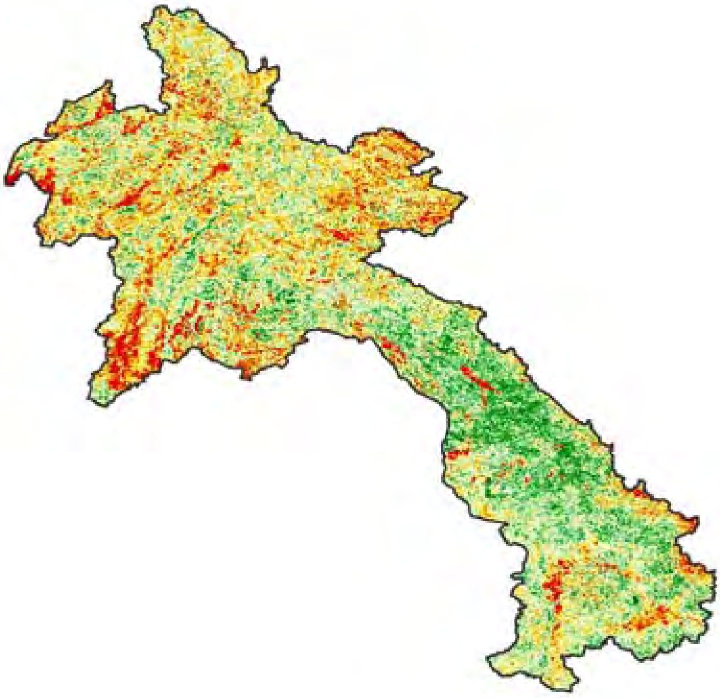
Land Management and Registration Project (LMRP)



Study on Potential Impacts of Climate Change on Land Use in the Lao PDR

Rod Lefroy, Laure Collet and Christian Grovermann

International Center for Tropical Agriculture
(Centro Internacional de Agricultura Tropical - CIAT)

July 2010

Potential impacts of climate change on land use in the Lao PDR

Report prepared for:	**Lao-German Land Management and Registration Project (LMRP), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH PO Box 9233, Vientiane Capital, Lao PDR**
Report prepared by:	**International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical - CIAT)**
Main Authors:	**Rod Lefroy, Laure Collet, and Christian Grovermann**
With inputs from:	**CIAT Headquarters/Colombia: Laure Collet, Mike Salazar, Andy Jarvis, Julian Ramirez, Louis Reymondin, Emmanuel Zapata,**
	CIAT Asia: Rod Lefroy, Thiphavong Boupha, Christian Grovermann (Technical University of Munich)
	GTZ-Lao PDR: Marcus Waldherr, FH-Eberswalde, associate of GTZ, Lao PDR Oliver Schoenweger, LMRP – GTZ, Lao PDR
	NAFRI-Lao PDR: Pheng Sengxua

Disclaimer

While every effort has been made to list the sources and ensure the accuracy of information in this report, no liability is accepted for errors of fact or opinion, or for any loss or damage resulting from reliance on, or use of, the information in this report.
This report is for the use of the Lao-German Land Management and Registration Project (LMRP), PO Box 9233, Vientiane Capital, Lao PDR, and is not to be disclosed to third parties without their consent.

Table of Contents

Executive Summary

Background and Justification

The likely impacts of climate change have become a major concern globally in recent years, although perhaps less so in many developing countries, which face a plethora of development challenges that have been considered to have only limited connections to climate change. This has begun to change, with many developing countries, such as the Lao PDR, becoming more concerned about the possible impacts of climate change and the need to consider adopting adaptation and mitigation strategies. In a country such as the Lao PDR, with a largely rural population, substantial reliance on agriculture, and significant forestry resources, the need to assess the likely impacts of climate change on land use has been recognized, but so has the problem of separating these impacts from those driven by other factors, such as population growth and economic development. This study aims to identify potential changes in climate, crop suitability, and land use that may result from climate change, as well as to identify some of the current and future impacts on land use resulting from other drivers.

Objectives of the study

The objectives of this study were: (i) to assess the evidence of climate change in the period from 1901 to 2002 and assess the likely changes in the climate to 2050; (ii) to assess the current bioclimatic suitability of Laos for different crops and assess the likely changes in suitability with the predicted changes in climate; (iii) to assess the recent changes in land use and the main drivers of these changes, and (iv) to assess the resilience of the current farming practices and make recommendations that may help prepare for future changes in climate.

