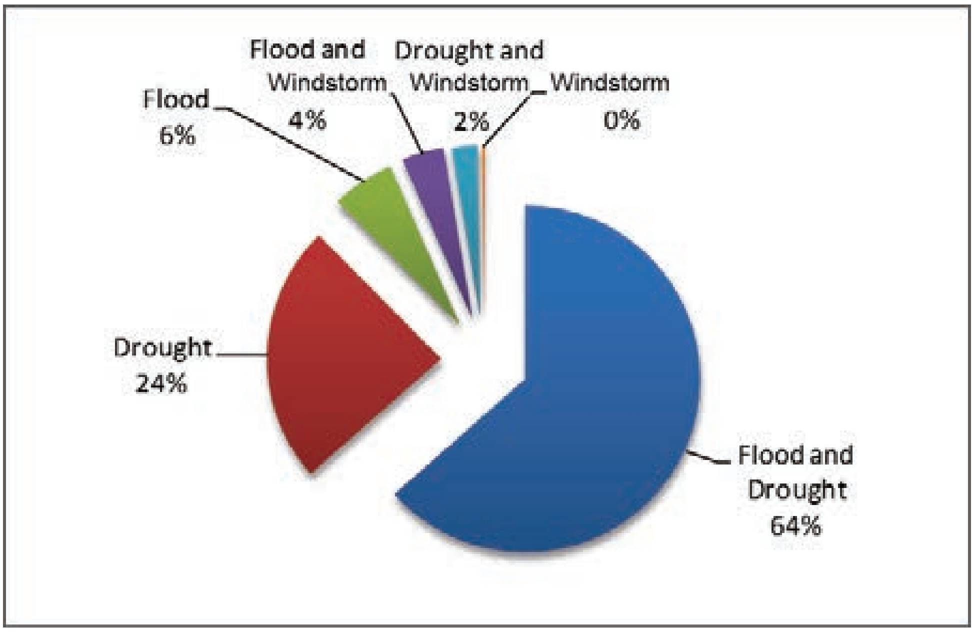


Figure 4.2: Type of climate hazards affecting communities in Prey Veng Province

The main results from the survey in Prey Veng Province (MoE 2006) were:

1. Local people have a high understanding of climatic hazards and their causes. Villagers, when asked in the survey, were clearly aware of changes in hydrological patterns resulting from the construction of dams, dikes and roads and from deforestation, which may increase the frequency and intensity of floods and the sedimentation of water storage structures;
2. The agriculture sector, particularly rice farming, is most affected by climate hazards. About 90% of economic loss due to climate hazards is related to crop harvest failure;
3. The preparedness of villagers for extreme climate events is low, as is their adaptation capacity to climate change. There are cases where local communities are resourceful when dealing with climate hazards, but these are exceptions and usually coincide with settlements with higher social capital and stronger local institutions;
4. Villagers may be aware of possible coping and adaptation mechanisms, such as rehabilitating water storage structures and irrigation canals, building dikes and water control structures and strengthening dwellings against windstorms. However, the lack of financial resources has generally prevented local communities from implementing these projects.

4.3 Historical and future climate change in Cambodia

Based on two GCMs (developed for the southern hemisphere by Australia and for the northern hemisphere by Japan) and MAGICC-SCENGEN from the Centre for Climate System Research (CCSR) and the Commonwealth Scientific and Industrial Research Organization (CSIRO) (NCSP 2000), it was found that the mean deviation between observed rainfall and GCM outputs ranged from 16 mm to 794 mm (model output, as monthly data, higher than observations). The deviations increased considerably in the wet season and decreased in the dry season (MoE 2002). Model outputs were then corrected for those deviations (Rizaldi Boer et al. 2011). Rainfall in Cambodia would increase from current conditions. The magnitude of the increase would vary with location, time, GCMs and the emission scenario. Lowland areas would be more affected than highland areas, according to the models. Under SRESA2, annual rainfall in 2100 would increase between 3% and 35% from current rainfall, depending on location, while under SRESB1 the increase would be smaller.

The two GCMs also suggested that temperatures in Cambodia would increase. However, the increase in temperature between the two models is not the same. Under scenario SRES-A2 (see IPCC 2000), the CCSR model suggested that the mean annual temperature would increase by about 0.60°C in 2025, with a further increase of about 1.00°C and 2.50°C in 2050 and 2100 respectively. The CSIRO model suggested that the increase in temperature from the current year's temperature in 2025, 2050 and 2100 would be about 0.30, 0.70 and 2.00°C respectively. Similarly, under the SRES-B1 scenario (see IPCC 2000), the increase from the current temperature in mean annual temperature in 2025, 2050 and 2100 using CCSR would be about 0.60, 0.90 and 1.60°C respectively, while using CSIRO it would be about 0.45, 0.75 and 1.35°C respectively.

4.4 Key sectors and scope of the V&A assessment

For the SNC, climate change impact and vulnerability were assessed for five sectors, namely agriculture (including water resources and focusing on rice production), forestry, coastal zone and human health. Adaptation options of each sector were proposed to address these climate vulnerabilities (Rizaldi Boer et al. 2011).

4.4.1 Agriculture

Introduction

Rice is the main agricultural commodity in Cambodia. Rice crop cultivated area is 2.58 Mha (NIS 2008), while four other food crops occupy about 13%: corn, cassava, soybean and mung bean (Figure 4.3). The remaining 4% is used for growing vegetables, sesame, peanut, sugarcane, sweet potato, potato, tobacco and jute.

Crop production in Cambodia is significantly correlated with climate. Significant loss in production due to the occurrence of floods and droughts is quite common. The major rice growing areas of the Mekong-Tonle Sap basin, for example, are exposed to flooding every year but in recent years have often been exposed to extreme flooding. Extended periods of flooding in the Mekong River and Tonle Sap Lake have ruined many deep-water rice crops. In La-Nina years, up to one-fifth of the total cultivation area (0.5 Mha) of wet season rice has suffered from flooding. In a normal year, the area experiencing flooding is approximately 10,000 ha. In agriculture areas where temporary flooding occurs, floods cause serious germination problems for some direct-seeded rice and most upland crops, including legumes.

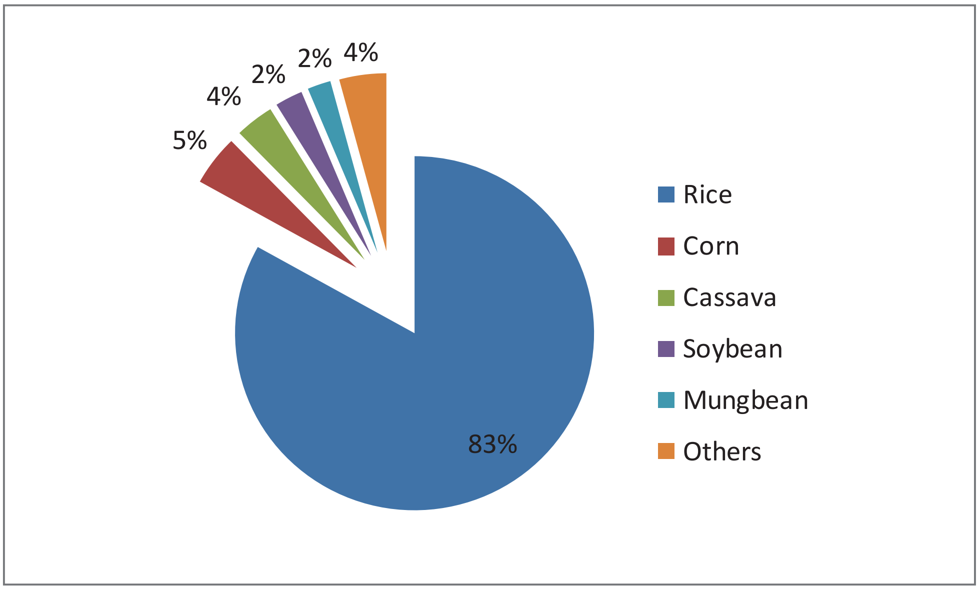


Figure 4.3: Percentage of harvested area of main agriculture commodities in Cambodia in 2007

In addition to drought, pests and diseases are also limiting factors for food crop production in Cambodia. The major pests of rice are gall midge, stem borer, brown plant hopper, green leafhopper, grasshopper, leaf folder, rice bug, case worm, armyworm and rats. The populations of some of these pests are likely to increase significantly under extreme climate conditions (MoE 2002).

Water resources for agriculture

Management of water resources and water related development is important to both macroeconomic growth and rural livelihoods in Cambodia (Batkosal 2009), and with climate change it will become increasingly challenging.

Greater climatic variability, such as increased rainfall irregularity, is expected to intensify competition between the extraction of water for sectoral uses (e.g. domestic water supply, agriculture and industry) and the in-stream water requirements for flow maintenance and ecological preservation. Reliable climate information is therefore required to support the allocation of water resources and for the appropriate operation of irrigation schemes.

Overview of Cambodia's water resources

Cambodia has 22 water catchments[5], many of which are being degraded as a result of the physical alteration of inland water systems, habitat degradation through deforestation, mining, agriculture and urbanization, excessive water withdrawal (especially for agriculture) and fisheries mismanagement (Carmen et al. 1998). These pressures affect both water quality and quantity.

Studies of climate change impacts on Cambodian river basins

Keskinen et al. (2009) conducted a preliminary study of the impact of climate change on the Mekong River Basin that revealed that climate change is likely to bring significant changes to the Basin, with the most significant impacts being felt in the longer term, i.e. towards the end of 2049. However, there are also non-climatic factors impacting the Mekong flows, such as the construction of large hydropower dams and reservoirs, large irrigation schemes and rapid urban development in the upper catchment of the Mekong River (Kummu and Sarkkula 2008, Keskinen et al. 2009). These developments impact both the quantity and

[5] These catchments are Prek Thnot, Siembok, Prek Chhlong, Prek Te, Prek Kampi, Sre Pok, Prek Krieng, Prek Preah, Se San, O Talas, Steung Sreng, Steung Sisophon, Steung Mongkol Borey, Steung Sangker, Steung Dauntri, Steung Pursat, Steung Baribo, Steung Chinit, Steung Sen, Steung Staung, Steung Chikre, Steung Siem Reap (MRC, 2000).

quality of the flow. The dry season water level is estimated to increase in the floodplains due to both hydropower development and climate change. Given the strong negative impacts of increased dry season water levels on the floodplain ecosystems, these kind of combined impacts are a serious concern, particularly for the Tonle Sap with its high fish production. They warrant careful study.

Keskinen et al. (2009) also found that in the case of the Tonle Sap, the impacts of changing climate will largely be felt through changes in the flows of the Mekong River, altering the area's unique flood pulse system, and therefore, also the high aquatic productivity of the lake-floodplain system. In terms of hydrological impacts, the future flood pulse in the Tonle Sap and the Cambodian floodplains during the wet season is likely to be wetter, with higher water levels and more extensive flooded areas. The duration of the floods is expected to be longer. The average water level during the dry season is also likely to increase.

Impact of climate change on the soil water balance

Only a small fraction of the river flow can be extracted for agriculture, as large areas of agriculture land are situated away from rivers and have no irrigation facilities. As a consequence, most agricultural areas in Cambodia are rain-fed. The next analysis focuses on the impact of climate change on soil water balance as this provides information on how the change in rainfall will affect the water availability in the soil.

The approach adopted is based on Thornthwaite and Mather (1955) and Nasir (1993). To evaluate the impact of climate change, the median of rainfall and temperature data of 14 GCMs, run under two emission scenarios and three time periods, were used as inputs to the soil water balance model.

The result of the analysis suggests that monthly soil water content can be grouped into seven soil water patterns. It is assumed that the optimum soil water content for crop growth is between 50% and 100% of the field capacity. The length of the growing period in areas with Patterns 1 and 2 will be about seven months, areas with Patterns 3, 4 and 5 will be about five months, areas with Pattern 6 will be three months and those with Pattern 7 will be about two months (Figure 4.4). Regions with Patterns 1 and 2 have the same growing period, but the start of planting season in regions with Pattern 1 is May, one month earlier than regions with Pattern 2. Similarly, for regions with a growing period of five months, the start of planting season is also different. The start of planting season for region 3 is June, region 4 is July and region 5 is August. For regions with Patterns 6 and 7, the growing periods are less than or equal to three months, meaning that without additional water supply from irrigation, these regions will be exposed to a higher drought risk than other regions.

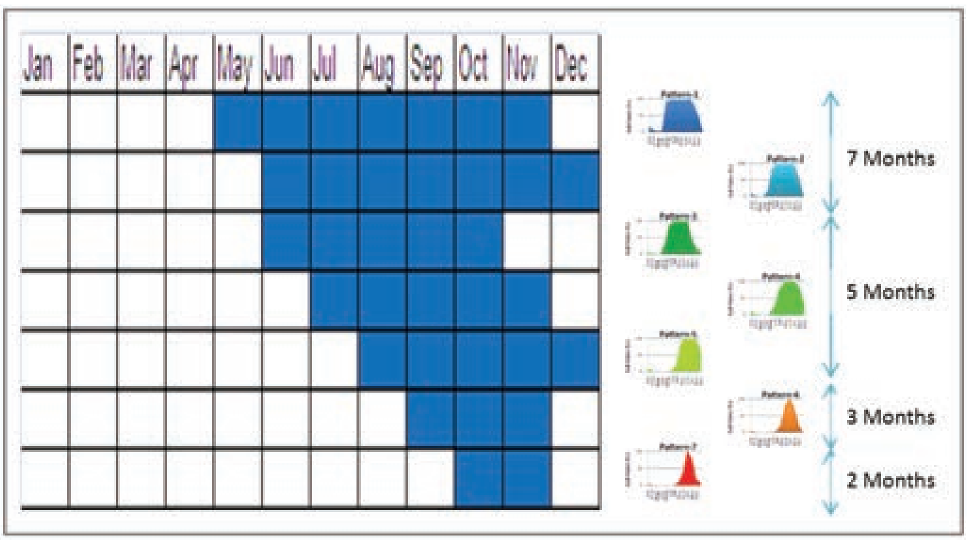


Figure 4.4: Length of growing season/period (LGP) in the seven patterns

Figure 4.5 provides an overview of soil water patterns for Cambodia under current (the baseline) and future climate. In 2025, most of the northeast region of Cambodia (Pattern 4) will have a longer growing period, irrespective of emission scenarios. Under the current climate, most of the northeast region has a growing period of about five months; in 2025 it will have a growing period of about seven months. Thus, the soil water pattern for this region will change from Pattern 4 to Pattern 2. For other regions the LGP will decrease.

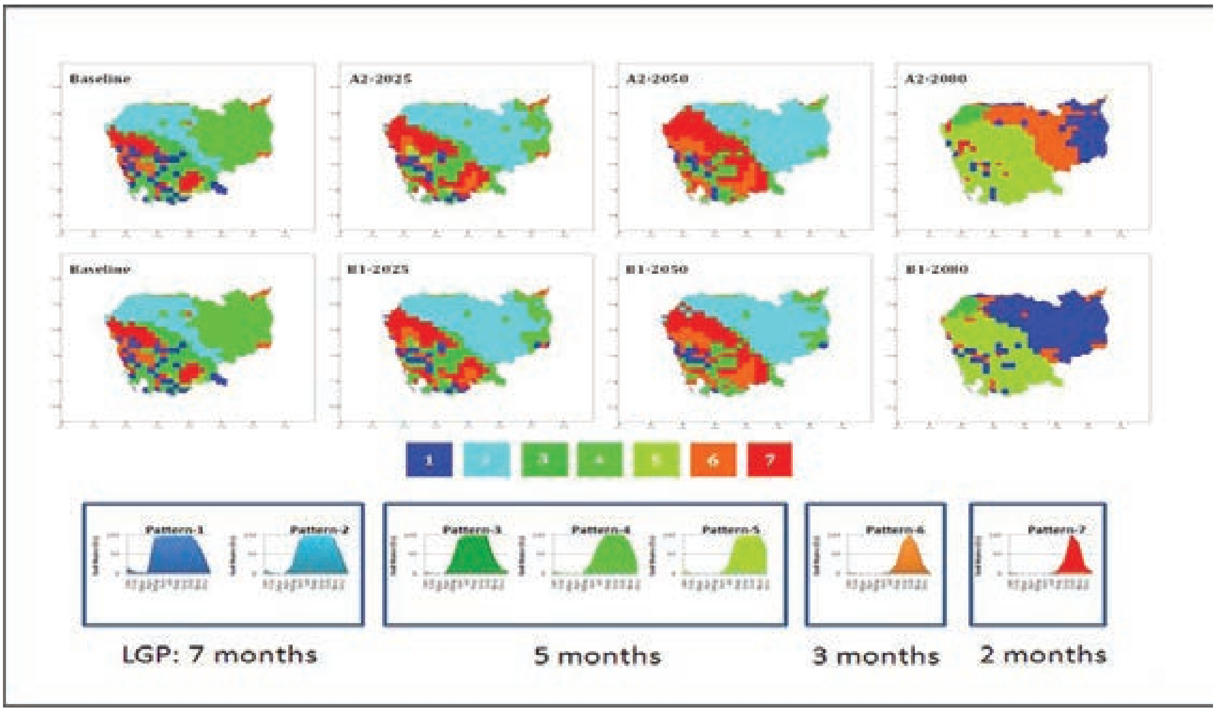


Figure 4.5: Maps of areas with soil water patterns under current and future climate

Focusing this analysis on agriculture areas, until 2050 the agricultural regions with LGP of between two and three months will increase, irrespective of the emission scenario. Under the current climate, the percentage of agricultural areas with LGP of about two to three months is about 22%, but in 2025 it will increase to about 38% under SRES-B1, and to 43% under SRES-A2. In 2050, it will further increase to about 60% under SRES-B1, and to 67% under SRES-A2. The results for 2080 will have to be studied in more detail in the future.

Conclusions

The analysis suggests that under future climate (2025 and 2050), most of Cambodia's agriculture areas will be exposed to higher drought risks. The LGP for most agriculture areas will be less than five months (between two and three months). Efforts to increase the planting index of more than 1.0 may be impossible without the development of irrigation facilities. In order to meet the Government's programme for increasing the planting index, the establishment of irrigation facilities in agriculture areas with LGP of less than five months must be prioritized before 2025.

Rice production

In terms of rice crop, only 13% of the cultivated area is irrigated, the rest is rain-fed. In the rain-fed system, farmers plant a rice crop once per year (referred to as 'wet season rice'), while in the irrigated system, farmers plant twice per year (both in the wet season and dry season, commonly referred to as '*dry season rice*').

Over the period 1980-2005 the area of wet season rice cultivated increased steadily, at a rate of 36,000 ha per year, while for dry season rice (irrigated rice) the area cultivated increased by about 8,800 ha per year. In 2007, the total area of cultivated rice reached 2,560,000 ha. Rice productivity also increased steadily, with wet season rice productivity increasing by about 0.041 t/ha per year and dry season rice almost doubling this, at 0.079 t/ha per year from 1980 to 2005. This increase in productivity is due to increases in fertilizer use and the use of better technology to protect the crop from pests and diseases.

The increase in rice productivity has changed Cambodia from a rice-importing country to a rice-exporting country. Since 1996, the volume of export has been in excess of 100,000 tons per year (Agriculture Development Plan, MAFF 1999). Total rice production in Cambodia reached about 7 million tons in 2007. About 80% of the rice production comes from 10 provinces (Figure 4.6), with the largest share coming from Prey Veng. However, the variability of Prey Veng's rice production is quite high compared to other provinces; this province is known to be most prone to flood and drought (MoE 2002).