Methods utilized

Assessing climate change requires long-term climate data, and yet there is little such data for the Lao PDR. Consequently, the first step in assessing recent changes in climate was to reconstruct the climate of the 20th century for the Lao PDR using available global and regional data, such as the dataset of the Climate Research Unit of the University of East Anglia, UK,. The likely changes in climate to 2050 were projected using scenarios from the Intergovernmental Panel on Climate Change (IPCC), focussing on the A1B scenario, which was developed as an intermediate scenario in terms of carbon emissions and economic growth. The changes in eight climate variables were calculated for the period from 1901 to 2002 and then the predicted change to 2020 and 2050 assessed, using the mean values for the period from 1982 to 2002 as the baseline for comparison.

The bioclimatic suitability for a range of 17 plant species, including major staple crops, annual and perennial cash crops, and trees, was assessed, both for the current climate and for the predicted future climates.

Changes in land use were analysed using Normalized Difference Vegetation Index (NDVI) data for the period from 2000 to 2009 and derived from the MODerate-resolution Imaging Spectroradiometer (MODIS) on board the NASA Terra satellite. These data enabled identification of significant changes in vegetation cover for the period and were used in conjunction with other data on land use.

The current status of the farming systems in the Lao PDR was evaluated through field visits to 12 villages in six districts of three provinces combined with expert knowledge of these and other areas of the Lao PDR.

Results and Conclusions

Analysis of past/current climate

As Lao farmers know, the Lao climate is highly variable, especially the rainfall patterns. This introduces a great deal of risk and uncertainty into the agricultural systems and especially those of smallholder farmers.

Analysis of the Lao climate from 1900 to 2002 highlighted this variability, especially in rainfall, but also did show some significant trends in climate variables. *During the 20th century, the* *minimum, mean, and maximum temperatures increased throughout the country, but particularly in the south and mainly in the last decade of the century.* Minimum and mean temperatures rose by between 0.1 and 1.0°C, and maximum temperatures rose by 0.5 to 4.5°C. Local experience supported these data.

There were significant trends in rainfall patterns over the 20th century, but even these trends remained within the range of the highly variable rainfall patterns. In addition to annual rainfall, the rainfall in April, May, and October were assessed as these are the critical periods at the beginning and the end of the wet season, respectively. The trends varied for different parts of the country. *The main change over the 101 year period was a reduction in the rainfall in May, by between 4 and 50mm, and an increase in the rainfall in October, by between 4 and 20mm. This resulted in a slight delay in the wet season.* In some parts of the country there was a slight increase in April rainfall, but with a trend for declining rainfall in May, rather than signalling an earlier start to the wet season it may constitute a greater risk of a false start to the wet season. *Total rainfall tended to increase by up to 115mm in the lower north and upper central part of the country, and decrease by up to 200mm in the upper north, lower central, and south of the country.*

Projections of the future climate

Using the mean projections of seven Global Climate Models and based on the A1B IPCC emission scenario the changes in climate were predicted for 2020 and 2050. *By 2050, the minimum and mean temperatures are predicted to increase by up to 2°C, compared to the mean value for 1982-2002, and the maximum is predicted to increase by up to 5°C.* Comparison to the mean values for a reasonably lengthy period, such as 1982-2002, is essential to avoid year-by-year variations, but it must be remembered that the mean temperatures for 1982-2002 were less than the temperatures at the very end of the 20th century, as much of the increase in temperature during the 20th century occurred during the final decade. This means that some of the predicted change from the mean of 1982-2002 to either 2020 or 2050 has already occurred during the later period of assessment, mainly in the 1990s, and some may have occurred from 2002 up to the present day. As such, the change from 1982-2002 to 2020 and 2050 may be significantly higher than the changes from 2002 or from the present day.

The predictions for rainfall suggest that rainfall in the early wet season, in May, will decrease and rainfall at the very start of the wet season in April and the end of the wet season in October, will increase. This is a continuation of the trend seen in the 20th century for a *delay in the main wet season, in June to October*, and perhaps an increased in the risk of a false start to the wet season, with more rain in April, but less rain in May. Thus rainfall variability remains the critical issue.