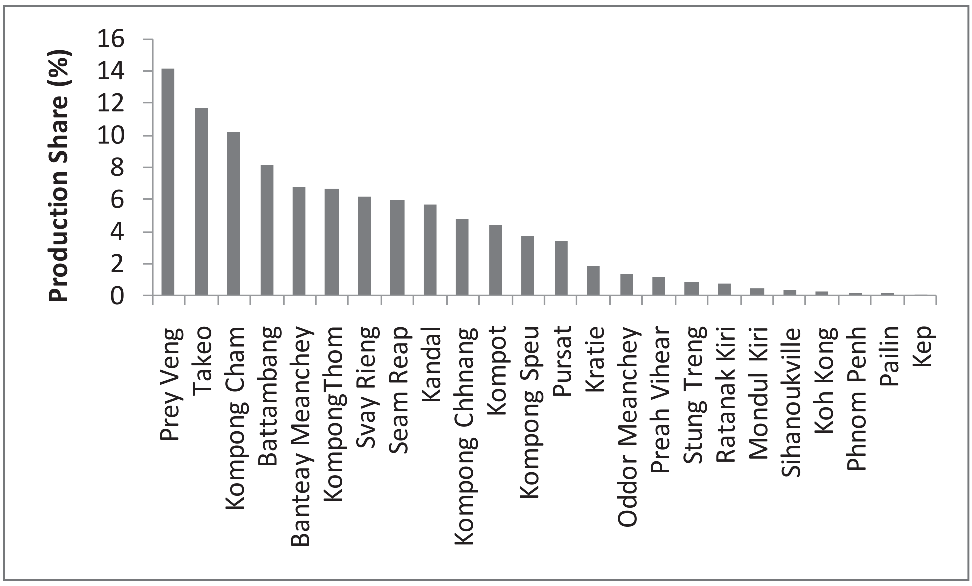


Figure 4.6: Share of province to national rice production in 2007

The RGC intends to maintain agriculture as the key sector driving economic growth and plans to invest in agricultural intensification and diversification in an effort to bolster economic growth, create employment and enhance rural incomes. This investment will also contribute to nutritional improvements, food security and growth in agricultural exports. The policy is to shift from 'expansionary' or 'extensive' agriculture to 'deepening' or 'intensive' agriculture, especially by increasing yields through intensification on existing land (Keam 2007).

Rice production and climate variability

As most rice cultivated in Cambodia is rain-fed, rice production is significantly correlated with rainfall during the planting season (May-October). If rainfall during the planting season decreases by more than 100 mm from the norm, production is expected to decline.

Based on data from the past 20 years, losses in production were mainly due to flooding (about 62%) and drought (about 36%). An insignificant loss in production is attributable to pests and diseases (2%). However, floods have not always coincided with high rainfall in Cambodia. Most flooding occurs due to increased water levels in the Mekong River and Tonle Sap Lake between early July and early October. These two bodies of water are linked to each other, and the increase in water levels in the Mekong River is closely related to rainfall throughout the basin. The Mekong River starts from the Tibet plateau. Therefore a study to investigate the relationship between regional rainfall in Tibet and its impact on the Mekong River may be required.

In the last 30 years, the most devastating floods were in 1984, 1996 and 2000. These floods destroyed almost one-fifth of the total area of wet season rice (Figure 4.7). The 1984 and 2000 floods were due to increased water levels in the Mekong River, rather than heavy rainfall in Cambodia. In 2000, flooding continued through to mid-October due to the occurrence of heavy rainfall in the west of the country. This flood reportedly destroyed the rice growing areas along the Mekong River. Floods destroy infrastructure, including irrigation facilities, and can result in loss of life.

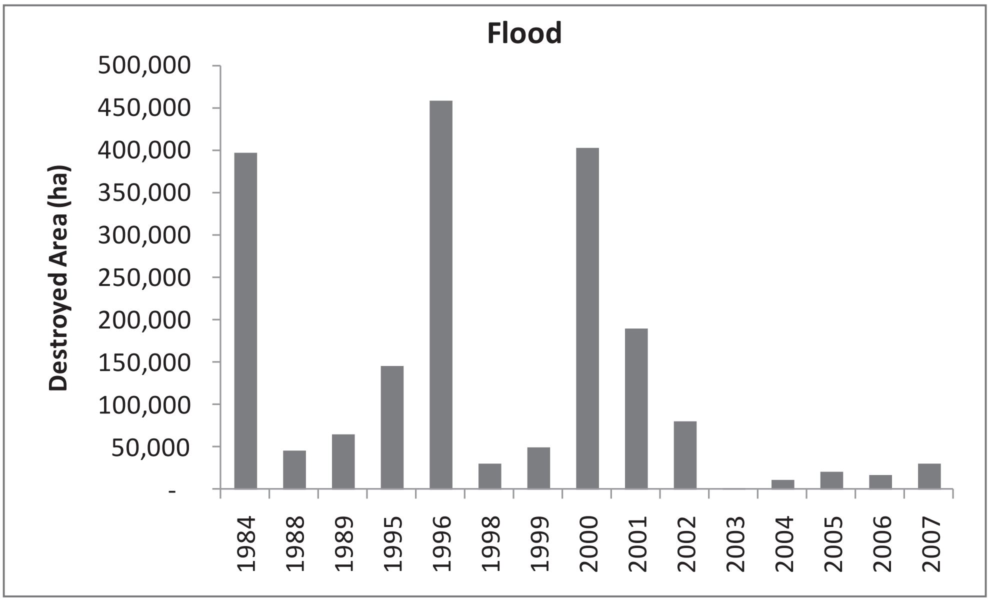


Figure 4.7: Total rice cultivation area destroyed by flood in Cambodia

Drought has also had a negative impact on rice production, with significant rice cultivation areas destroyed by drought in 1997, 1998 and 2004 (Figure 4.8).

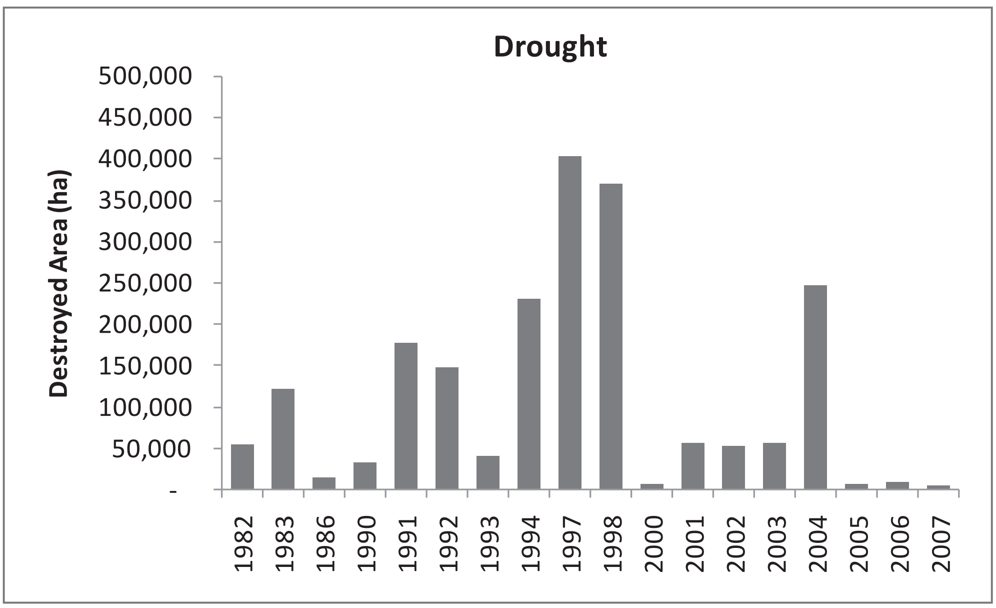


Figure 4.8: Total rice cultivation area destroyed by drought in Cambodia

Impact of climate change on Cambodia's rice production

To assess the impact of climate change on rice production in Cambodia, a study was done using a dynamic crop simulation model DSSAT (Decision Support System for Agro-technology Transfer; Jones et al. 2003). The model was run in nine main rice-growing provinces, only where the required soil data were available (Figure 4.9). Climate data were based on the historical and future climate data generated by 14 GCMs from Masutomi et al. (2009). The future climate was generated under a low and high emission scenario. The changes in CO_2 under two scenarios were used as input for the DSSAT model.

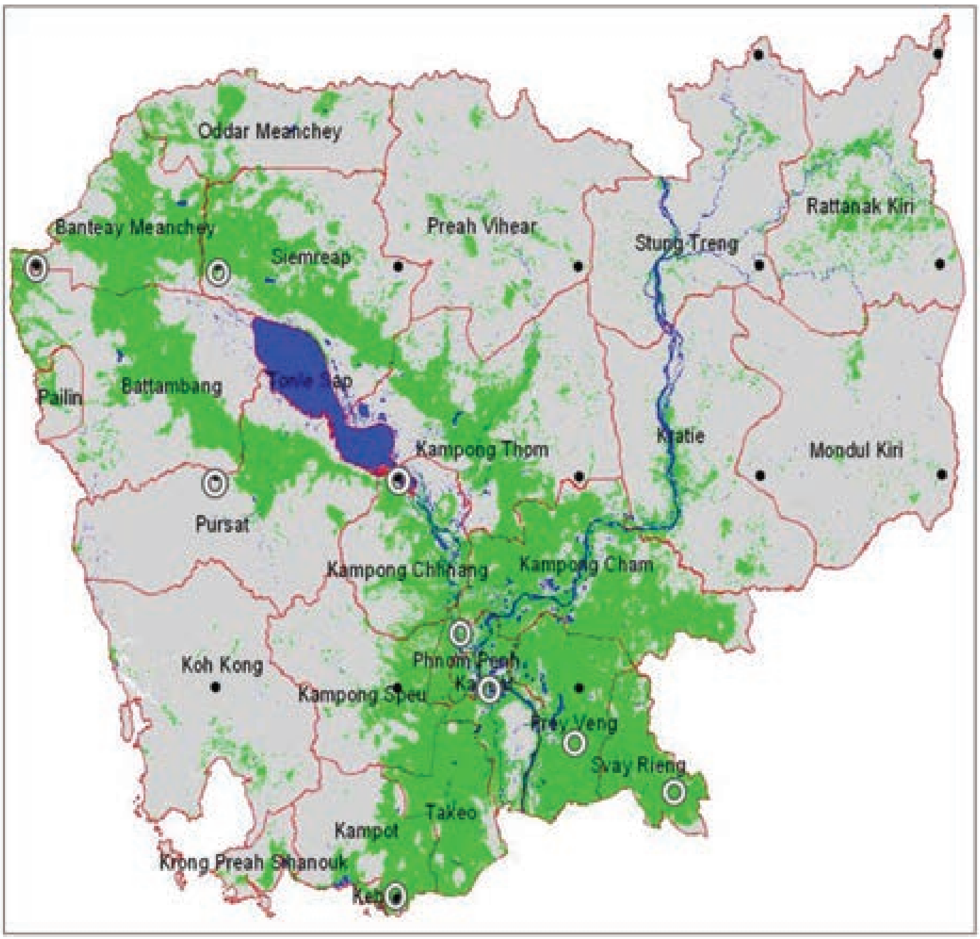


Figure 4.9: Locations for running the DSSAT model

Three types of analysis were done. First, to assess the optimum planting times for wet season rice (rain-fed system) and dry season rice (irrigated rice) the model was run under 24 different planting times throughout the year. This analysis informs the potential yield reduction if crops are planted at inappropriate times. Second, the impacts of climate change on rice yield in the nine provinces in 2025, 2050 and 2080 were assessed. Third, the supply/demand balance in 2025, 2050 and 2080 under different climate change scenarios and different government programmes for increasing rice yield were evaluated. This was to determine whether the Government's planned programmes for increasing rice production in Cambodia could meet the target under climate change.

The impact of climate change on yield is quite significant. Under the high emission scenario (SRES-A2), wet season rice yield (rain-fed) will continuously decrease until 2080, and could fall by up to 70% of current yield levels. Similarly, for dry season rice (irrigated rice), yields for crops planted in November and December could decrease by 40%. Under the low emission scenario (SRES-B1), the yield decrease is much less, ranging from 60% to about 20%. This suggests that achieving global reductions in emissions is important to Cambodia's agriculture.

Proposed adaptation options for rice production

In the context of adaptation, in the short term it is the intention of the RGC to focus efforts on increasing its capacity to cope with current climate risks through the improvement of climate risk management and community livelihood. Activities include:

1. Increasing the capacity to use climate information, such as the use of climate forecast information, in setting up better cropping strategies and agribusiness activity;
2. Implementing adaptation measures which also contribute to emission reduction, such as the introduction of technology that increase water use efficiency via the System of Rice Intensification (SRI);
3. Creating additional sources of income for communities from co-benefits of mitigation activities, such as generating carbon credits from reforestation or the use of manure and biomass waste (e.g. biogas for cooking and biomass energy in rice mills, composting, etc.).

Long-term efforts will be directed at increasing the resilience of the agriculture system to future climate risks through the revitalization of long-term policies and planning that take into account climate change. Key long-term activities include:

1. Institutionalizing the use of climate information in agriculture management and development;
2. Prioritizing structural intervention programmes (where and when a particular intervention should be in place to minimize the impact of increasing climate risk, such as constructing dams or irrigation schemes);
3. Expanding agriculture areas to regions with lower climate risk;
4. Creating climate insurance for vulnerable communities;
5. Generating more varieties resistant to drought, flood and high salinity;
6. Developing and implementing long-term research on climate modelling, mitigation and adaptation technologies.

4.4.2 Forestry sector

Introduction

The pressure on Cambodia's forests is high and will increase as the population grows. This situation will be aggravated by climate change. Forest degradation is likely to accelerate due to an increase in erosion as a result of increased rainfall. The change in soil water availability, caused by the combined effects of changes in temperature and rainfall, will directly impact the productivity of forests, as suggested by many studies (e.g. Whetton and Rutherford 1994, Achanta and Kanetkar 1996).

In the INC (MoE 2002), it was suggested that under a changing climate, the areas of wet and dry forests of Cambodia might decrease, while moist forests might increase. This section briefly reviews the forest condition in Cambodia and assesses the potential impacts of future climate change on forest ecosystems at the national level, under two emission scenarios.

Impact of climate change on forestry

The impact of climate change on the forestry sector was evaluated based on the soil-climate zone. The soil-climate zone is a function of soil water index and altitude. The soil water index represents the number of months when the soil water content is less than half of the value of the difference between the field capacity and permanent wilting point. The soil water content is estimated using the Bookkeeping method of Thorntwaite and Mather (1955) as in section 4.5. The soil-climate zone is divided into 12 zones, based on the soil water index and the elevation. The rainfall and temperature data needed to calculate the soil water index were taken from reconstructed climatic data and climate scenario data as discussed in section 4.3. It is assumed that there is no change in soil texture in the future.

The change in soil-climate zone due to climate change will have a direct impact on forest productivity. As suggested by Achanta and Kanetkar (1996), the net primary productivity of teak plantations in India is significantly related to the precipitation effectiveness index. A projected depletion of soil moisture due to climate change would most likely cause teak productivity to decline by about 6%, while the productivity of moist deciduous forests could decline by about 17%.

Deciduous and evergreen broadleaf forests dominate Cambodia's forests. Forestland is mostly located in low elevations (<500 m above sea level), with only a small percentage at high altitude - 9% at an elevation of between 500 m and 1000 m above sea level and about 2% at an elevation of more than 1000 m above sea level (Figure 4.10).

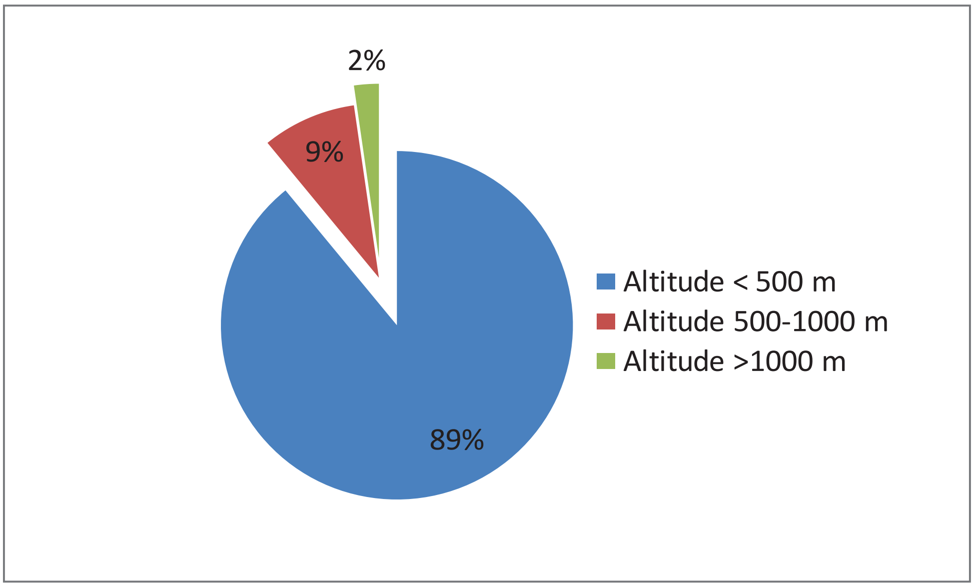


Figure 4.10: Percentage of forested lands of Cambodia by elevation

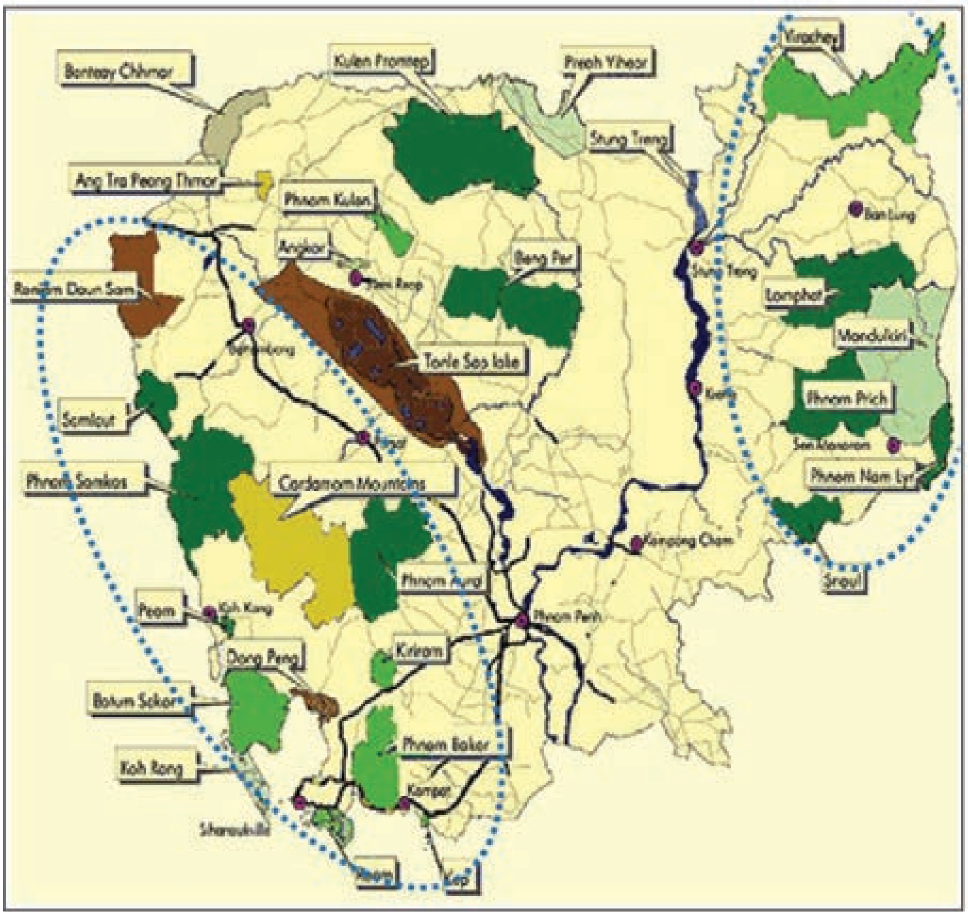
The analysis showed that under current climate (the baseline), the soil water regimes of lowland forests vary considerably. Half of all lowland forests have a soil water deficit for a period of between four and six months, 35% for a period of six to eight months and 4% for more than eight months. High altitude forests (more than 500 m) are typically exposed to a shorter water deficit period (less than six months).

Under emission scenarios SRES-B1 and SRES-A2, up to 2050 most lowland forests will be exposed to a longer dry period, particularly forest areas located in the northeast and southwest. More than 4 Mha of lowland forest, which currently has a water deficit period of between four and six months, will become exposed to a water deficit period of between six and eight months or more. However, by 2080, soil water conditions will be similar to current conditions.

Adaptation measures

Forest productivity will decline if the soil water condition becomes drier. This implies that if these forests are logged, it might take longer for them to grow to their original condition. Unsustainable forest management practices, combined with a greater risk of fire, increases the chances of exploited forests becoming shrubs or unproductive land in the future.

The findings justify the adoption of proposed protected forests by MoE and MEF (2003), as these forests are mostly located in the northeast and southwest of Cambodia (Figure 4.11). The pressure on these forests in the future may well increase with population growth, which is high in most communes near the protected forests.



Note: Locations of protected forests of Cambodia, MoE and MEF 2003

Figure 4.11: Risk of exposure of protected areas to longer dry periods in the future

4.4.3 The Coastal Zone

Overview of Cambodia's Coastal Zone

Cambodia's coastal zone covers a land area of about 17,237 km^2 plus an exclusive economic zone of about 55,600 km^2. The coastal zone includes the provinces of Koh Kong, Kampot, Preah Sihanouk and Kep (Figure 4.12). Cambodia's coastal zone population growth rate has been increasing steadily since 1981. Statistics by the Ministry of Planning (MoP) have shown that Cambodia's coastal zone population increased from 673,000 in 1994 to 845,000 in 1998 (26%) implying an annual average growth rate of 5.7%. By year 2006, the population annual growth rate in the coastal areas decreased to about 3%.

Natural resource base

Cambodia's coastal areas contain a diverse and biologically important range of natural habitats, including rivers, forests, mangroves, estuaries, beaches and coral reefs. Coral reefs have been found in a number of locations (Bauld 2005) accommodating 34 known species of hard coral and 14 species of soft coral (MoE/Danida 2002). Mangrove forests and mudflats are found throughout the coastal zone. They support both endangered/vulnerable wildlife and species of a commercial/livelihood importance, on which many communities living within the area depend.

Coastal natural resources face a number of pressures. For example, over-fishing by commercial vessels in recent years may have decreased fish stocks (PEMSEA 2002).

Over-exploitation of forest resources and mangrove ecosystems will lead to increased rates of erosion and sedimentation of rivers and estuaries in coastal areas. This will affect sea grass beds and coral reefs, essential to fish stocks and habitats. Over the period 1993 to 2002, forest and mangrove resources in coastal areas declined significantly, reaching about 270,000 ha and 12,000 ha or about 1.73% and 1.76% per year respectively. The rapid loss of forest cover and mangroves occurred mainly in Kampot and Preah Sihanouk provinces. If this loss continues, the attractiveness of coastal areas for tourism and recreation, and other economic opportunities, will also decline. Sewage, garbage and chemical pollution are also of concern (Danida 1999). Sea level rise as a result of climate change will aggravate the damage caused by the unsustainable management of the coastal zone.

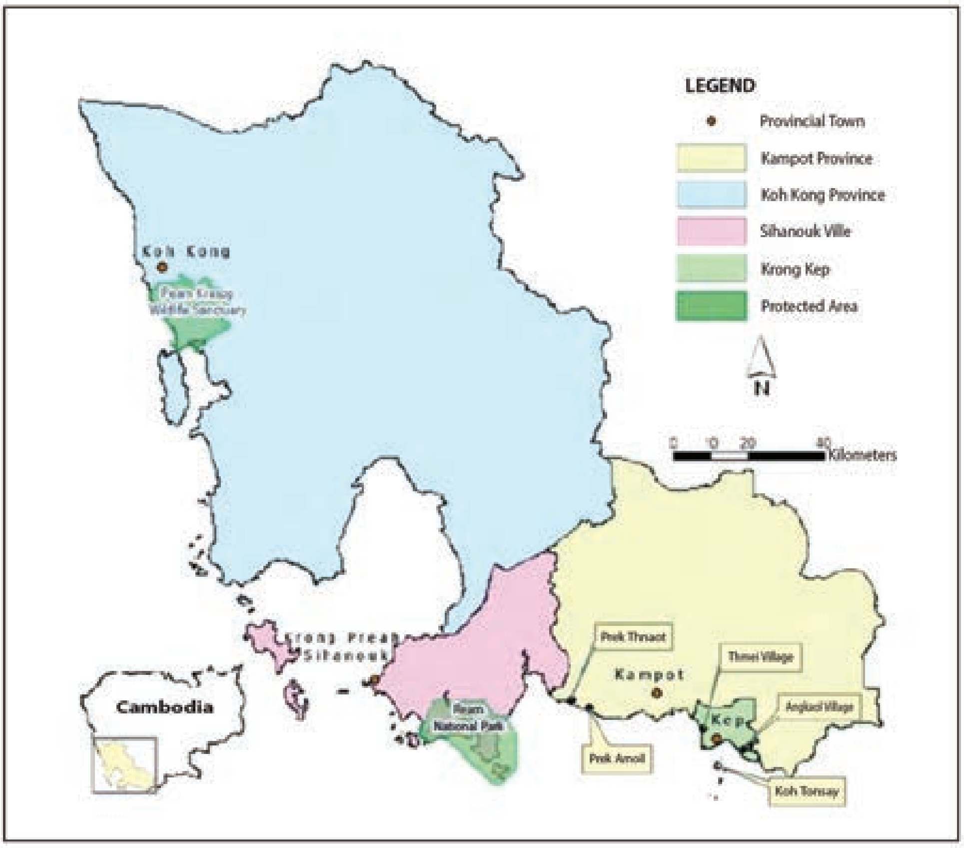


Figure 4.12: Coastal provinces and municipalities of Cambodia

Economic activities

Agriculture (including forestry and fisheries) is the main economic activity in the area, particularly in Kampot and Kep provinces where in 2005 about 45% and 60% of the area was used for agriculture activities respectively. The main farming activities in Kampot are vegetable growing, prawn culture and fishing, which engage about 70% of the population. In Kep, 80% of the population engage in agriculture activities, despite being a key tourism destination[6]. The agriculture area grew around 2% per year in these two provinces over the period 1993 to 2005. In Preah Sihanouk Province, the agriculture sector represents about 25% of the total area and employs about 30,000 people (51% of the total employment). In Koh Kong, agriculture is the primary economic activity, accounting for about 52% of total employment, i.e. crop cultivation and livestock breeding 32%, forest and forest products 4% and fisheries 16% (MoE and Danida 2002a-d). An increase in sea level might threaten prawn cultures.

[6] The service sector, which includes wholesale and retail sales, hotels and restaurants, transportation, stock, finance, assets, public administration, national defense, health education, communities, social services and private occupation, employs about 22,000 people (36% of the total employment).

Salt production is significant in Kampot and Kep. At present there are about 3,334 ha of saltpans in Kampot, around 60% of which are State-owned, while the community owns the remaining 40%. Annual salt production in Kampot is approximately 70,000-80,000 tons and serves domestic demand. In Kep, there are about 2,000 ha of saltpans. Based on a study by MoE and Danida (2002a-d), salt production could be expanded to the other coastal provinces. However, an increase in sea level leading to permanent inundation of coastal areas is a potential threat to salt production. The risk of sea level rise needs to be considered in future development plans.

The **tourism** sector is of growing importance to Cambodia, with the beaches and islands attracting an increasing number of tourists. A survey has indicated that tourism activity is highest in Kampot and Preah Sihanouk provinces. The sector is dependent on the ecological quality of the coastal zone (coral reefs, beaches, sea grasses, etc.).

To support economic activities in the coastal provinces, the Government plans to develop more **hydroelectricity power**. Some of the coastal rivers have hydroelectricity power potential, for example the rivers Tatai, Russei Chrum, Metoek and Kamchay. Hydroelectric dams at Kirirom National Park and Prek Thnuot have been designed (MoE and Danida 2002b). In Koh Kong, the Steung Metoek River also has the potential for hydroelectricity power development, with a capacity of 400-460 MW (MoE and Danida 2000c). Hydroelectric dams require high investment costs and are expected to have a long lifetime (more than 100 years), therefore climate change, including land use change scenarios, must be considered to ensure they are climate-proof.

Extreme climate events

Flooding is a common climate related problem in coastal areas. In Kampot, floods hamper transport by roads and bridges, particularly during the wet season, with economic consequences (MoE and Danida 2002a). In Kep municipality, floods occasionally occur along slightly hilly areas on lower land (plains) and create problems in some rice growing areas. Many families have moved out of these areas due to low agricultural productivity. In Koh Kong, areas affected by flood are found in the centre of the province, close to the border of Koh Kong and in Preah Sihanouk. They are mostly in the lower parts of slightly hilly areas. **Drought** commonly occurs in the dry season.

Strong winds often occur from November to January and cause problems for farmers by hitting rice yields. In the rainy season, strong winds come from the west or from the sea and can cause storms lasting up to seven days. During strong winds and storms, waves can reach 2–3.5m in height, making sea travel difficult. According to the records of the meteorological station inside Sihanoukville International Airport, between 1863 and 1979 strong winds rarely occurred, with the fastest wind being 9 m/s or 32 km/h. At this wind speed, no damage to infrastructure is caused.

Potential impact of climate change in coastal areas

Rising sea levels will potentially impact coastal systems in a number of ways, including inundation, flood and storm damage, loss of wetlands, erosion, saltwater intrusion and rising water tables. Other effects of climate change, such as higher sea water temperatures, changes in precipitation patterns and changes in storm tracks, frequency and intensity, will also affect coastal systems, both directly and indirectly through their interactions with sea level rise. Rising surface water temperatures, for example, are likely to cause increased coral bleaching and the migration of coastal species toward higher latitudes. Changes in precipitation and storm patterns will alter flood risk and storm damage. The bio-geophysical effects in turn will have direct and indirect socioeconomic impacts on tourism, human settlements, agriculture, freshwater supply and quality, fisheries, financial services, and human health in the coastal zone (McLean et al. 2001, Nicholls 2002). The resident population of the coastal zone (present or projected levels) could be affected by increased flooding or, ultimately, would need to move because of frequent flooding, inundation or land lost to erosion. There could also be changes in marketed goods and services, such as land, infrastructure and agricultural and industrial products.

The impact of global warming on the change in maximum wind speed in the coastal zone of Cambodia is based on daily wind speed data from PRECIS for four 30-year periods: 1961-1989, 1990-2019, 2020-2049, and 2050-2079. The area permanently inundated by a one-metre rise in sea was also assessed using GIS.

The wind speed frequency analysis suggested that the western and southern part of Cambodia's coastal zone might be exposed to a higher risk of strong winds in the future. The southern part of the coastal area is where most of the susceptible communities are located. Under current conditions, winds with a speed of more than 40 km per hour will occur only once in 30 years at most, and in the future (2020-2049) they may occur once in 15 years. While the potential damage to infrastructure caused by these winds may be minor, such winds can seriously damage crops, such as maize, if there are no windbreaks. The risk of exposure to high sea waves is also relatively high. At this wind speed, sea waves can reach 6 m in height. Fishermen are advised not to fish under these conditions.

Analysis of the impact of sea level rise on coastal areas suggests that a total area of about 25,000 ha will be permanently inundated by a sea level rise of 1 m, increasing to 38,000 ha at a sea level rise of 2 m (Table 4.1).

Table 4.1: Total area of the coastal zone being inundated permanently due to 1 and 2 m sea level rise

Land Cover (ha)[1]	Sea Level Rise	
	1 m	**2 m**
Mangrove	11,832	18,495
Wetlands	10,509	12,477
Grassland/Shrubs	1,288	3,669
Crop lands	629	2,209
Other lands	384	866
Forest lands	289	370
Settlements	220	436
Total	**25,151**	**38,522**

Note: [1] Based on land use cover data of 2006 corrected by land use/cover map of 1997

Of the 25,000 ha, about 80% of the inundated area is situated in Koh Kong Province, and 11% in Preah Sihanouk Province. Around 26 communities in Koh Kong Province will be affected by the impact of sea level rise, while in Preah Sihanouk, Kampot and Kep provinces about 17, 25 and five communities respectively will be impacted. Rizaldi Boer et al. (2011) estimated the area loss due to a sea level rise of 1 m to be about 44,000 ha, with 56% of the city of Koh Kong in danger of being flooded. The locations of the coastal zone that would be inundated are presented in Figure 4.13.

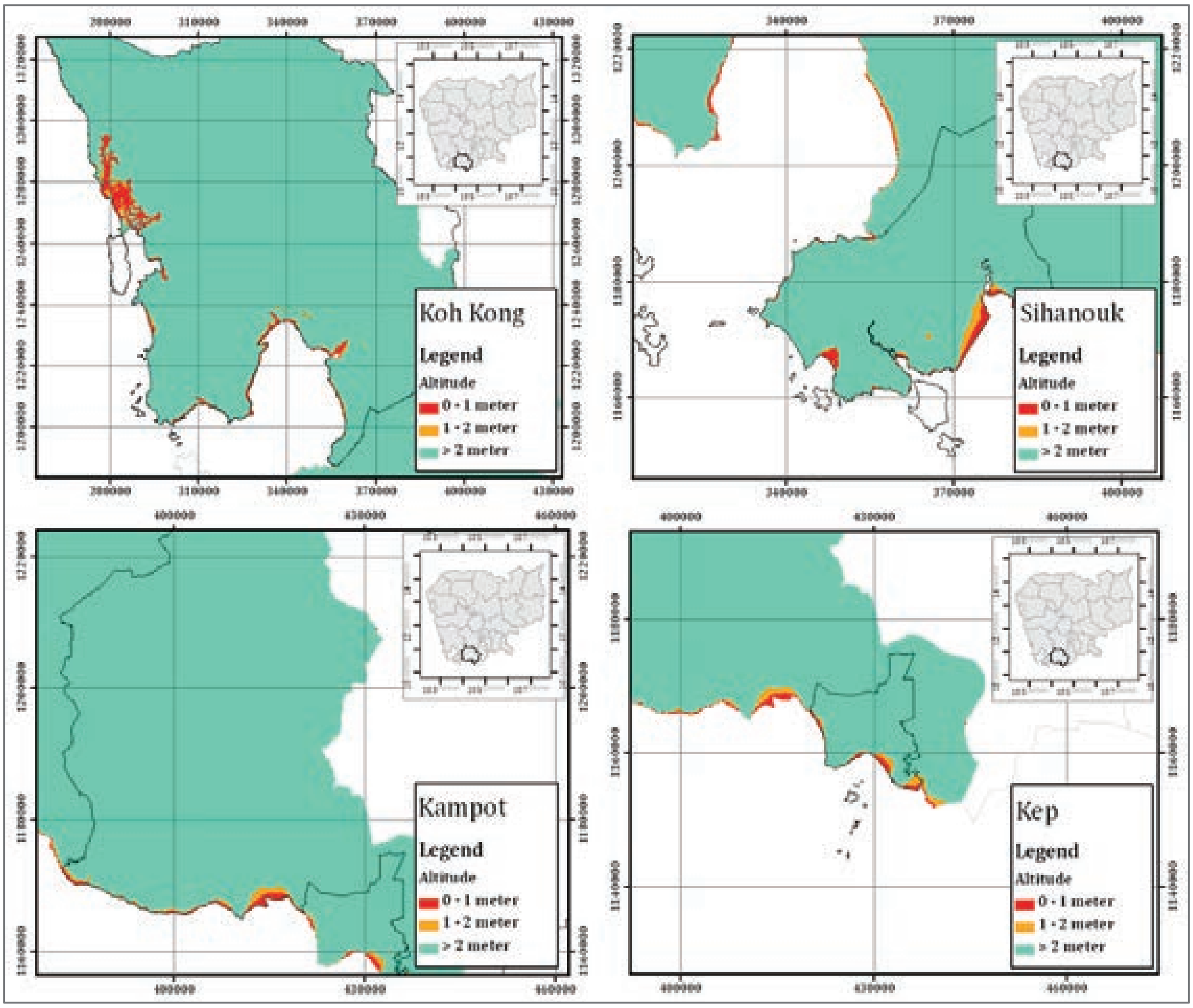


Figure 4.13: Area of coastal zone being inundated due to sea level rise

Based on the IPCC 4th Assessment Report projection (IPCC 2007), the mean global sea level rise in the next 100 years will range between 20 cm and 80 cm. The NASA GISS E-R model projected a 90 cm increase of sea level by year 2100. According to the 4th Assessment Report, the annual rate of sea level rise under scenario SRES-A1b (rate of emission is quite similar to SRES-A2) in Cambodia will be about 1.7 cm/year. Thus the permanent inundation of areas of coastal zone due to a sea level rise of 1 m, as shown in Table 4.1, is likely to occur in the next 90 years.

The occurrence of high tides in the coastal area will temporarily inundate the lowland areas of the coastal zone. Based on observations in Preah Sihanouk Province on 24 May 2010, high tide in this area could reach more than 1 m and last for more than six hours. In combination with extreme waves and later with the sea level rise, the damaging effect of waves in the future will be more severe than now. The height of extreme waves for Cambodia’s coast could reach 3 m. Higher ocean waves will increase the intensity of coastal erosion and abrasion, resulting in greater onshore destruction.

Adaptation assessment

Long-life infrastructure development requiring high investment should be redesigned taking into consideration climate change (climate proofing). In areas where the likelihood of strong winds and sea level rise is quite high, a new climate-proof building code would need to be introduced. Planting windbreakers in some of the agriculture areas may also be necessary to reduce the negative impact of the strong winds on annual crops.

The analysis has shown that communities in Kampot Province are currently facing climate related problems, and these vulnerabilities need to be incorporated into the design and development of adaptation plans in coastal areas.

Further study to improve the current analysis is required using a regional climate model, a more refined resolution of the topographic map (contours with 20 cm intervals), and with a wider scope (including studies on salt water intrusion, coastal erosion by extreme waves as a result of increased wind speed and sea level rise under changing climate, mangrove rehabilitation for buffer zone, etc.).

4.4.4 Health

Introduction

Climate change can impact human health directly and indirectly. In terms of direct impacts, an increase in the frequency and/or intensity of extreme weather events may result in death, injury, psychological disorders and damage to public health infrastructure. The indirect health impacts of climate change include changes in the geographical range and incidence of vector-borne diseases, infectious diseases, malnutrition and hunger as a result of ecosystem disturbance. Furthermore, sea level rise may displace populations and cause damage to infrastructure (see section 4.4.3), leading to increased susceptibility to infectious diseases and psychological disorders.

Many infectious diseases, such as malaria, dengue fever, diarrhoea and other water- and food-borne diseases are influenced by climate change. This section reviews the incidence of malaria in Cambodia and its connection with climate variability. It assesses malaria transmission risk under a changing climate and provides recommendations to effectively control this disease under current and future climate.

Malaria incidence and climate variability

Malaria is one of the leading causes of mortality and morbidity in Cambodia. In 2003, it was the third most common cause of outpatient attendance (accounting for 2.4% of patients), the principal cause of hospitalization (accounting for 4.2% of inpatients) and the leading cause of hospital mortality (accounting for 9.5% of deaths). It is also a key contributor to anaemia complications during pregnancy, low-birth weight and poor child growth. Multi-drug-resistant strains of *Plasmodium falciparum* are common, particularly in the west of the country. In fact, the provinces of Cambodia that border Thailand are at the epicentre of the global multi-drug-resistant malaria problem.

Cambodia's forests cover 59% of its landmass and these areas provide refuge for *Anopheles dirus* and *Anopheles minimus,* which are the main vectors of malaria in the region. From an estimated 2 million people with cases of malaria, more than 1.6 million lived in high transmission areas within 1 km of the forest. These areas are sparsely populated, with an average of just five inhabitants per square kilometre (compared to 132 inhabitants per square kilometre in non-malaria central areas of the country).

The number of malaria cases in the highland provinces is higher than in the lowland and coastal provinces; 1,000 compared to 100 cases per 100,000 people. This difference is partly due to the difference in climatic conditions between lowland and coastal areas (MoE 2002).

By observing monthly variations of malaria cases, it was found that in some provinces in Cambodia malaria cases tended to increase at the beginning and end of the rainy season. A strange case was found in Mondul Kiri Province where, at the beginning of a La-Nina year, malaria cases increased very quickly and then dramatically decreased at the end of the rainy season. This peak seems to be abnormal and totally different from other provinces within the region. This phenomenon cannot be explained due to a lack of available data, and therefore further study is needed.

Analysis of climate change on malaria incidence in Cambodia

Building on the INC, two assessments were done for the SNC:

1. An assessment of how prone Cambodian provinces were to malaria, based on malaria data from between 2000 and 2005 from the Ministry of Health (MoH) (2006);
2. An assessment of malaria transmission risk under current and future climate.

The extent to which provinces in Cambodia are prone to malaria is based on five indicators:

1. Percentage of confirmed malaria cases;
2. Trend in the percentage of confirmed malaria cases over six years;
3. Percentage of deaths caused by malaria;
4. Trend of the percentage of deaths caused by malaria over six years;
5. Percentage of population at risk.