In addition to changes in mean values of weather variables, there is a need to consider the extreme events. There is very limited capacity for prediction of extreme events in the Global Climate Models, temporally let alone spatially, however, there is good evidence globally that the changes observed in mean values are driven, in part, by changes in the extreme values. In particular, where increases in temperatures have been observed, the trend has been for less cold nights and more hot nights (more so than less cold days and more hot days) and even where there has been limited change in rainfall, the incidence of heavy and very heavy rainfall appears to have increased. While the incidence of tropical storms and hurricanes is highly variable, as influenced by such factors as the El Nino-Southern Oscillation, *there is evidence that the number and intensity of storm events has increased in the last few decades of the 20th century, and this trend appears likely to continue and increase*, and there is no reason to believe that this will not be the case in the Lao PDR.

In summary, the climate has become and is likely to continue to become hotter and with a slightly delayed wet season. The variations in rainfall, even if the trends are for significant change in rainfall patterns, are within the order of the normal year to year variations, so the climate change induced variations in rainfall patterns are unlikely to be observed easily, at least for some time, which may lead to some complacency. The incidence of extreme events, such as hotter nights and days and heavy storms, is likely to increase.

Climate variability, and in particular rainfall variability, irrespective of climate change, will remain a major challenge for Lao farmers, especially as the current farming systems are susceptible to less than ideal rainfall patterns, whether too dry or too wet.

Crop suitability: Current and projected

The bioclimatic suitability of a range of 17 crops/trees was assessed against the current and predicted 2050 climate. Current crop suitability matches current cropping patterns for most, but not all crops. *The change in bioclimatic suitability for the predicted 2050 climate was positive for some crops (sugarcane, cassava, rubber, banana, teak, and paddy rice), negative for some crops (maize, soybean, chilli, common bean, sweet corn, Arabica coffee, Jatropha, and eucalyptus), no change for some crops (peanuts and upland rice), and positive and negative, in different parts of the country for Robusta coffee.*

It should be noted that this assessment of bioclimatic crop suitability does not take into account possible positive or negative interactions between bioclimate and soil type, crop agronomy, crop management, and pest and disease incidence, which can have strong mitigating effects. Also, the crop parameters used are for a species mean, not for varieties that are specifically adapted to more extreme climates. The use of well-adapted varieties may thus increase suitability, while that of less well-adapted varieties may reduce suitability.

Of the negative changes in suitability, the most critical is probably for maize, which has become an important cash crop for smallholders in recent years. There is scope for improving the current maize production systems, as for other crops, which should make them more resilient in the current climate and likely to make them more resilient as climate change develops further towards the predictions of 2050. In addition, being such an important crop worldwide, it is likely that there will be further developments in terms of improved varieties that can cope better with the bioclimatic environments expected in the future. The main challenges in this area are likely be the development of greater tolerance to higher temperatures and to drought.

Land Use Changes

The analysis of land use and land use change indicated large changes in land use in recent times, and specifically for the period from 2000 to 2009. *The area of agricultural land has increased significantly, and this, at least in part, explains the reduction in vegetation cover seen across the Lao PDR through analysis of satellite images. Other causes for reductions in vegetation cover are forest logging, the development of hydropower schemes, mining, and urban development. All of these changes are being driven by population growth and economic development, both within the Lao PDR and in the neighbouring countries, with a specific driver, at least for some sectors, being the increasing levels of Foreign Direct Investments.*

There is no evidence that the changes that have occurred in the climate, especially from the last decade of the 20th century, has had any direct affect on land use change. Similarly, with the main drivers of land use change – population growth, economic development, and foreign direct investment – showing no sign of reducing in the next years, and in fact more likely to continue to increase, there is no evidence that the predicted changes in climate to 2050 will have major affect on land use change compared to the effects of these other major drivers. This does not mean that both land use and climate should not be monitored carefully, nor that some adaptation strategies to cope with current climate variability and projected climate change should not be considered as relatively high priority, but, *in comparison to other drivers, it is unlikely that climate change will affect land use change directly or significantly*.

Recommendations

Assessment and monitoring

Satellite imagery: *The methods used for analysis of land use change, and specifically the use of MODIS NDVI, proved to be very useful. This warrants further investigation and development as a tool for monitoring land use and land use change*, whether as affected by climate change or not, as well as for use in more specific studies. For instance, much greater use could be made of the temporal information on NDVI, with data recorded every 16 days, which was hardly explored in this study, especially as the resolution of satellite images improves.