Transmission risk under current and future climate is based on a formula by Reiter (2001) and recommended by the World Health Organization. The formula includes variables on mosquito density per human, the average number of bites per day per mosquito**,** the probability of a mosquito surviving through any one-day and the incubation period (i.e. the time taken for the pathogen to develop and for the mosquito to become infectious). The mosquito survival rate and the incubation period are both affected by climate.

The extrinsic incubation period is calculated based on a formula by Macdonald (1957), which looks at the temperature required over time for the parasite to develop. *P. vivax* and *P. falciparum* have the shortest extrinsic incubation times (Oaks et al. 1991). The extrinsic phase takes the least amount of time when the temperature is 27^{o}C (Pampana 1969), while below 20^{o}C, the life cycle of *P. falciparum* is limited. Larval development also depends on temperature: higher temperatures increase the number of blood meals taken and the number of times eggs are laid by mosquitoes (Russell et al. 1963, Martens et al. 1995). The extrinsic incubation period for *P. vivax* and *P. falciparum* was calculated based on data from 22 provinces in Cambodia provided by MoH (2003-2007).

Mosquito (*Anopheles dirus* and *Anopheles minimus*) density per human per month was estimated from monthly rainfall. This was based on the fact that mosquitoes need water for egging. The equation was developed based on mosquito population data collected in five provinces - Battambang, Kampong Cham, Pursat, Steung Treng and Ratanak Kiri (MoH 2006).

The average number of bites per day per mosquito was estimated using observation data from three provinces: Pursat, Ratanak Kiri (O'chum and Borkeo Districts) and Pailin for *Anopheles dirus* and *Anopheles minimus* over two periods: August-September and November-December 2008 (MoH 2008). A probability of 0.5 is assumed. The transmission risk in each grid of GCM was generated using climate data from the GCM.

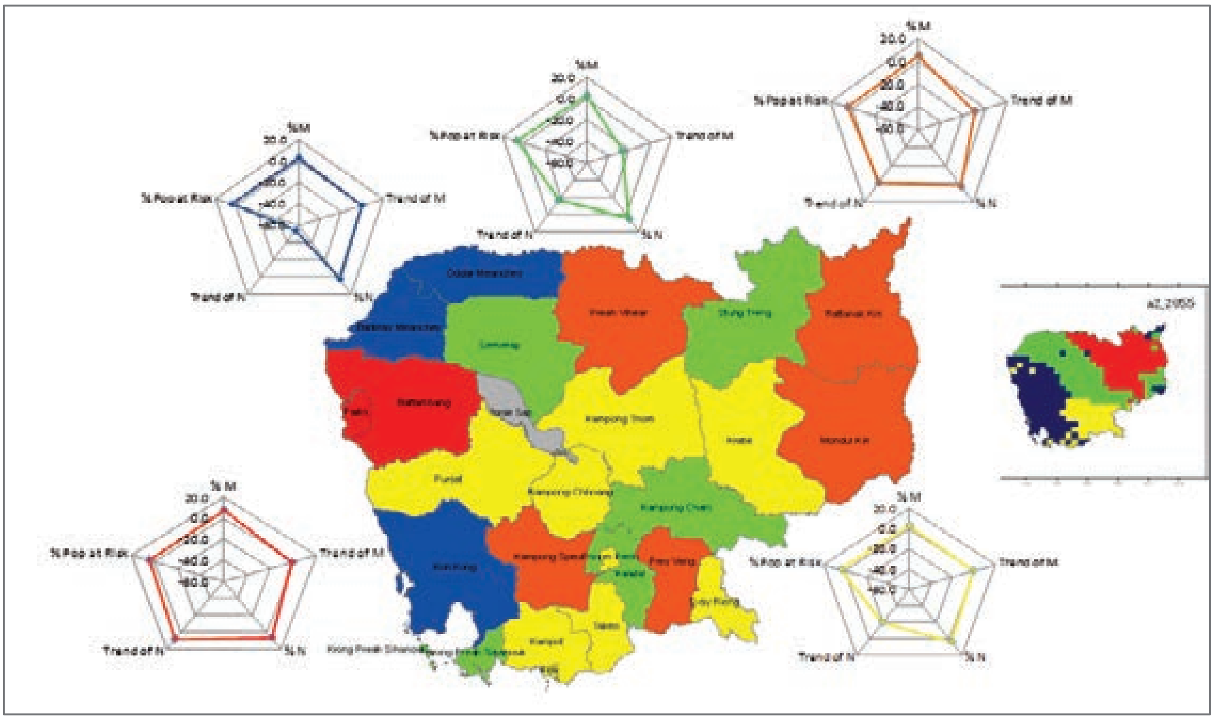
Proneness to Malaria

Battambang was found to have the highest percentage of confirmed cases (13%), followed by Pursat, Kompong Speu and Preah Vihear, while Kandal, Preah Sihanouk, Phnom Penh, Svay Rieng, Takeo, Kep and Prey Veng have the lowest percentage of confirmed cases.

Most provinces (19 out of 24) show a decreasing trend in the percentage of confirmed cases over six years. However, there are two provinces that may need special attention, namely Svay Rieng and Kep. While these provinces presently have a low percentage of confirmed cases, cases are increasing at a high rate.

In four provinces: Battambang, Kampong Cham, Siem Reap and Pursat, malaria causes more than 10% of deaths. The percentage of deaths caused by malaria is decreasing, except in Pailin and Ratanak Kiri, but the percentage of population at risk is still relatively high, particularly in Kampong Cham.

Based on the five indicators, the provinces were grouped into five clusters using hierarchy cluster analysis. Figure 4.14 shows the general pattern of the five indicators in the five clusters (http://*celade*.cepal.org/khmnis/census/ khm2008/. 2 Article 31).



Note: Red = 'very prone', orange = 'prone', yellow = 'quite prone', green = 'less prone' and blue = 'not prone'

Figure 4.14: Spatial distribution of malaria vulnerability in Cambodia

For the 'very prone' cluster (red) the mean percentage of confirmed malaria cases slightly decreased at a rate of 1% per year, but the percentage of death cases increased at a rate of 8.8% per year. This is the only cluster that has an increasing percentage of deaths attributable to malaria. Battambang and Pailin are the only provinces categorized as 'very prone' to malaria. This may be because health facilities are not well established compared to other provinces, or because community awareness and practices on malaria prevention and control are less well established compared to other provinces.

Five provinces are classified as 'prone' to malaria (orange) - Preah Vihear, Ratanak Kiri, Mondul Kiri, Prey Veng and Kampong Speu. The values of the indicators in these provinces were almost identical with the first cluster (red), but they have decreasing trends in the number of cases confirmed and the death rate. The 'quite prone' provinces (yellow) are characterized by a high negative death trend, while the least prone (green and blue) provinces are characterized by a high negative trend in malaria incidences and deaths.

Malaria transmission risk

Numerous studies indicate that the number of cases of malaria incidence is closely related to rainfall and temperature (Martens et al. 1995). Based on data from a number of provinces, it was found that malaria is highly correlated with rainfall and temperature - malaria cases increase as the rainfall increases and decreases as the temperature falls. Based on regression analysis, rainfall explains about 70% of the variability in malaria cases. Temperatures in Cambodia range from 24^{o}C to 30^{o}C, and seasonal variability is low. This may explain why the effect of temperature is less visible than that of rainfall.

Based on observations in five provinces (Battambang, Kampong Cham, Pursat, Steung Treng and Ratanak Kiri, MoH 2006), it was found that rainfall affects mosquito populations. The mosquito population in a particular month will be high if rainfall has been high in the previous two months. This suggests that malaria risk in the transition season (before the start of dry season) tends to increase if the rainfall in the wet season increases above normal.

Based on the fact that malaria is influenced by rainfall and temperature, changes in climate in the future will result in changes in malaria risk. Based on Reiter (2001) climate change will affect malaria risk due to its influence on the incubation period and rainfall. An increase in temperature will shorten the incubation period, and an increase in rainfall will increase the mosquito population.

The transmission risk is generally high in the months of September to November (Figure 4.15).

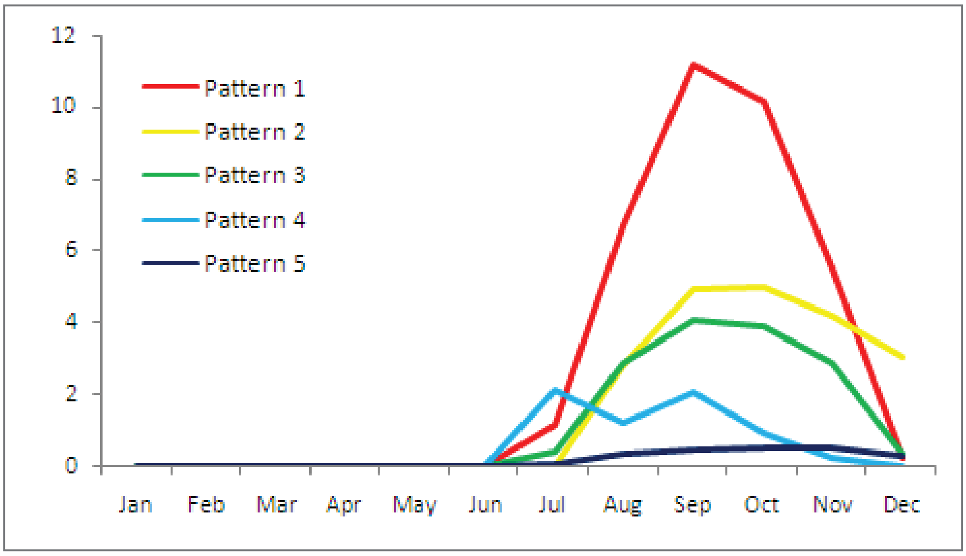


Figure 4.15: Risk transmission patterns of each cluster

Rainfall has a stronger influence than temperature on malaria transmission risk. Every 100 mm increase in monthly rainfall is followed by an increase in the mosquito density per human in the following two months by about 30 mosquitoes.

From the spatial analysis of malaria transmission risk, it was found that the spatial pattern of malaria risk in Cambodia changes as rainfall and temperature in the future change. The spatial pattern of the malaria risk transmission in the future under the high and low scenario is similar. However, the area under high transmission risk is larger in SRES-A2 (high emission) than in SRES-B1 (low emission). In both emission scenarios, the transmission risk tends to increase until 2050 and then decreases again in 2080. In 2050, the transmission risk in the provinces located in the northeast, Preah Vihear, Stung Treng, Ratanak Kiri and part of Mondul Kiri and Kratie, will increase.

Adaptation options

In general, adaptation programmes are aimed at reducing: (i) the number of malaria cases, and (ii) deaths caused by malaria. Reducing the transmission risk can reduce malaria cases. Improving access to health facilities can reduce death cases due to malaria. Some programmes and activities that could potentially address these two issues are presented in Table 4.2.

Since rainfall is significantly correlated with mosquito populations, the use of rainfall information for a malaria early warning system offers potential. The presence of this system could assist preparations for managing a possible increase in malaria risk and incidence in a particular season.

This study needs refinement. This refinement includes improving the model used for predicting mosquito density from rainfall, and using more observation data from provinces located in coastal and highland areas that take into account forest conditions.

Table 4.2: Adaptation programmes, activities and target

Main goal	Programme	Activity	Target
Reducing the number of malaria cases	Improving hygiene and health	Education about hygiene, environment and health	Student Public Housewife
		Increasing the capacity of women	Housewife
	Socialization techniques for early detection of malaria cases	Studies of prediction model of malaria cases	Researcher Student
		Socialization techniques for early detection of malaria occurrence	Public Student
	Mosquito population reduction programme	Termination of the mosquito life cycle	Public
		Fogging	
	Mosquito reduction programme	Dissemination and use of mosquito nets	Public
		Dissemination of anti-mosquito materials	Public
Reducing the number of deaths caused by malaria	Improve the ability to deal with cases of malaria	Increase the ratio of health workers (nurses, doctors, pharmacists): total human population	
		Increase general awareness of how to manage patients	Public
	Increasing the availability of treatment and diagnostic aids	Maintain the availability of drugs, devices and distribution	
		Improve completeness and quality of equipment to treat patients	

5 Greenhouse Gas Mitigation in the Energy Sector

5.1 Introduction

One of the main objectives of the UNFCCC is to control the atmospheric concentration of GHG to a level that would not seriously affect the climate system. GHG mitigation is a commitment by all Parties to the Convention, as stated in Article 4.1(b). However, this commitment is based on common as well as individual responsibilities of Annex I Parties (developed countries) and Non-Annex I Parties (developing countries). As a least-developed country, Cambodia needs to continue implementing sustainable economic development. Rapid economic growth in an environmentally sustainable manner is a national priority. In this context, Cambodia has identified mitigation measures in the context of the development process. Based on the national GHG inventory, mitigation assessments were conducted for the relevant sectors of energy, LUCF and Agriculture.

5.2 Overview

5.2.1 Baseline emissions scenario

Under the baseline emissions scenario, total emissions increase from 2,643 $GgCO_2$-eq in 2000 to 5,533 $GgCO_2$-eq in 2010, and to 25,549 $GgCO_2$-eq in 2050 (see Table 5.1). Although the increase is very high, the emissions per capita are very low compared to neighbouring countries[7]: 0.2 tCO_2-eq per person per year in 2000 increasing to 1.3 tCO_2-eq per person per year in 2050, where the population is expected to grow from 12.76 million in 2000 to about 23 million in 2050.

The transport sector is expected to have the largest increase and share of emissions in 2050 at 10.816 $GgCO_2$-eq, followed by the energy industries (all emissions related to electricity generation) with 8,888 $GgCO_2$-eq. The energy industry emissions should be divided between the other sectors, as an increase in electricity use is expected across the board, but especially in the manufacturing industries, commercial and residential sectors (Table 5.1 & Figure 5.1).

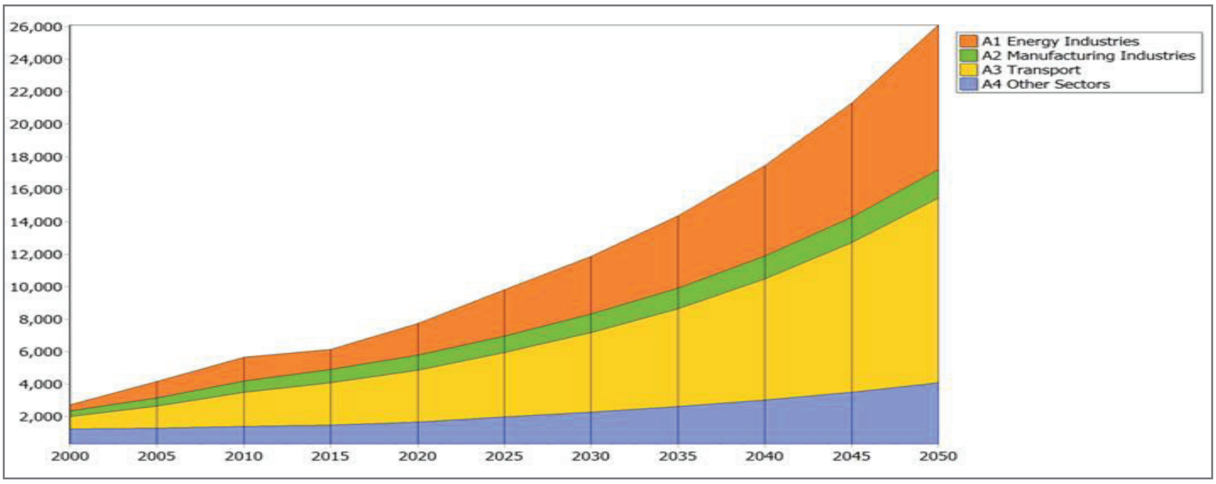


Figure 5.1: Total energy demand by sector 2000-2050

[7] Emission in tCO2 eq. per capita (http://www.nationmaster.com/graph/env_co2_emi_percap-environment-co2-emissions-per-capita): Lao PDR 0.066, Vietnam 0.57, Thailand 2.67498, Cambodia 0.039.

Table 5.1: Total emissions including Biogenic Carbon Dioxide 2000-2050 in $GgCO_2$-eq

Standard emissions /Year	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
A1 Energy Industries	385	1,008	1,453	1,212	1,931	2,849	3,539	4,430	5,567	7,023	8,888
A2 Manufacturing Industries	320	508	689	828	923	1,024	1,144	1,270	1,414	1,578	1,766
A3 Transport	709	1,249	2,000	2,465	3,040	3,751	4,631	5,720	7,069	8,742	10,816
A4 Other Sectors	1,229	1,304	1,392	1,482	1,658	1,977	2,285	2,623	3,025	3,505	4,079
Sub Total	2,643	4,070	5,533	5,987	7,551	9,601	11,599	14,043	17,075	20,848	25,549
All figures in GgCO2 eq.											
Biogenic CO2 Emissions /Year	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
A2 Manufacturing Industries	243	999	1,663	1,935	2,138	2,366	2,643	2,950	3,314	3,743	4,253
A4 Other Sectors	10,284	9,373	8,595	7,807	6,878	6,549	6,016	6,276	6,577	6,923	7,324
Sub Total	10,527	10,372	10,258	9,742	9,016	8,915	8,659	9,227	9,890	10,667	11,577
Total	**13,170**	**14,442**	**15,791**	**15,729**	**16,567**	**18,516**	**20,258**	**23,270**	**26,965**	**31,515**	**37,126**

Source: Generated with LEAP, using default emissions

Note: Some deviations for the year 2000 compared to Table 3.2 due to model use and model data requirements, sector definitions and combination into CO_2-eq.

5.2.2 Mitigation options

For each sector and fuel type, a list of mitigation options was formulated based on previously successful projects, pilot projects, feasibility studies, literature reviews and expert opinion. These mitigation options were screened based on UNFCCC documentation (UNFCCC 2004) to determine the most viable options for Cambodia. The indicators were:

1. **Social acceptability -** the extent to which the technology adheres to the habits, rituals and customs of the targeted beneficiary;
2. **Technical feasibility -** the extent to which the technology/option is technically feasible;
3. **Environmental acceptability -** the extent to which the technology/option can be implemented without negatively affecting the environment;
4. **Economic acceptability -** the extent to which the technology contributes to local and macroeconomic development;
5. **Political acceptability** - the extent to which the technology is acceptable from a political point of view;
6. **Level of maturity of the technology in Cambodia -** the extent to which the mitigation option is already proven in Cambodia;
7. **Ease of implementation -** the level of effort required to promote the implementation of the technology;
8. **Appropriateness of the technology for the user -** the extent to which the technology meets a need or solves a problem;
9. **Affordability -** the extent to which the technology/option can be financially recovered by savings.

Indicators that have not been evaluated are: consistency with development goals, consistency with the CMDGs and their appropriateness concerning the Climate Change Vulnerability Assessment. These assessments could be undertaken as part of the development of the next Climate Change Strategy and Action Plan.

The results of the mitigation screening are shown in Table 5.2. A high score indicates that the option has high potential in Cambodia. The assessment also reveals the barriers and opportunities facing individual options. For example, solar energy scores high on all indicators except affordability, suggesting that financial support schemes could accelerate implementation of this option.

Table 5.2: Scoring of mitigation options against feasibility parameters

	Mitigation Options per sector	Feasibility Indicators: Social acceptability	Technical feasibility	Environmental acceptability	Contribution to economy	Political acceptability	Maturity in Cambodia	Easiness of implementation	Appropriateness to the user	Affordability to the user	**Total Score**
A1	**Energy Industries (Electricity Supply)**										
1	Grid Connection REEs	5	5	4	4	5	5	5	5	4	**42**
2	Grid Connection Auto Producers	4	5	5	5	5	5	5	5	2	**41**
3	Grid Connection Battery Charging Stations	5	5	4	4	4	5	5	5	4	**41**
4	Solar Power Plant	5	5	5	4	5	4	5	5	3	**41**
5	Solar Home Systems	5	5	5	3	5	4	5	5	2	**39**
6	Pico Hydro	4	5	5	3	5	2	5	4	5	**38**
7	Mini and Micro Hydro	4	5	5	3	5	2	4	5	4	**37**
8	Rice Husks for Electricity Generation	4	4	3	4	4	4	4	4	3	**34**
9	Energy efficiency end users	2	5	5	3	4	2	2	2	5	**30**
10	Energy efficient buildings	3	5	5	3	4	2	2	4	2	**30**
11	Methane emissions reduction from hydro dams	3	4	4	4	4	2	2	3	4	**30**
A2	**Manufacturing Industries and Construction**										
1	Rice Milling Efficiency/Technology Change	5	5	4	5	5	3	3	4	3	**37**
2	Garment Industry Efficiency/Technology Change	5	5	4	5	4	3	3	4	3	**36**
3	Brick Works Efficiency/Technology Change	5	5	4	4	4	3	3	4	3	**35**
4	Rubber Factories Efficiency/Technology Change	5	5	4	4	4	3	3	4	3	**35**
5	Efficient Cookstoves for Small Scale Industries	5	5	4	4	4	4	3	3	3	**35**
6	Organic Waste Methane recovery	4	4	4	4	4	2	4	4	4	**34**
7	Rice Husk Briquettes	5	3	4	4	4	2	4	3	4	**33**
8	Efficient Charcoal Production	5	4	3	4	3	3	3	4	4	**33**
9	Landfill gas recovery	5	4	4	3	4	2	3	4	3	**32**
10	Cement Production heat recovery	4	4	4	3	4	3	3	4	3	**32**
11	Biofuel	3	4	3	4	4	4	4	3	3	**32**
A3	**Transport**										
1	Hybrid Cars	4	4	4	4	4	4	4	4	3	**35**
2	Motor Vehicle Inspection	3	5	5	3	4	4	3	3	4	**34**
3	Electric scooters and Bicycles	3	4	5	4	4	4	4	3	3	**34**
4	Short lunch to reduce ½ the house to work travel	3	5	5	4	2	3	4	4	4	**34**
5	City Transport Master Plan	3	4	5	3	3	3	3	3	4	**31**
6	Public city transport	3	3	5	3	3	3	2	2	4	**28**
A4	**Commercial Institutional**										
1	Air conditioning from diesel gensets HVAC	4	4	4	4	4	2	3	4	4	**33**
	Residential Sector										
1	Efficient Cookstoves	4	4	4	5	4	4	5	5	5	**40**
2	Biodigesters	4	4	5	5	4	4	4	5	4	**39**
3	Water Filters	3	4	5	5	4	4	4	4	4	**37**
4	Solar Lanterns	3	3	4	5	4	3	4	3	3	**32**
5	Tree Planting for Cooking fuel	4	2	4	3	4	2	2	4	5	**30**
	Agriculture										
1	Wind Water Pumping	4	4	5	4	4	3	3	4	4	**35**
2	Large biogas plants pigs and cows	3	4	5	4	4	3	3	4	4	**34**
3	Agricultural Waste Briquettes	3	4	4	4	4	3	3	4	3	**32**

The emission mitigations in CO_2-eq for each option are presented in (Table 5.3). For the manufacturing industries, not all mitigation options are calculated due to unavailable data, or difficulties estimating the mitigation potential of options due to a lack of baseline data. In many cases, significant savings can be achieved with low-cost interventions, however, substantial reductions often require more costly changes in technology, behavioural change and solutions to investment barriers.

Table 5.3: Baseline emissions compared to the potential of all proposed mitigation options

Year	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**
Total Baseline Emissions	5,533	5,987	7,551	9,601	11,599	14,043	17,075	20,848
Energy Industries								
Grid Connection REEs	3	12	30	51	80	106	140	172
Grid Connection Auto Producers	18	152	269	268	309	354	430	492
Grid Connection Battery Charging Stations		5	12	16	16	14	12	10
Solar Power Plant	0	0	1	2	5	9	18	36
Solar Home Systems	0	6	16	22	22	19	16	12
Pico Hydro	-							
Mini and Micro Hydro		2	3	4	4	4	4	4
Rice Husks for Electricity Generation	27	67	167	417	445	463	481	498
Energy efficiency end users	22	55	138	344	592	797	1,002	1,264
Energy efficient buildings	50	85	193	285	354	443	557	702
Methane emissions reduction from hydro dams	-							
Sub Total Savings	**120**	**384**	**829**	**1,409**	**1,826**	**2,210**	**2,659**	**3,191**
% savings compared to Baseline	2%	6%	11%	15%	16%	16%	16%	15%
	Year							
Manufacturing Industries	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**
Rice milling, Garment, Rice Mills, Brick Works	326	373	429	497	580	681	803	953
Organic Waste Methane recovery	-	-	-	-	-	-	-	-
Rice Husk Briquettes	-	-	-	-	-	-	-	-
Efficient Charcoal Production	-	-	-	-	-	-	-	-
Landfill gas recovery	-	-	-	-	-	-	-	-
Cement Production heat recovery	-	-	-	-	-	-	-	-
Biofuel	13	32	79	147	147	147	147	147
Sub Total Savings	339	405	508	644	727	828	950	1,100
% savings compared to Baseline	**6.1%**	**6.8%**	**7%**	**7%**	**6%**	**6%**	**6%**	**5%**
	Year							
Transport Sector	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**
Hybrid Cars			2	6	15	37	92	229
Motor Vehicle Inspection	62	154	192	238	297	369	461	574
Electric scooters and Bicycles	4	9	22	54	78	95	116	141
Flexible work hours	-							
City Transport Master Plan	-							
Public city transport	-							
Sub Total Savings	**66**	**163**	**216**	**298**	**390**	**501**	**668**	**944**
% savings compared to Baseline	1.2%	2.7%	3%	3%	3%	4%	4%	5%
	Year							
Other Sectors	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**
Efficient Cookstoves, Biodigesters, Water Filters	3	7	17	39	96	136	160	170
Solar Lanterns	0.6	6.2	31	56	50	44	44	44
Tree Planting for Cooking fuel	-							
Wind Water Pumping	0.0	0.4	3	5	9	11	14	16
Sub Total Savings	4	14	51	100	155	191	218	230
% savings compared to Baseline	0.1%	0.2%	0.7%	1.0%	1.3%	1.4%	1.3%	1.1%
Total Savings	**528**	**966**	**1,603**	**2,452**	**3,098**	**3,730**	**4,495**	**5,465**
% savings compared to Baseline	9.5%	16.1%	21%	26%	27%	27%	26%	26%

Note: $GgCO_2$-eq excluding LULUCF sectors

The proposed options in the energy industry sector contribute the most to emissions mitigation: 17% compared to the baseline in 2050. The results in the energy industry sector could actually be divided over the other sectors but are all calculated under the energy industry sector following IPCC guidelines. The manufacturing and transport sectors save 6% and 7% respectively, compared to the baseline emissions. The mitigation options proposed in the other sectors have a relatively low contribution to the total mitigation, at 1% in 2050, however the result of most of these mitigation options is not calculated in the energy and transport mitigaton analyses, but in Agriculture, Forestry and Other Land Use (AFOLU) /LULUCF.

5.2.3 Implementation strategies

The successful implementation of each mitigation option depends on several parameters. Some require the dissemination of information to convince users about the potential savings, other mitigation options will only take off once pioneers have proved that the option works. For a number of options, policies or strategies have to be developed and implementation might not happen before penalties and/or incentives are in place. The mitigation options were further analysed under four possible implementation strategies to draw out the conditions under which the various options could be implemented. The strategies are of increasing complexity and effectively build on each other. The emission savings for each scenario are mutually exclusive and can be added together if different scenarios are combined. The highest amount of emission savings would be achieved when all four strategies are implemented. This would reduce the baseline emission of 25,549 Gg CO_2-eq per year in 2050 by 7,094 Gg CO_2-eq or 28%. The strategic categories are discussed below.

The short-term win-win strategy (less than one year)

This scenario includes mitigation options that are short-term (less than one year) win-win measures. The private sector can implement these options profitably but may not do so due to low awareness or limited investment finance. Dissemination of information and linking banks with the private sector are therefore required to facilitate uptake.

Under this strategy it is estimated that 573 Gg CO_2-eq can be saved per year in 2050. The mitigation options include connecting battery charging stations, offices and companies to the national grid, and connecting pico-hydropower, for which the costs are very low (though there are not many suitable streams in Cambodia).

The extended short-term win-win carbon finance strategy (one year)

This strategy includes carbon finance[8]. Several projects can apply for funds from the CDM. With carbon finance it is likely that the private sector will be incentivized to implement mitigation options such as solar grid power, rice husk for electricity generation, methane recovery, cement heat and power systems, and combined electricity and cooling (HVAC) projects. The total saving in year 2050 could be 588 Gg CO_2 eq. per year, or 2% compared to the baseline emissions.

Medium-term green growth support strategy (one-three years)

The private sector is often reluctant to experiment with new technologies, but donor funding can provide information, training and funding for pilot projects that can trigger market acceptance. There is evidence of this effect in Cambodia, for example the introduction of a biomass gasifier from India resulted in local entrepreneurs developing their own gasifiers within one year, while the efficient cook stove project has resulted in the production of one million efficient stoves by the private sector.

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[8] Carbon finance is income that is acquired by selling emission offsets resulting from the implementation of technology that results in lower GHG emission than the baseline. Emission offsets, or carbon credits, are used by entities (countries, companies) to meet their emission reduction targets.

The medium-term green growth support strategy requires donor financing to drive the private sector towards investing in sustainable energy development or green growth. The total savings can add up to 1,385 GgCO_2-eq, or 6% compared to baseline emissions. The options include SHS, mini and micro hydropower, efficiency and technology improvements in main industrial sectors, fuel wood efficient technologies, solar lanterns, wind water pumping and charcoal briquettes from agricultural waste.

Long-term green growth planning strategy

A long-term green growth planning strategy requires a mix of government planning, donor support, private sector involvement and carbon finance. Savings are not calculated for all mitigation options due to a lack of data. However, the options assessed can save 4,548 GgCO_2-eq per year in 2050 or an 18% reduction compared to the baseline. The mitigation options include national grid extension planning and implementation, energy efficiency, methane recovery from hydroelectric dams, efficient charcoal production, biofuel and transport mitigation options.

Baseline development

The increasing energy demand in the energy and transport sectors over the past decade is a result of economic growth and improved living standards for thousands of families. For the coming decades, this growth is expected to continue, resulting in increased energy demands and higher GHG emissions. Under the baseline, development emissions are expected to rise from 2,645 GgCO_2-eq in 2000 to 25,549 GgCO_2-eq in 2050, equivalent to 0.2 tCO_2 per capita in 2000 and 1.3 tCO_2 in 2050, with a population of more than 23 million. The increase in emissions is substantial, but still relatively low compared to neighbouring countries such as Thailand, with emissions at 3.7 tCO_2-eq per capita in 2007. The transport sector will have the largest share in emissions in 2050, at 10,816 GgCO_2-eq, followed by the energy industries sector (all emissions related to electricity generation) at 8,888 GgCO_2-eq.

Economic growth also results in a shift from traditional fuel sources, such as fuel wood, to fossil fuels. The increased dependency on fossil fuels also reflects Cambodia's transition from a mostly rural agricultural country to a more urban-oriented society. In 2000, 77% of the total energy needs in Cambodia were met by firewood and charcoal. In 2010, the share of firewood and charcoal in total energy use fell to 49% and is projected to be only around 13% in 2050. In 2050, although many households will still depend on fuel wood or charcoal for cooking, most will have switched to LPG and electricity. The Government plans to connect thousands of households to the National Grid over the coming decades to reach 70% coverage by 2030. The number of vehicles will increase rapidly and require improved road structures and transport plans.

Combination of mitigation strategies

In terms of implementation of mitigation options, four strategies were considered; 1) A Short-Term Win-Win Strategy; 2) an Extended Win-Win Carbon Finance Strategy; 3) a Medium-Term Green Growth Support Strategy; and 4) a Long-Term Green Growth Planning Strategy. The highest amount of emission savings can be achieved when all four strategies are implemented. The proposed mitigation options have the capacity to reduce the baseline emission of 25,549 GgCO_2-eq per year in 2050 by 7,094 GgCO_2-eq to 18,455 GgCO_2-eq, or by 28%.

Recommendations

To achieve the potential emission reductions, private sector investment, financial support from carbon financing (either Voluntary Emission Reduction (VERs) or Certified Emission Reduction (CERs) following CDM procedures), donor support and government regulations are required.

Several recent developments, such as the dissemination of efficient cook stoves, bio digesters and ceramic water filters have contributed to reduced emissions, however large-scale dissemination could result in much higher savings. The first two technologies already receive carbon credits based on VERs that provide for subsidies and improvement, monitoring, evaluation and quality control of the technology. There are many more potential technologies that could benefit from VERs.

Energy and emission data collection should be improved in most sectors to improve estimates of total demand and to understand process efficiency in order to define the optimal mitigation options. The baseline emissions are calculated with the most recent available data and projections for demand in the future. However, the emissions could, in reality, be much higher or lower depending on future developments. For this reason the projections need to be improved every few years based on new or improved energy demand-forecasting studies, taking the newest developments into account.

Renewable energy investments have been limited and fragmented. Coordinated efforts from the Government and donors for data collection, research, feasibility studies, pilot projects and finance to undertake the up-scaling of successful pilots are a high priority to start reducing GHG emissions, while allowing for thriving green growth. This is also necessary to enable better energy planning, strategy development and implementation.

By promoting a green growth agenda, the RGC aims to avoid expensive mitigation measures in the future. Such a path is likely to involve high initial costs and possible slightly lower economic growth in the short term, but in the long term it will result in an affordable and sustainable energy supply and a reduced reliance on fossil fuels. This path has the potential to put Cambodia ahead of neighbouring countries that still depend largely on fossil fuels.

So far government strategies are not yet fully developed to support a green growth development with low carbon emissions or a so-called low carbon economy. In the coming years it is recommended that the Government develop such policies followed by strategies and action plans for implementation.

6. Greenhouse Gas Mitigation in the Agriculture, Land Use Change and Forestry Sector

6.1 Overview

The analysis of GHG mitigation in the sector includes the following steps: establishment of a business as usual (BAU) scenario to 2050, identification of GHG mitigation options, screening of GHG mitigation options, an analysis of the barriers and opportunities associated with the most suitable GHG mitigation options and the development of GHG mitigation scenarios.

6.1.1 Baseline emission scenario

Baseline projections were developed for the agricultural sector (rice cultivation, agricultural soils and livestock) and the LUCF sector. Since activity data is generally only available to 2005/2007, emissions were calculated until 2005/2007 and then projected to 2050. Where possible, the modelling of GHG emission takes into account the current macroeconomic conditions, policy conditions, market conditions and events in other sectors.

Cambodia has a high population growth rate and consequently the demand for products and services is likely to increase in the future. This will stimulate agricultural productivity, land encroachment and the demand for wood (products) with a consequent increased pressure on forests. In addition, the projected growth in GDP will increase the consumption of goods that have a higher GHG emission and intensity, e.g. meat and chemical fertilizers.

Table 6.1 details the GHG emission forecast on a five-year interval for the AFOLU sector. Under BAU, emissions are forecast to increase from -8,822 Gg CO_2-eq in 2000 to 34,112 Gg CO_2-eq in 2050. While the LUCF sector remains a net sink, the total sink capacity decreases from -30,421 to around -5,000 GgCO_2-eq.

Table 6.1: BAU GHG emission in AFOLU (Agriculture and LUCF) in GgCO_2-eq/year[9]

	LUCF			Agriculture				AFOLU
Year	**Emissions**	**Uptake**	**Total**	**Livestock**	**Rice**	**Agr. soil**	**Total**	**Total**
2000	20,044	-50,465	**-30,421**	4,872	14,365	2,362	**21,599**	**-8,822**
2005	27,060	-52,945	**-25,885**	5,836	16,842	3,111	**25,790**	**-95**
2010	34,465	-53,241	**-18,776**	5,836	17,940	3,552	**27,328**	**8,835**
2015	34,946	-53,439	**-18,493**	6,359	18,676	3,870	**28,905**	**10,412**
2020	35,049	-40,932	**-5,882**	6,882	19,620	4,206	**30,708**	**24,826**
2025	35,261	-41,106	**-5,845**	7,405	20,488	4,547	**32,439**	**26,594**
2030	33,402	-41,300	**-7,898**	7,927	21,178	4,888	**33,993**	**26,095**
2035	36,616	-41,463	**-4,846**	8,450	21,704	5,231	**35,386**	**30,540**
2040	36,669	-41,620	**-4,951**	8,973	22,117	5,582	**36,672**	**31,721**
2045	36,388	-41,765	**-5,377**	9,496	22,436	5,941	**37,873**	**32,496**
2050	37,103	-41,940	**-4,836**	10,018	22,625	6,305	**38,948**	**34,112**

[9] The GHG emissions from the category of burning of savannahs and field burning of agricultural residues make an insignificant contribution to total emissions and were not included in the mitigation analyses.

6.1.2 Mitigation options for agriculture and LUCF

In total, 46 GHG mitigation options were identified and assessed – 14 relating to livestock, 12 to rice cultivation, 9 to agricultural soils and 11 to the LUCF sector. In order to identify the most suitable options to reduce GHG emissions, the UNFCCC screening matrix (UNFCCC 2006) was adapted for use in Cambodia. The matrix provides a qualitative ranking of options based on four main categories – feasibility, implementation feasibility, consistency with MDGs and data availability. The GHG mitigation options were scored based on expert judgment. Other factors were also taken into account in determining the overall attractiveness of an option, such as the relative GHG abatement cost, the mitigation potential and government plans (Table 6.2).

Table 6.2: Screening Criteria

Criteria	Description
Feasibility	- Social acceptability: extent to which the option adheres to the habits, rituals and custom of the users; - Technical feasibility: extent to which the option is technically feasible; - Environmental acceptability: extent to which the option impacts the environment; - Economic acceptability: degree to which the option contributes to the macro-economy; - Political acceptability: degree to which the options fit with government policies and plans.
Implementation feasibility	Level of maturity of the option in Cambodia: - Private incentives for the adopter: does the option provide incentives (i.e. financial, time saving) for adoption? - Decrease in import dependency*: does the option reduce import dependency? - Long-term sustainability*: likelihood that the option is adopted for a long period and that it continues to save emissions in the future.
Consistency with MDGs	- Improvement of the quality of life: degree to which the option improves living conditions; - Potential to reduce environmental degradation: degree to which the option contributes to counteracting environmental degradation; - Domestic employment*: the extent to which the option results in local job creation; - Overall consistency with MDGs*: the extent to which the option aligns with the MDGs for Cambodia.
Data availability and quantity	- Availability*: degree of data availability of the option; - Quality*: quality of the data that are available i.e. is there a scientific consensus on the effect of the option.

Note: * Extracted from the UNFCCC Example Screening Matrix (UNFCCC, 2006)

Only options that had a high score on the screening matrix, favourable abatement costs and the potential for implementation were further assessed. Table 6.3 presents the options considered as most viable in Cambodia.

Table 6.3: Viable GHG mitigation options

Sector	GHG mitigation option
Livestock	- Small-scale and large-scale biogas and composting - Aquaculture - Fodder production
Rice cultivation	- Drainage in rainy season - Switch to sulphur fertilizer - Compost/bio-slurry
Agricultural soils	- Organic input agriculture and bio-slurry - Crop management
LUCF	- Agro-forestry - Reforestation, REDD+

6.2 Livestock

6.2.1 Emission projections to 2050

GHG emissions will increase proportionally to the number of livestock kept. The dominant farming system in Cambodia is a mixed livestock / rice system, as rice production depends heavily on draught and manure from cattle and buffalo (FAO 2005). Milk production is limited and confined to a few intensive farms near Phnom Penh and to smallholders. Chickens are owned by 90-95% of rural households.

The livestock sector contributes 20.6% to the income earned from agriculture, approximately 7.6% of total GDP (FAO 2005). While it is dominated by smallholders, there is an emerging trend of large-scale commercial businesses entering the livestock industry (FAO 2005). The sector is currently characterized by low productivity levels, primarily caused by low quality feed (Pen, Savage, Stur and Seng 2009) (Devendra and Sevilla 2009).

Based on the GHG inventory, the predominant share of GHG emission from the livestock sector is from enteric fermentation of ruminants, non-dairy cattle and buffalo. Emissions from manure management are dominated by swine manure. Poultry has an insignificant emission share of less than 1% or 31 $GgCO_2eq$/year, and therefore was not included further in the analysis.

The GHG emissions to 2050 are based on the projection of historic trends and a validation exercise. Based on 1985-2007 data, livestock numbers are expected to increase substantially by 2050. This trend is driven by the increasing demand for livestock products, in particular meat, due to the growth in population and real GDP per capita. The population of buffalo however will remain stable, as the agricultural sector will rely less on animal draught power in the future. In terms of livestock units, non-dairy cattle will be by far the most prevalent in 2050, but the share of swine is growing.