Database: Easy access to high quality data on agriculture, forestry, population, expenditure, and economic development, as well as to comprehensive meteorological data, is essential for monitoring land use change and particularly with respect to climate change. The more readily these data are available and the better the quality of the data, the more likely that good studies and on-going monitoring of development will be undertaken at least by government and, if there is broad access, by other agencies. The current systems of accessing data is neither easy nor comprehensive. A reliable electronic database of appropriate parameters would aid the work of government. *Easily accessible and accurate databases of agricultural production, land use, forest cover and use, population, expenditure, and climate would be useful* simply to monitor these activities effectively, but, in addition, they would allow the monitoring of more complex issues, such as climate change and the impact of climate change, and land use planning, particularly for agricultural and forestry concessions, for mining and hydropower developments, for land tenure issues and land titling, and for the planning of infrastructure developments.

Improving the farming systems: productivity, sustainability, and diversity

Risk reduction: The current farming systems of many villagers in the Lao PDR are quite risky, with limited resilience, and, in some cases, with limited sustainability, resulting in many households in many villages experiencing significant rice shortfalls each year. Much of this risk is associated with the current climate, rather than with a changing climate, and particularly with the very variable rainfall patterns. While total rainfall in the wet season can vary significantly, the most critical variability in climate are the highly variable start to the wet season, in April, May, and June, and the end of the wet season in October. *Any measures that can be taken to reduce the risks associated with the current variable climate will help current livelihoods and are almost certain to help villagers cope with the projected changes in climate.* There are a wide range of technologies that can be used, alone or in combinations, to reduce the susceptibility to variable rainfall. These include mulching, cover crops, and cropping systems management to *reduce water loss*; water capture, diversion, levelling, and control across mini-watersheds to *better manage the supply of water*; and changes in crop and farming systems to *manage the demand for water*.

Sustainability: A number of options for improving the sustainability of the current farming systems are outlined. In particular, it was felt that there should be a focus on (i) increasing the availability of water and the efficiency with which it is used in lowland rice farming systems, (ii) increasing the sustainability of non-rice cropping systems, such as maize, which have significant risks due to unsustainable land management practices, particularly those leading to soil erosion, (iii) improved livestock production and linking livestock producers to markets, (iv) more diversified cropping and farming systems, based on rice, other annual crops, perennial crops, and livestock, so as to achieve greater biological and economic efficiency and resilience, and (v) improved marketing and, where possible, value-adding of crop, livestock, and forestry products, and perhaps specifically of non-timber forest products.

R&D: *The research, development, and extension efforts in the Lao PDR should focus on achieving more sustainable and resilient farming systems for the current climate*, rather than taking a specific focus on the likely future climate. Research and development aimed at increasing sustainability under the current climate would benefit from exploitation of intra-species differences in temperature, drought, and flooding tolerance, as well as looking at changes in farming systems, including changing the management of water, the crop species used, or the way in which crop species are mixed and livestock are integrated. Although the aim of this work would be for improved, more resilient, and more sustainable farming systems now, such activities are very likely to help prepare for any of the predicted changes in climate.

The adoption of, and impact from, these modified and improved farming systems are likely to be gradual, much like climate change. This poses significant challenges for researchers, as confirming gradual improvement can be expected to be much more difficult than confirming the larger, more dramatic, and punctuated changes that may have short-term benefits in productivity but that do not lead to the required longer-term benefits in resilience, sustainability, and productivity. Similarly, extension, adaptation, and adoption of gradual improvements in the current farming systems can be expected to be slower with modifications of a system, rather than with more dramatic shifts in farming systems. These larger shifts, while appearing to have more impact, may end up being less sustainable and resilient, or at least are likely to take much longer to prove they are more resilient, sustainable, cost-effective, and eco-efficient. Thus, while in some ways more difficult, for research and extension, the focus should be on more gradual modification of current farming systems, rather than a complete overhaul of the farming systems.