The Cambodian diet is expected to be significantly more meat-based in 2050, increasing from around 15 kg to 42 kg annually in 2050. This shift mirrors trends in neighbouring countries, for instance, the International Food Policy Research Institute (IFPRI) projects that per capita meat consumption in China in 2020 will be 73 kg/year, and in Southeast Asia, including Cambodia, 30 kg/year (IFPRI, 2003). The projection for Cambodia is slightly lower than the average for Southeast Asia, at 25 kg/year, explained by the fact that Cambodia starts off at a much lower consumption in 2000, 15.6 kg/capita compared to 24.4kg/capita in Vietnam and Thailand.

The livestock sector comprises three emission sources: enteric fermentation; methane emission from Animal Waste Management Systems (AWMS); and nitrous oxide emission from AWMS. Table 6.4 shows the emission forecast in five-year intervals for the period 2000 to 2050 based on the extrapolation of trends. In 2050, emissions will have doubled, increasing from 4,872 in 2000 to 10,018 $GgCO_2$-eq/year[10].

Table 6.4: BAU GHG emission projection sub-sector livestock by source (2000-2050)

Year	Enteric fermentation ($GgCO_2$-eq/year)	Manure management CH_4 ($GgCO_2$-eq/year)	Manure management N_2O ($GgCO_2$-eq/year)	Total ($GgCO_2$-eq/year)
2000	3,627	461	784	4,872
2005	3,817	579	937	4,712
2010	4,222	611	1,004	5,836
2015	4,581	674	1,104	6,359
2020	4,941	737	1,205	6,882
2025	5,300	800	1,305	7,405
2030	5,659	862	1,406	7,927
2035	6,019	925	1,506	8,450
2040	6,378	988	1,607	8,973
2045	6,737	1,051	1,708	9,496
2050	7,097	1,114	1,808	10,018

6.2.2 Mitigation options

The GHG mitigation options considered for the livestock sector fall into three main strategic groups: reducing emissions from manure (biogas and composting); reducing emissions both from manure management and/or enteric fermentation; and reducing enteric emissions.

Small-scale and large-scale biogas supplemented with composting. Biogas and anaerobic composting were considered as a combined option. While biogas generation is preferable over composting, only families with at least 20 kg of manure can potentially run a biodigester. It makes sense therefore for farmers with less than 20 kg opt for the second-best alternative - composting. Creating co-operatives with small-scale farmers might be another option for the use of biodigesters.

Biogas is produced in a digester from animal and human waste in a controlled anaerobic environment. On-site treatment of farm waste through a biodigester avoids methane emissions, and can generate electricity for the farm and surrounding villages. As the electrification rate in rural areas is low, utilizing local resources such as animal waste presents a low cost electrification option. Biodigesters also address a number of other development issues in rural areas, such as reliance on traditional fuels, indoor air pollution, low-quality lighting, energy security and reliance on imported chemical fertilizers.

Digesters have a lifespan of more than 10 years and a payback period of three to four years; hence for the majority of its lifetime a biodigester can help reduce expenditure on cooking and lighting fuels, and chemical fertilizer. The National Biodigester Programme (NBP) estimates that households can save up to

[10] Note that the figures for 2000 differ slightly from the SNC inventory (Chapter 3). This is because the SNC inventory used the average livestock population of 1998, 1999 and 2000, and these projections used the actual livestock number for each year as reported in the NIS (2009).

US$12/month. Lower health care costs as a result of improved hygiene and sanitation are also possible (Buysman 2009). For these reasons the Government supports the promotion of biodigesters in Cambodia, however NBP is yet to be included in the national strategic policy of MAFF.

The total mitigation potential depends on **manure management practices**. To understand this better a baseline survey is required in Cambodia. Typically, swine manure is stored as slurry, which has a high emission factor. Hence, methane capture and use will significantly reduce emissions. In larger farms cow dung and urine are likely to be captured together (in contrast to smallholders) with the waste being mixed and stored as slurry. The methane reduction opportunities are, in this case, similar to large pig farms. Based on IPPC default emission factors, the emission reduction potential of biogas is estimated at 85%. The baseline emission from cows and pigs in large-scale farms are 9 GgCO_2-eq/year, and the emission reductions are 7.66 GgCO_2-eq/year if all medium and large-scale farms install a biodigester.

Manure composting entails the treatment of manure in an aerobic environment. This environment can be maintained by sheltering manure against rain, ensuring the manure is not wet by urine, and turning over the heap regularly to promote aeration. A risk with composting is the loss of nitrogen in the form of N_2O, which not only causes GHG emission but also denotes a loss in fertilizer value. Nitrogen loss may be reduced through the addition of a high C-substrate to increase the C:N ratio, which reduces N volatilization as N_2O (Koneswaran and Nierenberg 2008). Training on how to prevent nitrous oxide emission is therefore also required.

The emission reduction potential of manure composting depends, as with biodigesters, on the baseline AWMS, and for this a baseline survey is required in Cambodia. According to the literature, the estimated emission reductions are around 10-35% (Smith, Martino and Cai 2008). The NBP estimates that a compost shelter costs around US$30. Assuming a lifespan of two years and 35% of emissions reduced from the manure of two cows and three pigs, the savings are around 0.4 tCO_2-eq over the lifespan, hence, the mitigation costs are US$0.012/t$CO_2$-eq.

Fodder production and improved feeding practices can also contribute to a reduction of GHG emissions. These are not considered in this phase of the assessment.

An overview of the mitigation options in the livestock sector is presented in Table 6.5.

Table 6.5: Overview of livestock mitigation options

Practice	Score	Relative mitigation Potential[1]	Max potential[1] (Gg)	Gross abatement costs (US$/ t$CO_2$-eq)	Challenges / barriers and feasibility	Co-benefits and contribution to sustainable development	Environmental risks/impacts
Methane capture and use (Biogas production)	70 (small scale) 66 (large scale)	Up to 85%	1,168 (small scale) 767 (large scale)	10.9[2] 200	Costs are prohibitive for many farmers, lack of support network	Win-win option. Environmental protection and energy security, good quality light and smokeless cooking fuel	Possibly nitrate leaching if applied to the soil
Aerobic treatment	58	10-35%		0.012	Incentives to implement this option needed, lack of nationwide promotion network	Less odour if done properly and composting results in stabilized material that is an excellent fertilizer	Risk of NH_3 volatilization

Note: [1] Potential is calculated for year 2000; [2] Including savings, the net abatement costs of the NBP digester are negative: -$75/t$CO_2$-eq.

6.3 Rice cultivation

6.3.1 Emission projections to 2050

Rice production is projected to increase from 4,025 Gg/year in 2000 to 10,323 Gg/year in 2050, a 2.4-fold increase. This growth is higher than the population growth, which is forecast to be 1.9 times higher in 2050 compared to 2000. With an estimated growth of 5% in 15 years, rice yield in 2050 approaches 3t/ha, which is below the yield of Vietnam (4.59 t/ha), and higher than the 2007 yield in Thailand of 2.67t/ha. The area of rice harvested is estimated at 3,275 kha, which is below the potential land available (4,400 kha).

The baseline scenario forecasts that Cambodia's emissions from rice field cultivation increase by 65.9% from 2000 (14,365GgCO_2-eq) to 2050 (23,833 GgCO_2-eq) (Table 6.6).

Table 6.6: The BAU GHG emission forecast for the sub-sector rice cultivation

	Year	Yield (t/ha)	Rice production (Gg)	Surface area (thousand ha)	Rice export (Gg)	Emission (GgCO_2-eq)	Per capita emission (tCO_2-eq)
Available data	1985	-	1,812	1,450	-	-	-
	1990	-	2,500	1,855	-	-	-
	1995	-	3,452	1,924	-	-	-
	2000	2.12	4,025	2,079	-	14,365	1.13
	2005	2.48	5,986	2,438	-	-	-
Projections	2010	2.63	7,147	2,720	2,382	18,792	1.25
	2015	2.67	7,678	2,875	2,559	19,864	1.21
	2020	2.71	8,218	3,028	2,739	20,918	1.18
	2025	2.76	8,707	3,156	2,902	21,804	1.15
	2030	2.80	9,121	3,253	3,040	22,472	1.12
	2035	2.85	9,477	3,325	3,159	22,973	1.09
	2040	2.90	9,799	3,383	3,266	23,371	1.06
	2045	2.94	10,089	3,427	3,363	23,675	1.03
	2050	2.99	10,323	3,450	3,441	23,833	1.00

6.3.2 Mitigation options

A number of options were evaluated for mitigating GHG emission from rice cultivation in Cambodia (Table 6.7). These can be broadly categorized into four groups: water management measures, fertilization management measures, measures aimed at keeping the soil oxidized, and measures targeted at the selection of appropriate rice cultivars.

Only three options were ultimately considered suitable for Cambodia (based on their feasibility score and cost). They are discussed below.

Table 6.7: GHG mitigation options in sub-sector rice cultivation

Category of option	GHG mitigation option
Water management	Drainage in dry season
	Intermittent drainage in rainy season
Fertilization management	Sulphated fertilizers Compost
	Biogas slurry
Strategies aimed at keeping the soil oxidized	No tillage during rainy season / dry season Direct seeding during dry season / rainy season
Rice cultivars selection	Cultivars that release less methane to the atmosphere Short-cycle cultivars

Water management – Intermittent drainage in the rainy season

Intermittent drainage consists of draining a rice field for a short period during the rice life cycle - this shortens the anaerobic phase during which organic matter is converted into methane. The optimal time to drain is considered to be mid-season or during the reproduction period which corresponds to the warmest period in the rice cycle (Wassmann, Neue, Buendia and Lantin 2000). According to Pathak et al. (2005) drainage does not interfere with the rice yield. Based on studies in China and Japan, mitigation potential ranges from 23% to 60% (Yue et al. 2005, Wang et al. 2000, Xiaoyuan 2005).

In Cambodia, drainage is not common practice due to the lack of water and irrigation infrastructure, however it is encouraged as part of the SRI technique promoted by the Government. During the dry season, draining rice fields is *not* considered to be an option in most areas due to water scarcity. Drainage and irrigation are cheaper in the rainy season and therefore more affordable and technically feasible. A conservative mitigation potential of 25% was adopted for wet season drainage, at gross GHG abatement costs of around US$20/t$CO_2$-eq (Pillot 2007, Yu and Fan 2009).

This option requires infrastructure, machinery and regular maintenance of the drainage/irrigation systems. Incentives are currently lacking in Cambodia to encourage farmers to take on the additional costs and the time needed to implement this option. There is also the risk of water shortages due to erratic rainfall, especially in the months of July and August in Cambodia, which would prevent farmers applying drainage. Natural factors, such as topography, energy availability and soil characteristics may also constrain irrigation or drainage.

However, irrigation development at the national scale is part of the Ministry of Water Resources and Meteorology's (MOWRAM) Strategic Development Plan (NSDP 2006-2010) and has real potential in Cambodia. The two main water resources in Cambodia, the Mekong River and the Tonle Sap Lake, have the potential to irrigate 1.2 million hectares in Cambodia (Sao and Chhun 2004). The fact that drainage practice is included in the SRI methodology presents the opportunity to promote drainage as part of a proven methodology resulting in higher yields (Anthofer 2004).

Fertilization management

Methane is produced from organic matter in flooded rice fields, however certain fertilizers can suppress the methane produced. Two categories of options – **sulphated fertilizer** instead of urea and **compost** instead of manure – are considered as potential mitigation options for Cambodia.

The mitigation potential of **sulphated fertilizer** is estimated at 9% to 73% for Phosphogypsum and 10% to 67% for Ammonium Phosphate in the rainy season (Wassmann, Neue, Buendia and Lantin 2000). In

Cambodia, the main fertilizers are animal manure, imported compost, urea (46-0-0), Diammonium phosphate (DAP) (18-46-0) and NPK (15-15-15) (MAFF 2007). Sulphated fertilizers are not yet available (Seng 2010 and Yang 2010), but are expected to enter the Cambodian market in the next few years. Sulphate fertilizers would not involve any changes to current practices as this involves switching from fertilizers such as urea or DAP which are applied using the same techniques. They are therefore culturally and technically feasible to implement.

However, farmers currently lack knowledge of these options, and the potential of sulphated fertilizer may be limited by its cost. In the Philippines, it is twice the price of urea (Wassmann, Neue, Buendia and Lantin 2000). The total costs are estimated to be around US$59/t$CO_2$-eq abated for Ammonium Sulphate and about US$40/t$CO_2$-eq abated for Phosphogypsum. There is a risk of soil acidification through the application of sulphated fertilizers, but this could be avoided through proper use and guidance on application.

Before this option can be implemented, scientific and applied research and expert advice are needed to determine the optimal fertilizer use based on soil types, rice varieties and environmental characteristics. Following this, communication campaigns are needed to inform farmers and change habits, and markets need to be developed.

Composted fertilizers such as bio-slurry and compost have less organic material available for anaerobic decomposition than farmyard animal manure. The mitigation potential is estimated at 58% to 63% for compost in a flooded rice field scenario, and 10% to 16% for bio-slurry in a scenario where a rice field is submitted to intermittent drainage (Wassman et al. 2000). Bio-slurry used in flooded rice fields is likely to have similar emission reduction potential to compost, as most organic matter is removed during anaerobic digestion.

The adoption of composted fertilizer to mitigate emissions from rice cultivation is considered highly suitable in the Cambodian context. The most common fertilizer used in Cambodian rice fields is a mix of farmyard manure and urea (Pillot 2007). Using compost or bio-slurry instead of farmyard manure as soil amendments is already practiced in rice cultivation. The Government and civil society promote composting and organic fertilization. The use of compost and bio-slurry is included in the SRI methodology package and is widely promoted all over the country through government programmes and NGOs. Application of compost or bio-slurry improves the soil structure and is an investment in the future, improving the long-term fertility and structure of the soil.

The mitigation costs are US$22.7/t$CO_2$-eq for bio-slurry produced in NBP digesters and $13.1/t$CO_2$-eq for compost.

The costs of biogas plants, the time needed to produce compost and the transportation of slurry to rice fields are key constraints facing the use of bio-slurry as fertilizer, and not all farmers have enough livestock to produce sufficient bio-slurry or compost required for rice field fertilization. There is, in general, a lack of machinery for composting (shredders for medium- to large-scale composting processes) which would allow the composting of green manure. Without such machinery, composting can only be sourced from manure. The number of biogas plants is too low for large-scale implementation of bio-slurry however, the sector is growing with 3,000 plants per year and will reach the scale required for large-scale implementation in this decennia. Cooperative use of machinery can be an option for small-scale farmers.

An overview of available options to reduce emissions from rice cultivation is provided in Table 6.8.

Table 6.8: Overview of the options – Rice Cultivation

Practice	Score	Relative mitigation potential	Max potential (Gg)	Gross abatement costs (US$/ tCO_2-eq)	Challenges/ barriers and feasibility	Co-benefits and contribution to sustainable development	Environmental risks/impacts
Water management: drainage in the rainy season	44	25% (23 to 60%)	4,121	20.4	Costs related to irrigation systems (pumps, canals, pipes, water retention strucure) Topography/hydrology dependent	Potentially encourages root development and improves yield	Rain-fed rice fields are dependent on rainfall. Drainage brings uncertainties and risks of dramatic water shortages.
Phospho-gypsum	47	15%	2,474	39.5	Costly	None	Risk of soil acidification
Fertilizer management: composting	53	20% (20 to 63%)	3,933	13.1	Difficult to transport	Removes odours Decreases expenditure on fertilizers	Small
Fertilizer management: biogas slurry	52	Same as compost	262	22.7	Difficult to transport. Need to invest in biodigester which carry high investment costs	Similar proportion to chemical fertilizers; allowing a quick uptake of nutrients by the plants (Buysman, 2009)	Small

6.4 Land Use, Land Use Change and Forestry

6.4.1 Emission projections to 2050

The Land Use, Land Use Change and Forestry (LULUCF) sector is a major emission source and carbon sequestration pool. Forecasting emissions in the LULUCF sector is complex and depends on reliable activity data, especially regarding forest areas, the rate of annual land use change, areas of forest converted, annual growth rates and the biomass density of forests.

Emission forecasts for the LUCF sector are based on the GPG (IPCC, 2001). The main assumptions adopted in the analysis are: (i) the historical rate of land use change is representative of current and future trends; and, (ii) the rate of demand for forest products is dependent on population pressure (a function of population and GDP growth per capita).

The baseline scenario (Table 6.9) predicts that emission uptake decreases from 30,419 $GgCO_2$-eq in 2000 to 4,836 $GgCO_2$-eq in 2050; this amounts to an uptake reduction of 84.1%. Between 2000 and 2015, significant contributions to the net uptake of GHG emission in Cambodia are attributable to the sink function of abandoned lands; this uptake is accounted for over a period of 20 years. As most forests in Cambodia were or are under human pressure or disturbance, the forests are not in equilibrium, and will continue to sequester until reaching the climax state. Over the period 2010-2050, emissions remain stable from forest and grassland conversion. Changes in biomass stock activities as a result of resource extraction are level with increasing reforestation activity by the private sector and the Forestry Administration.

Table 6.9: Projected emission data LUCF (GgCO_2-eq)

Year	Population (000)	Forest and grassland conversion	Changes in biomass stocks	Abandonment	Gross GHG emissions	Per Capita uptake/emission (tCO_2-eq)
2000	12,760	8464	-26,176	-12,707	-30,419	-2.38
2005	13,866	15,534	-28,710	-12,707	-25,883	-1.87
2010	15,053	22,895	-28,963	-12,707	-18,775	-1.25
2015	16,357	22,895	-28,680	-12,707	-18,492	-1.13
2020	17,707	22,895	-28,777	0	-5,882	-0.33
2025	18,973	22,895	-28,740	0	-5,845	-0.31
2030	20,100	22,895	-30,792	0	-7,897	-0.39
2035	21,121	22,895	-27,741	0	-4,846	-0.23
2040	22,086	22,895	-27,846	0	-4,951	-0.22
2045	22,997	22,895	-28,271	0	-5,376	-0.23
2050	23,795	22,895	-27,731	0	-4,836	-0.20

6.4.2 Mitigation options

Based on screening, four mitigation options are identified as being the most attractive: REDD+, reforestation, agro-forestry, and urban and rural cook stoves. As most of the savings from cook stoves are attributable to the energy sector, this option is discussed as a mitigation option in the energy sector. The others are discussed below.

Other options were not selected for a variety of reasons. **Reduced impact logging** would be hard to implement on a large scale due to investment, technology and equipment barriers, particularly in remote areas. **Bioenergy** requires further study especially in terms of its economic viability. More than 80% of agriculture land is established through forest conversion (CCCO 2003). **Agricultural intensification**, that is producing more crops on land already in production, could reduce pressure to convert forestland to agriculture, and thereby reduce emissions associated with land conversion. However, agriculture intensification requires investment in rural infrastructure and irrigation and can have negative environmental impacts associated with chemical inputs.

Forest protection and management: Forest protection through REDD+

REDD (Reducing Emissions from Deforestation and Forest Degradation) is a proposed mechanism by which least-developed countries are paid for their efforts to reduce the destruction or conversion of protection or production forest. REDD+ is an emerging mechanism and includes the sustainable management of forests, forest restoration and reforestation. While REDD only covers payments for reductions in emissions, REDD+ includes incentives to increase forest carbon stocks and the sustainable harvesting of forest resources. It seems likely that a post-Kyoto protocol will include REDD+ and important pilot efforts are already underway in developing countries in the voluntary carbon offset markets.

Cambodia received funding for a full UN-REDD Country Programme in 2011. Prior to this, the country had already prepared a REDD+ Readiness Roadmap. The Country Programme focuses on effective management of the REDD+ Readiness process and stakeholder engagement, development of the National REDD+ Strategy and Implementation framework, improved capacity to manage REDD+ at sub-national levels and design of a monitoring system.

As the predominant source of readiness funding for Cambodia, the UN REDD National Programme has been designed to support implementation of the Roadmap, in particular with activities under four components:

Component 1: National REDD+ readiness management arrangements and stakeholder consultation (Sections 1 and 2 of the Roadmap).

Component 2: National capacity building towards development of the REDD+ strategy and implementation framework (Sections 3 and 4 of the Roadmap).

Component 3: Sub-national REDD+ capacity building and demonstration (sub-national activities found in Sections 2-6 of the Roadmap).

Component 4: Support to development of the monitoring system (Sections 5 and 6 of the Roadmap).

The roadmap also included an assessment of land use, drivers of land-use change and forest governance. A multi-agency REDD+ Taskforce was established to oversee the roadmap development and to coordinate REDD+ related activities at the national level. Subsequently, Cambodia has received funding for a UN-REDD National Programme, funding through the Forest Carbon Partnership Facility, and support from Japan and others. The UN-REDD inception process was completed at the end of 2011, and implementation of the programme has now commenced.

An effective way to reduce emissions associated with forest degradation is to increase the production capacity of forest areas, regenerate forests and protect them from conversion to other uses. As estimated by the Forestry Administration, avoided reforestation schemes might be possible on an area of up to 5 Mha (NFP 2009). Abatement costs per ton of carbon are estimated at US$ 0.36/tCO_2-eq.

As REDD+ is a recent and developing mechanism, abatement costs differ widely. The transaction costs, including scheme design, negotiation, implementation, enforcement and validation, are adapted from payments for environmental services and cost estimates derived from forestry projects under the CDM. Cost estimates vary from US$0.01/t$CO_2$-eq for tropical countries based on payment for environmental services (PES) schemes (Grieg-Gran 2006), to US$0.66-16.4/t$CO_2$-eq for transaction costs involved in a wide variety of forestry projects (Antinori and Sathaye 2007). Cacho et al. (2005) estimated the transaction costs related to forestry projects in tropical countries range from US$0.14 to US$1.07/tCO_2-eq (Cacho, Marshall and Milne 2005). The ranges in abatement costs reflect the uncertainties around REDD+ in terms of establishing baselines of deforestation and carbon density estimates.

The majority of forests in Cambodia are between a stage of ‘little disturbed forest’ and an eventual stage of forest cover stabilization (forest-agricultural mosaics). The MDG target is to maintain 60% forest cover (NFP 2009). However, available data (Forestry Administration 2006) and the baseline projection show a long period of forest cover loss. This indicates that effective management and protection of forested areas is still low, resulting in forest degradation and forest cover loss. The RGC recognizes the need to strengthen conservation measures and implement deforestation reduction strategies. The REDD+ scheme therefore offers a welcome means of rewarding Cambodia's efforts to reduce emissions from forest degradation and deforestation.

The conservation effort needs to be implemented jointly with activities addressing the root causes or drivers of deforestation. REDD+ could include a wide buffer zone around the avoided deforestation zone. Inside the buffer zone a menu of different options, such as agro-forestry, sustainable managed plantations and agricultural intensification aimed at reducing the drivers of deforestation could be supported.

There are a number of barriers to the uptake of REDD+. The development of a fully functional international REDD+ scheme under UNFCCC could require years (IWG-IFR 2009). Implementation of REDD+ activities takes time, and the initial start-up and implementation costs of a national REDD+ scheme are substantial. Furthermore, sustainable forest management is complicated by unsecure land tenure, a lack of resources to monitor and prevent illegal activities, and technical capacity and resources to monitor and analyse forest degradation.

Actions that could facilitate the uptake and success of REDD+ in Cambodia include: strengthen protection/management of all forests and implement deforestation reduction strategies; development of markets for legal and sustainable forest products; integration of forests in land use planning; and clearly defined land tenure and carbon ownership rights.

Reforestation has potential for GHG sequestration in Cambodia due to the large areas of scrublands / degraded forestlands. Options for afforestation are more limited due to competition with existing land use forms. Afforestation and Reforestation - Clean Development Mechanism (AR-CDM[11]) projects are eligible as carbon offset projects under the CDM. AR-CDM projects have the possibility to contribute to pre-financing or financing establishment and maintenance cost.

A reforestation programme was started by the Department of Forestry and Wildlife in 1985 (CCCO 2003). The rate of planting varies between 289 hectares and 897 hectares per year. Degraded land and forests that were restored up until 1998 totalled only 85,000 ha, or less than the annual rate of deforestation that occurred in the period 1984-1994. Recent data by the Forestry Administration (FA 2008) showed that the pace of reforestation has increased in recent years.

Acacia and Eucalyptus trees were common species in past reforestation initiatives. Abatement costs are estimated to be 1.9 $/tCO_2$ for short rotation Acacia and 1.4 $/tCO_2$ for short rotation Eucalyptus (Makundi and Sathaye 1999).

More recently, partly driven by a higher commodity price, rubber plantations have expanded (Hang 2009) (Guidal 2008). Growing rubber trees is a high-cost and long-term investment. Rubber trees can be tapped from year six up to their maximum life span of 25 to 30 years (Hang 2009). The Economic Institute of Cambodia (Economic Institute of Cambodia 2007) estimated that the total five-year investment cost per hectare was US$1,624 in 2006, which was about half of the investment cost of US$3,086 in 2008 (Hang 2009). In calculating the abatement cost, the data from 2008 is used to present increasing prices of labour and land. Estimates of the CO_2 sequestration during the lifecycle are based on the Marubeni Corporation Rubber Tree Afforestation for Carbon Sink CDM project. It is estimated that 7,600 ha will generate 7,398,326 tCO_2-eq during the project lifetime. Abatement costs are estimated at 3.17 $/$tCO_2$-eq.

Cambodia is known within the region to be a low-yield producer and high-cost processor of rubber compared with Malaysia, Thailand and Vietnam (Hang 2009). Moreover, Cambodia's natural rubber is produced as Cambodian Specified Rubber, which is below the international standard of Technically Specified Rubber (TSR). Predominantly Vietnam is accepting the lower quality rubber. Poor soil and climate

[11] AR-CDM: Payments for carbon sequestration from afforestation and reforestation projects under the CDM.

conditions of land in a degraded state often require an additional effort to re-establish a plantation (fertilizer, time).

Agro-forestry systems involve growing perennials, like trees, in association with food crops and livestock on the same area of land. Agro-forestry systems provide three potential mitigation benefits:

1. Sequestration and carbon storage in trees and in soils through mulching techniques introduced;
2. Potential to offset GHG emissions associated with deforestation;
3. Production of high quality fodder for ruminant animals, which could reduce emissions from enteric fermentation.

Sequestration in agro-ecosystems holds great promise as a tool for climate change mitigation (Albrecht 2003), in particular because they also offer opportunities for synergies with development objectives. Increased carbon stocks can be achieved through reduced respiration losses associated with changes in tillage practices and through changes in land use (Verchot 2007). Trees intercropped with annual crops store and sequester carbon. The CO_2 sequestration rate in trees is estimated to be 1 to 1.26 tCO_2/ha/yr in an intensively used agro-forestry system (IPPC 2006). ENCOFOR[12] estimated the sequestration rate at 4.62 tCO_2/ha/yr for a rotational agro-forestry system, whereas a study conducted in Battambang (Steele 2007) found an annual carbon sequestration rate of 5.26 tCO_2/ha/yr with the implementation of fast growing species like *Leucaena leucocephala* in a bioenergy system. With an estimated annual harvest of 80% of the annual growth for biomass energy production, the sequestration would total 1 tCO_2/ha/yr. This sequestration rate is comparable to the sequestration potential found in the IPPC literature.

In 2003, the INC of Vietnam estimated abatement costs of planting scattered trees at 2.56$/$tCO_2$ (Socialist Republic of Vietnam 2003). A study in 1995 estimated the initial cost of establishing management practices to conserve and sequester agro-forestry in the range from 0.27$/$tCO_2$-eq to 18.81$/tCO_2-eq. The establishment costs of agro-forestry systems within the tropics were estimated to be 1.36 $/$tCO_2$-eq to 2.72$/tCO_2-eq (Dixon 1995).

Agro-ecosystems are also promising adaptation measures. For example, improved agro-forestry systems can reduce the vulnerability of small-scale farmers to inter-annual climate variability (UNFCCC 2008). Additional benefits include the provision of shade, soil improvement and reductions in soil erosion. Harvests from trees (fuel wood) could be used for bio-energy, while leaves and other edible parts could be used as high quality forage for livestock. Production of biomass energy from under-utilized lands could meet household energy demands without the need to extract wood from forests. Agro-forestry promotes biodiversity, energy and food security, and can enhance rural employment and the economy.

The wide scale adoption of agro-forestry systems is limited by the availability of land. The potential arable land area in Cambodia is estimated at 3.6 Mha (USDA, Commodity Intelligence Report 2010). The production of crops increased towards 500,000 hectares under cultivation in 2009 (RCG 2009).

Barriers to uptake include the initial workload, possible social conflict, limited knowledge and integration of trees in current farm systems, and the need for access to agricultural extension services, market information and financial services.

To help overcome these barriers, the Government recognizes the need to increase farmers' knowledge of the benefits of crop and product diversification and farm adaptation to climate change. Rural tenure rights on farmland and forestland should be strengthened. Development of incentives to encourage farmers to adopt mitigation practices, for example, seeds of multipurpose tree species indicated for use in an agro-forestry system, should become widely available at low cost to farmers.

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[12] ENCOFOR: Environment and community based framework for designing afforestation, reforestation and revegetation projects in the CDM: methodology development and case studies, http://www.joanneum.at/encofor/

Factors working in favour of the uptake of agro-forestry in Cambodia include the fact that household ownership (tenure) of agricultural land and home gardens is perceived as more secure than on disputed forestlands, which should encourage tree planting (Steele 2007). Several tree species to be used in an agro-forestry system have been identified by the Cambodia Tree Seed Planting Project (Danida, FA 2005). The selection of multipurpose trees, which produce biomass energy, could be instrumental in reducing pressure on forests.

Table 6.10: Overview of the options LUCF

Practice	Relative mitigation potential (tCO_2/ha/year)	Challenges / barriers and feasibility	Co-benefits and contribution to sustainable development	Environmental risks/impacts and benefits
Forest protection through REDD+	4.7	The effectiveness of forest management and protection largely depends on addressing the drivers of deforestation. REDD+ scheme under development. High transaction costs.	Social economic benefits in a well-integrated system, resource availability, climate benefits.	Resource and biodiversity conservation. Climate benefits.
Sink enhancement and management. Afforestation and reforestation	Acacia: 13 Eucalyptus: 27 Rubber: 32	Low development benefits. Land use competition with other land uses.	Numerous benefits, such as habitat for wild life, forest dwellers, water retention and filtration.	Indirect through resource-demand mitigation.
Agro-forestry	1-2	Not well integrated in the Cambodian context. Household capacity (time, money and interest)	Development benefits by seasonal cropping, diet improvements, climate resilience, fuel and resource self-dependence	Direct by soil improvement, Indirect through resource demand mitigation

7. Other Information

7.1 Integration of climate change into relevant policies

Cambodia recognizes the importance of integrating climate risk into national and sector policy, planning and budgetary processes and into the design of individual projects. Currently, such integration faces a range of barriers and is limited at both the national and sub-national level. However, there are a number of recent and proposed initiatives focused on developing the capacity and information needed to address this.

The Cambodia Climate Change Strategic Plan 2014-2023 has been developed with support from Development Partners (EU, UNDP, Sida and Danida) under the Cambodia Climate Change Alliance (CCCA) to fill the policy gap, complement on-going efforts and meet the emerging challenges of development, environment and climate change issues.

As a least-developed-country party to the UNFCCC, Cambodia is eligible for funding support to develop its National Adaptation Programme of Action to Climate Change (NAPA). NAPA is supportive of the RGC's development objectives as outlined in the NSDP 2006-2010, adopted in May 2006. The NSDP stresses the need to improve agricultural productivity through the expansion of irrigation and the management of water resources to reduce vulnerability to disasters. Implementation of the Cambodian NAPA contributes to the achievement of the CMDGs. The latter includes CMDG 7: 'Ensure environmental sustainability'. It aims to integrate the principles of sustainable development into country policies and programmes and reverses the loss of environmental resources in accordance with 14 specific targets, including Target 7.9: 'Reducing fuel wood dependency from 92% of households in 1993 to 52% in 2015'. The Rectangular Strategy, Phase 2 stresses the RGC's commitment to mobilize resources to address climate change. The NSDP Update 2009-2013, adopted in 2010, stresses that climate change is a major priority of the RGC and focuses on key climate change actions such as institutional capacity strengthening, sectoral mainstreaming, strategy and action plan development, financing, actual project implementation, education and awareness raising.

The integration of climate change into strategies, policies and projects is at an early stage in Cambodia. For example, The **NSDP 2006-2010** was Cambodia's medium-term development plan, which links the vision of the Government's Rectangular Strategy for growth, employment, equity and efficiency to concrete goals, targets and strategies. It contains a statement about the impacts of climate change and it acknowledges that natural hazards could affect progress, but there is no systematic assessment of the climate risks to achieving its goals, strategies and targets. The NSDP has been revised for extension for the period 2009 to 2013. The next revision is under preparation.

At the national level, a detailed review of the implications of climate change on various sectors has not been undertaken by most line agencies. The SNC does however provide the basis for this analysis. The impacts of climate change on wider economic performance and the achievement of socio-economic objectives needs to be better articulated, and climate change needs to be brought to the forefront within MEF and MoP.

At the **sub-national level, climate risk management** is yet to be integrated into provincial policy, planning and budgeting processes. Such a processes face a number of barriers, including a lack of budget, limited understanding of climate risks and a lack of technical capacity. To date there has been no training at the provincial and community levels to develop this capacity. However, the **National Programme for Sub-**

National Democratic Development (NPSNDD) is expected to enhance opportunities for sub-national governments to integrate climate resilience in their actual local development activities.

On-going and proposed initiatives. There are a number of key projects targeting the integration of climate change policies into policies and plans at various government scales. A key initiative is the **Pilot Programme on Climate Resilience (PPCR).** This programme is designed to pilot and demonstrate ways to integrate climate risk and resilience into developing countries' core development policies and planning. Cambodia is one of nine countries worldwide selected for participation in the programme. The PPCR in Cambodia is to be jointly implemented by the World Bank Group and ADB, with participation from the International Finance Corporation (IFC).

The CCCA programme was designed to be fully aligned with and strengthen the national institutional framework for climate change. It plays a unique role in strengthening the national institutional framework for the coordination of the climate change response. It is implemented by the Ministry of Environment (MoE), in its capacity as Chair and Secretariat of the NCCC. In 2009, the RGC launched a new **Strategic National Action Plan for Disaster Risk Reduction, 2008-2013 (SNAP)**. The SNAP covers a number of themes that overlap with the climate change agenda, including mainstreaming disaster risk reduction into national, sectoral and local development policies and plans; national and local risk assessments; improved flood forecasting and early warning capabilities; education and awareness raising; and the promotion of structural and non-structural measures to enhance resilience.

7.2 Activities related to technology transfer

Cambodia sees the transfer of mitigation and adaptation technologies to developing countries, in particular least-developed countries, as imperative to combating climate change and supporting sustainable development. Such initiatives offer possible win-win solutions for the global climate, as developing countries can avoid traditional routes to economic growth by increasing energy efficiency, reducing environmental pollution and GHG emissions, while sustaining socio-economic development.

In Cambodia, most transfer of technologies related to climate change occurs through the implementation of CDM projects and mainstreaming efforts on adaptation. As of 2015, MoE, acting as the Cambodian Designated National Authority for CDM, has approved 11 CDM projects. Of these, 10 projects have been registered at the CDM Executive Board of the UNFCCC. These CDM projects are associated with the use of renewable energy, industrial waste heat, agricultural and livestock wastes to generate electricity and heat, and hydropower. Most of the proponents of the CDM projects are private companies.

Under the UNFCCC, the CDM of the Kyoto Protocol is the practical means for transferring mitigation technology to developing countries. At a global scale, the CDM has proven relatively successful. However, in terms of geographical distribution and equity, CDM has many limitations, in particular for least-developed countries: high transaction costs, low absorptive capacity, unattractive investment environment, etc. At the Poznan conference in 2008, parties to the UNFCCC decided on Technology Transfer actions including financial mechanisms (by GEF) and a Least Developed Countries Fund. In March 2013, Cambodia submitted its Technology Needs Assessment and action plan on mitigation to the UNFCCC (MoE 2013a).

Table 7.1: Summary of CDM projects in Cambodia

Name of CDM Project Activity	Type of Project	Supplemental Information	Approval Date (D/M/Y)	Annual emission reduction (tCO_2/yr)
Angkor Bio Cogen Rice Husk Power Project	Biomass	Rice husk	19/1/2006	51,620
T.T.Y. Cambodia Biogas Project	Biogas	Agricultural waste	4/7/2007	50,036
Methane-fired power generation plant in Samrong Thom Animal Husbandry	Biogas	Animal waste	15/10/2007	5,593
Kampot Cement Waste Heat Power Generation Project (KCC-WHG)	Waste heat/gas utilization	Cement production line	20/11/2008	17,107
Kamchay Hydroelectric BOT Project	Hydro	New reservoir	20/11/2008	370,496
Biogas Project at MH Bio-ethanol Distillery, Cambodia	Biogas	Agricultural waste	29/6/2009	52,831
W2E Siang Phong Biogas Project Cambodia	Biogas	Agricultural waste	3/11/2010	27,121
Lower Steung Russei Chrum Hydro-Electric Project	Hydro	New reservoir	2/11/2011	701,199
Cambodia Steung Atay Hydropower Project	Hydro	New reservoir	3/1/2012	266,472
Steung Tatay Hydroelectric Project	Hydro	New reservoir	16/1/2012	563,074

Cambodia was selected for a GEF–Technology Needs Assessment project looking at renewable energy technology such as the use of rice husks as fuels in urban areas (industrial, commercial, domestic use). The project is focused on south-south technology transfer from countries such as India, China and Thailand building on similarities in terms of culture and costs. The project recognizes the need to cover the whole transfer chain if it is to be successful – covering operation and maintenance, spare parts, training and local capacity building. A draft report has been submitted to the GEF for approval. A second GEF project on industrial energy efficiency is looking at the transfer of process technology to produce high-end products from rice husks.

The transfer of **adaptation technologies** to Cambodia is equally, if not more, important than the transfer of mitigation technologies, given Cambodia's vulnerability to the impacts of climate change. The Cancun Agreement of December 2010 brought adaptation to the same level of international cooperation with mitigation. The Technology Executive Committee will look after technology transfer for adaptation, among others (UNFCCC 2010).

7.3 Systematic observations

Meteorology and hydrology

Systematic observation involving the recording of hydrological and meteorological data is the responsibility of MoWRAM.

From the 1910s until the early 1970s, data for hydrological and meteorological stations were recorded daily at 50 hydrological stations on the Mekong, the Tonle Sap and the tributaries. Only about 20 hydrological stations have been repaired since the mid-1980s. The water quality database from the years 1985 to 1997 has data relating to the stations, the chemical data of each sample and the river discharge and temperature value of each sample. Cambodia now has 13 stations for recording data related to water quality.

The Department of Meteorology (DoM) of MoWRAM has 38 meteorological stations that record rainfall, 23 that record evaporation and 14 stations that record wind speed. As is the situation with the hydrological stations, the meteorological stations were destroyed during the war. LWS, an international NGO, assisted with the reparation of the stations in the early 1990s but instrumentation is limited. Data is recorded manually at 20 stations and sent to Phnom Penh periodically for inclusion in the database. The former 9 automated stations are out of operation. A proposal has been developed for the rehabilitation and modernization of these stations (MoWRAM / DoM 2009).

In Cambodia, meteorological data collection is still limited. The number of manually operated rainfall stations is about 200; it should be increased. In the DoM, for data processing purposes, stations send data to the provincial centre once per month by post or messenger. Provincial centres send collected data from stations to DoM monthly in the same manner. For forecasting purposes, key stations send data (weather forecasts) daily to DoM by radio and television all the year round. Rainfall, air temperature, wind speed, wind direction and relative humidity are observed by only two main stations (Pochentong and Sihanoukville). Since 2012, a radar station is operational in Phnom Penh: the Techno Sen. The station is equipped with high-performance facilities to enable the DoM to produce and broadcast weather forecasts.

Land use and forest cover data

The Mekong Secretariat, in cooperation with MAFF and with financial support from UNDP and FAO, prepared the first-ever Cambodia Land Cover Atlas 1985/87-1992/93. Two sets of LANDSAT-MSS images and one set of LANDSAT-TM images false colour composite obtained during the dry season at a scale of 1:250,000 were used to prepare maps of the atlas. Topographic maps at a scale of 1:50,000 and at a scale of 1:250,000 covering Cambodia were used as references during interpretation of images and digitizing of the interpretation results. Panchromatic aerial photographs at a scale of 1:25,000 to 1:27,000 taken during the 1992/93 dry season were used as references and as 'ground truth data' to develop the interpretation keys and check the interpretation. The classification of 27 land cover types was mainly based on existing classification of vegetation types in tropical Asia.

Agricultural data

MAFF has recorded the most detailed data relating to agriculture in Cambodia in cooperation with FAO, WFP and CARDI.

FAO/WFP made an estimate of 1995/96 production of wet and dry season rice and cereals in 1996, undertaking a survey of communities and by reviewing data from various sources. In 1998/99 MAFF, in collaboration with WFP, made a more detailed assessment by surveying wet-season paddy production in 1,312 communities in 15 provinces (out of a total of 23), which accounts for more than 97% of the country's rice production. Information collected included planted area, harvested area and damaged area, the nature of the damage, and yields. FAO supported a study of wood energy consumption in 1996, which found that an estimated 0.6 cubic meters/person/year or 6 million cubic metres of fuel wood is used per year.

Census data

With the support of UNFPA, the National Institute of Statistics carried out the national census in 1998. The census information, which was compiled and is available to the public in both hard and digital copies, is the only comprehensive data set available on Cambodia. One of the advantages of the database is that the geographic codes used are compatible with existing GIS data, therefore allowing the extraction of useful census information for data analysis on natural resource and environmental management.

7.4 Climate change research

The key higher education institutions in Cambodia are the Royal University of Phnom Penh (RUPP), The Institute of Technology Cambodia (ITC), the Royal University of Agriculture (RUA), the Prek Leap School of Agriculture and the National Institute of Public Health.

Some climate change relevant research is carried out at RUPP, especially by the Department of Environmental Science, and to a lesser extent by the Department of Biology (Dany et al. 2010). Related climate change studies include: a study looking at the relationship between city development and water quality; studies in ecosystem services with CDRI; a study with the Australian National University looking at the role of vulnerability and adaptation in strategy and policy development; a FAO project looking at the correlation between cereal production and El Niño Southern Oscillation; and a small-scale biofuels study.

Within the Environmental Science Department of RUPP, which includes units in natural resource management and pollution and urban studies, climate change awareness and research capabilities require development. Training is required to develop analytical skills, for example in statistical analysis, research design and policy analysis. There is limited on-going research on mitigation.

RUA also undertakes climate change related research such as a study looking at agro-forestry and climate change. RUA offers introductory courses in climate change, but needs support from expert institutions to provide more detailed information and to teach specific topics such as REDD and PES. Funding for more Masters students on climate change research and advanced courses for staff is also required.

In 2010, the Cambodian Climate Change Department of MoE, with support from Danida, Oxfam and UNDP, commissioned the Research and Learning Group at the BBC World Service Trust to conduct a nationwide research study to explore knowledge, attitudes and practices in relation to climate change.

The study gathered and documented experiences across the country related to people’s perceptions of changes in climate, environment and natural resources. The report draws on these findings to provide recommendations for raising public awareness about climate change in Cambodia and engaging policymakers and the general public in local, national and international dialogue and actions related to climate change.

7.5 Information on awareness

Engagement of households and communities is key to the development of effective local responses to climate change that address poverty and the vulnerability faced by the poor.

A national survey of climate change perceptions and awareness undertaken in 2007 found that 85% of respondents believed that Cambodia’s climate is changing, but only 59% of respondents (including 82% of farmers) had heard of the term ‘climate change’ and associated the change with human practices. Of those aware of climate change, 97% believed they would be affected and 61% were very concerned about it. However, respondents had a generally low level of awareness of the specific causes and impacts of climate change, or that it was a global issue. Location, age, gender and occupation were significant factors in determining awareness. The young and educated had higher levels of awareness, and men had higher levels of awareness than women. Television and the radio were found to be the most common sources of receiving information on health and the environment.

There have been initiatives to raise the general awareness of climate change in Cambodia. With support from UNDP, UNEP, Danida, Oxfam America and other NGOs, the Climate Change Department of MoE organized a series of climate change awareness campaigns, using Khmer media, essentially television and radio broadcasts, as well as local newspapers. The campaign used original content and translation into Khmer of short films, documentaries and other available multi-media resources such as student debates, video spots, radio talk shows, posters, newspaper and magazine articles, drawing contests and exhibitions.

A survey was conducted to assess the level of understanding of climate change and to identify knowledge gaps and training needs with government ministries, committees, academic institutions and the media.

The survey found that only around 10% of respondents had good understanding about climate change and the vulnerability of their sector. It is suggested that greater knowledge is need to successfully mainstream climate change into sectoral policy, plans, programmes and projects. The majority of respondents had fair understanding of adaptation and general knowledge on climate change, but greater understanding of GHG mitigation (Table 7.2).

Table 7.2: Respondents' level of understanding for government institutions

	Level of understanding (%) E: Excellent (≥85%), VG: Very good (84-70%), G: Good (69-50%), F: Fair (<49%)											
	General knowledge on CC				**Adaptation**				**Mitigation**			
Institution	**E**	**VG**	**G**	**F**	**E**	**VG**	**G**	**F**	**E**	**VG**	**G**	**F**
Health (29)[1]	0.0	7.0	45.0	48.0	0.0	0.0	66.0	34.0	14.0	45.0	31.0	10.0
Non-health (40)[1]	**2.5**	**7.5**	50.0	40.0	0.0	5.0	60.0	35.0	**37.5**	20.0	27.5	15.0
MIME (25)[1]	0.0	12.0	40.0	48.0	0.0	8.0	44.0	48.0	16.0	28.0	36.0	20.0
Total	**1.1**	**8.5**	**45.7**	**44.7**	**0.0**	**4.3**	**57.4**	**38.3**	**24.5**	**29.8**	**30.9**	**14.9**

Note: [1] In brackets, the number of respondents.

Academic institutions also understood mitigation better than adaptation and, for the majority, their level of understanding was fair to good.

In terms of media, the survey covered the following television and radio organizations: The National Television (TVK) and Radio, Apsara Television and Radio, Bayon Television and Radio, TV9 and Radio (FM107) and Phnom Penh Municipal Television (TV3) and Radio. These organizations do not have specific climate change programmes, however a few occasionally organize discussions on the environment or disaster risk reduction. Interviewees acknowledged their limited understanding on the subject, and this is a clear area where capacity building is needed.

7.6 Information on education, training and capacity building

Article 6 of the UNFCCC and Article 10(e) of the Kyoto Protocol require all parties to promote and facilitate, at the national, sub-regional and regional levels, the development and implementation of educational and public awareness programmes, public access to information, and training for scientific, technical and managerial personnel with regard to climate change and its effects.

Since 2000, there have been about 80 training, workshop, public awareness and other capacity building activities related to climate change conducted in Cambodia. This figure may be much lower than the actual activities, as many climate change capacity building activities have not been recorded. There is no system in place at present to record and monitor the outcome of the activities. Most capacity building activities were supported by Japan, Korea, the Netherlands, Denmark, UNDP, UNEP, ADB, EU, World Bank and other NGOs.

From 2003 to 2005, Cambodia participated in the implementation of a global project entitled, "Capacity Development for the Clean Development Mechanism (CD4CDM)". The project was financially supported by the Netherlands' Ministry of Foreign Affairs via the UNEP. The overall development objective of this project was to generate, in selected developing countries, a broad understanding and develop institutional and human capacity to "fully participate as equal partners with developed countries in the formulation and implementation of the Clean Development Mechanism (CDM)".

Since October 2003, the Institute for Global Environmental Strategies (IGES) of Japan supported the capacity building programme for the CDM, and the new market mechanism in Cambodia. Several workshops and trainings were conducted under this support, which aim to build the capacity of the Cambodian DNA and project developers.

In 2009, Danida and Oxfam America provided support to the Climate Change Capacity Strengthening and Awareness Raising Programme in Cambodia. Under this supported project, extensive climate change awareness raising activities were conducted, including provincial seminars, debates on TV and radio, newspaper articles, climate change campaigns, drawing contests among students and climate change material development, etc.

7.7 Efforts to promote information sharing

As the national focal point, the Department of Climate Change, General Secretariat, National Council for Sustainable Development/Ministry of Environment is the core agency responsible for climate change activities in Cambodia. At Regional Level, Cambodia participates in a number of regional information sharing platforms and forums, such as WGIA, Asia Adaptation Platform, ASEAN Working Group on Climate Change (AWGCC). In October 2011, Cambodia hosted the WGIA in Phnom Penh to share capacity building for measurability, reportability and verifiability.

At national level, DCC as the technical national focal point plays an important role as the coordinating body for climate change activities, including information and networking. The Climate Change website (www.camclimate.org.kh) was established and hosted by DCC to disseminate information. There is no network related to research activities in Cambodia, however, notable improvements in networking have been observed recently among members of the climate change technical team of the NCSD.

8. Constraints, gaps and related needs

8.1 Introduction

Insufficient technical and financial resources act as major constraints to the preparation of national communications on a continuous basis. While the NCCC[13] and the DCC are permanent institutions, their mandates extend beyond national communications, and include the facilitation, coordination and implementation of mitigation and adaptation measures. In line with national development priorities, government funding is likely to continue focussing on adaptation to climate change and poverty reduction, and other measures with immediate social impacts. Thus, full cost funding of national communications will remain necessary in the short term to assist Cambodia in fulfilling its reporting obligations. In addition, development and implementation of effective climate change strategies is constrained in a variety of ways in Cambodia. These include limited human capacity; the lack of reliable and comprehensive data sets and research in preparing GHG inventory, mitigation analysis and vulnerability assessments; lack of technology and awareness; policy and institutional shortfalls; and significant financial constraints.

8.2 Human resources

Strengthening the technical and institutional capacity of key government institutions responsible for coordinating and implementing policies, strategies and activities related to climate change is considered a priority.

Technical and financial support, dedicated and qualified staff and good governance are critical for effective implementation of climate change response measures. The effective operation and sustainability of the NCCC and other inter-ministerial working groups requires professionals with appropriate work experience, technical ability and management skills across relevant ministries and institutions. This requires adequate support and facilitation from all Development Partners.

Strengthening technical and institutional capacity for long-term systematic observations at national level is also crucial for the monitoring of climate and its changes.

Capacity building is also critically needed at sub-national levels to address climate change issues. Local authorities, for example, are not widely engaged in climate change issues, therefore training schemes are needed.

Agriculture is not only the most vulnerable sector, but it also supports the most vulnerable groups, which comprise the majority of the population. Current farming methods are heavily reliant on seasonal irrigation, with droughts and floods having devastating effects on harvests and livelihoods of rural Cambodian people. There are currently very few activities to help farmers cope with the new burdens of climate change. The lack of crop diversification and limited knowledge of animal husbandry compound these challenges, as no alternative sources of income are available when the main crop or livestock is affected. Coordination, knowledge and access to information (including crop pricing and marketing opportunities) among agricultural communities at a rural, provincial and national level are limited. Interventions to raise awareness regarding climate risks and to provide better market information could strengthen resilience.

There is a need for further development on teaching and research in climate change across Cambodia's academic institutions. Training should cover analytical skills on specific topics, for example, climate change impact assessments, GHG mitigation, REDD+ and PES.

[13] Now the NCSD, following the 2015 institutional reform of MoE and NCCC.

8.3 Improvements in the GHG inventory

The 2000 inventory marked an improvement to the INC inventory in the area of Biomass Annual Increment. However, a number of data gaps hampered the 2000 inventory. The main constraints relate to the lack of reliable data and information, and the lack of expertise in the respective sectors. Due to the lack of availability of relevant data, assumptions were made and data have been obtained from secondary sources. The following are examples of some of the challenges encountered in preparing the GHG inventory:

- Lack of activity data and local emission factors (general IPCC default values were used);
- Data classification is different from IPCC Guideline categories, in particular for LUCF;
- Lack of sustainable GHG inventory system;
- Insufficient financial support for regular inventory preparation;
- Lack of national experts for GHG inventory preparation.

To address these constraints, it is very important for relevant agencies to enhance cooperation in sharing data, information and expertise required for GHG inventory preparation. Building reliable and sustainable inventory systems is to be continued and enhanced, while the need to improve inventory preparation in Cambodia has also been identified, and includes:

1. The understanding of recent IPCC guidelines, such as the GPG and IPCC 2006 Guidelines. In order to apply these guidelines, national capacity building and technical assistance are required. These include training on uncertainty analyses and quality assurance/quality control procedures. Provision of relevant information;
2. Energy balance sheet to build up disaggregated data for the sub-sectors of the energy sector;
3. Development of GHG inventory and data management system;
4. Improving the accuracy of activity data for key sources and sinks and developing national emission factors;
5. Mobilization of resources from all sources for regular GHG inventory preparation.

8.4 Climate vulnerability and adaptation

The vulnerability and adaptation assessment identified a number of constraints:

1. Climatic risk and climate modelling in national and sectoral plans is still limited in Cambodia, in particular in mainstreaming adaptation to the negative impacts of climate change into national development planning;
2. Insufficient relevant data and information to conduct an assessment for immediate climate change adaptation action in Cambodia under the conditions of increased likelihood of floods and droughts;
3. Limited research conducted for related sectoral impact to climate change;
4. There has been limited analysis of the wider impacts of disasters on macroeconomic or budgetary performance or on their wider socio-economic consequences, including on progress in poverty reduction;
5. There is a shortage of capable technical experts and financial resources for running impact assessments and adaptation measure development models.

Cambodia has identified a number of actions to address these constraints, which include:

1. Strengthen technical and institutional capacity of relevant line ministries in conducting climate change impact assessments, climate change projections and mainstreaming climate change into sector and sub-sector development plans;

2. Promote research for related sectoral impacts of climate change;
3. Evaluation and prioritization of the proposed measures for all affected sectors, for example, agriculture, water resources, human health and forests and ecosystems.

8.5 Mitigation

The mitigation analysis identified the following data constraints:

1. Insufficient short-term and long-term planning information and data for all sectors to conduct mitigation analysis and projections of national emissions;
2. Financial constraints for mitigation analysis and the implementation of identified options;
3. Lack of national registry system for GHG mitigation;
4. Shortage of technical experts capable of conducting analysis in all sectors.

Actions to address constraints for GHG mitigation were identified as:

1. In general, efforts in energy data collection need to be strengthened to improve the estimates of total demand and to understand process efficiency so that optimal mitigation options can be designed;
2. Better evidence of the effectiveness of the mitigation options in practice in Cambodia, and an understanding of the willingness of the private sector to implement mitigation options;
3. More detailed studies of mitigation opportunities are needed, including an evaluation of the technical, market and economic potential;
4. Overall feasibility studies are needed, together with pilot projects and specific data collection, and updated energy demand analyses, to enable better planning, strategy development and implementation;
5. Research on the feasibility of mitigation emissions from hydropower and other renewable energy.

8.6 Research and analysis

The following areas of research and analysis are recommended.

Vulnerability and adaptation assessment:

1. Evaluation and prioritization of the proposed measures to increase rice production (extensification, intensification and diversification) is needed to ensure the impacts of climate change are managed cost-effectively;
2. Most flooding occurs due to increased water levels in the Mekong River and Tonle Sap Lake between early July and early October;
3. As discussed in Chapter 4, the increase in rainfall predicted for 2080 due to global warming is not very convincing. To increase confidence in rainfall predictions, the water resources analysis needs refinement. This could be done by using more GCMs and applying a high-resolution downscaling method to the GCM outputs;
4. Conduct a study to investigate the relationship between regional rainfall up-stream and its impact on Cambodia;
5. The non-climatic factors impacting the Mekong flows, such as the construction of large hydropower dams and reservoirs, large irrigation schemes and rapid urban development in the upper catchment of the Mekong River, impact both the quantity and quality of the flow and warrant careful study;
6. In coastal areas, further study is required to improve analysis, using a regional climate model and a more refined resolution of the topographic map (contours with 20 cm intervals) with a wider

scope (e.g. salt water intrusion, coastal erosion by extreme waves as a result of increasing wind speed and sea level rise under changing climate, mangrove rehabilitation for buffer zone, etc.);

7. The analysis of the impacts of climate change on the incidence of malaria in Cambodia needs refinement along with more observational data from provinces in the coast and highland areas;
8. There has been limited analysis of the wider impacts of disasters on macroeconomic or budgetary performance or on their wider socio-economic consequences, including on progress in poverty reduction.

GHG mitigation:

1. Better evidence of the effectiveness of the mitigation options in practice in Cambodia and understanding of the willingness of industries to implement the mitigation options;
2. More detailed studies of mitigation opportunities are needed, including an evaluation of the technical, market and economic potential;
3. Some preliminary costing of the adaptation and mitigation measures was possible for the SNC, however, more detailed financial and economic studies are required to demonstrate the economic benefits of the various options and possible financing approaches;
4. Overall feasibility studies are needed, together with pilot projects, specific data collection and updated demand analyses, to enable better energy planning, strategy development and implementation;
5. Research on the feasibility of mitigating emissions from hydropower.

8.7 Technology transfer

The technology constraints identified in the SNC are summarized below. The Technology Needs Assessments for mitigation and adaptation (MoE 2013 a, b) mention some important technology needs which have been used to formulate Technology Action Plans.

One barrier to technology transfer is weak coordination and sharing of information among stakeholders. There is a need to strengthen relevant stakeholders to coordinate information on activities, projects and other information related to climate-friendly technology development and transfer.

Advanced technologies are manufactured outside Cambodia and are expensive. This requires training experts who can check the technical and environmental soundness of equipment under conditions found in Cambodia. These experts then need the proper incentives, job security and motivation to remain in their jobs.

There is a range of technology initiatives that could promote the uptake of renewable energy. In terms of solar energy, there are currently no facilities to test PV systems or components or produce components/PV panels for the solar system, and there is a lack of funding to scale up solar lantern projects through improved technology. For hydropower, appropriate and efficient technology needs to be identified, as well as related training needs, so that a Cambodian operator can operate and maintain it. Biomass gasification is an appropriate technology for rural areas, but technology is lacking and training is needed to increase capacity in operation and maintenance. For rice mills, technology assistance and low interest loans are needed to promote uptake. Technology is also needed to tap into Cambodia’s wind potential.

In terms of infrastructure needs, Cambodia’s transportation and irrigation infrastructure are inadequate and require development and funding. Funding is also required to repair and maintain Cambodia’s observation network.

Table 8.1 summarizes needs in terms of technology and infrastructure.

Table 8.1: Summary of needs for technology and infrastructure

General	- Establishment of a government body to 'enforce' the submission of all activities, projects and other information related to climate change - Establishment of an agency in Cambodia to certify imported technologies
Technology specific: mitigation	- Investment in energy-efficient urban transportation and irrigation infrastructure - Vehicle emission standards - Energy-efficient lighting - Energy-efficient appliances - Establishment of facilities to test PV systems or components or produce components/PV panels for solar systems - Assistance to develop hydro power technology in Cambodia - Promotion of appropriate biomass gasification, rice milling and wind technology
Technology specific: adaptation	- Household safe water supply - Rainwater harvesting from rooftops - Wells, small reservoirs, small dams and micro-catchments for community water supply - Mangrove management

Source: MoE 2013a, b

8.8 Policy and institutional arrangement

Sound policies and institutions underpin successful climate change strategies. The general integration of climate change risks into policy, plans and strategies at national and sub-national levels needs further strengthening. Cambodia has already developed guidance on these issues through the Cambodia Climate Change Strategic Plan, National Policy on Green Growth and National Green Growth Strategy, which are meant to guide future development toward low-carbon and climate-resilient development.

In 2013, the RGC launched the National Policy on Green Growth 2013-2030, which includes a national policy and a strategic plan. The national policy, developed by MoE, aims to strike a balance between economic development and environment, society, culture and sustainable consumption of natural resources to enhance people's well-being and living conditions. The Strategic Plan For Green Growth 2013-2030 is to guide the Cambodian economy towards a greener economy, focusing on effective use of natural resources, environmental sustainability, green jobs, green technologies, green finance, green credit and green investment.

The Cambodia Climate Change Strategic Plan 2014-2023 was launched in 2013 to support building a greener, low-carbon and climate-resilient, equitable, sustainable and knowledge-based society to contribute to the global efforts to address climate change.

8.9 Financial support

Cambodia has limited financial means to address constraints, gaps and adaptive capacity to the adverse effects of climate change. In addition to the inadequate financial resources, the financial management mechanisms to effectively implement the adaptation and mitigation options highlighted in this SNC are not in place. Therefore, international support is still needed to assist in the implementation of adaptation and mitigation options highlighted in this SNC and the priority activities in the Cambodia Climate Change Strategic Plan.

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