Mitigation strategies

Mitigation or not?: Given the current level of greenhouse gas emissions in the Lao PDR, the size of the population, the rate of economic growth, and the size of the agricultural and forestry sectors, *it is unlikely that any strategies to reduce Lao emissions or increase carbon capture will have a significant affect on the global or even regional emissions and thus on climate change. This does not mean, however, that mitigation strategies should not be adopted,* for at least three reasons. Firstly, some of the mitigation strategies may have very localized and positive microclimate effects on agricultural or forestry activities, particularly with respect to the availability of water. Secondly, many of the strategies will lead to direct or indirect economic impacts as the costs of greenhouse gas emissions are factored into the cost of inputs and the prices of products. Thirdly, there is the need to be a good global citizen by participating in mitigation efforts.

Mechanisms of payment: While the Clean Development Mechanism (CDM) has been a method for funding some activities that reduce greenhouse gas emissions, this approach was not available for agriculture and only available in restricted cases for forestry. Future developments in carbon trading and in schemes such as Reducing Emissions from Deforestation and forest Degradation (REDD) may present opportunities for payments for reductions in emissions and increases in carbon capture, although the all important measurement and validation steps are likely to limit the usefulness for agricultural systems, especially for the subsistence and low-intensity agricultural systems in the Lao PDR. For these reasons, the direct benefits for smallholders are likely to be limited. Again, this does not mean that mitigation strategies in forestry and agriculture should not be implemented, but that the drivers of adoption may not be direct payment for mitigation per unit of reduced emission or increased carbon sequestration. *The most likely drivers would be the increased resilience and sustainability of the farming systems and the cost savings as the real costs of emissions are factored into production costs and product prices.* As an example, reduced costs are most likely to be the incentive for the development of sustainable agricultural practices that reduce petro-chemical inputs and thus result in smallholder farming that are more eco-efficient and that become more economically competitive as oil prices rise. A major value of direct or indirect mitigation payment schemes, such as Payments for Environmental Services (PES), may be simply in achieving initial adoption of improved practices, which then pay for themselves through increased eco-efficiency, rather than the value to farmers of one-off or on-going payments for services. In the end, it may be possible for one-off payments for adoption of emission reductions to be replaced by loans for adoption of improved practices that are paid back as greater efficiency is achieved.

Abbreviations

ADB	Asian Development Bank
CDM	Clean Development Mechanism
CGIAR-CSI	CGIAR Consortium for Spatial Information
CGIAR	Consultative Group for International Agriculture Research
CIAT	International Centre for Tropical Agriculture (Centro Internacional de Agricultura Tropical)
CIP	International Potato Centre (Centro Internacional de la Papa)
COP	Conference of Parties
CRU	Climatic Research Unit (University of East Anglia)
DAFO	District Agriculture and Forestry Office
DAPA	Decision and Policy Analysis
FH-Eberswalde	Fachhochschule Eberswalde (University of Applied Sciences of Eberswalde)
GCM	Global Climate Models
GHG	Greenhouse Gas
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
MAF	Ministry of Agriculture and Forestry
MODIS	Moderate Resolution Imaging Spectroradiometer
NAFRI	National Agriculture and Forestry Research Institute
NAPA	National Adaptation Plan of Action
NCCR	Swiss National Centre of Competence in Research
NDVI	Normalised Difference Vegetation Index
PAFO	Provincial Agriculture and Forestry Office
PES	Payment of Environmental Services
RCM	Regional Climate Model
REDD	Reducing Emissions from Deforestation and forest Degradation
RMSI	Risk Management Solutions India
Sida	Swedish International Development Cooperation Agency
SRES	IPCC Special Report on Emission Scenarios
TUM	Technische Universität München (Technical University of Munich)
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WREA	Water Resource and Environment Administration

Acknowledgements

This report is based on a study undertaken by CIAT. Much of the data used has been collected and analysed by the Climate Change group based at CIAT headquarters in Cali, Colombia, particularly Mike Salazar, Laure Collet, and Andy Jarvis, but significant contributions were made through additional data collected in the Lao PDR and through discussions with a wide range of individuals and groups within the Lao PDR. In particular, we would like to acknowledge and thank the following for their inputs: NAFRI (particularly Dr. Pheng Sengxua), MAF (particularly Dr. Somphanh Chanphengxay and the Center for Statistics and Information), PAFO and DAFO in the four target provinces (Attapeu, Luang Namtha, Luang Prabang, and Sayabouri), the Climate Change Office of WREA (particularly Syamphone Sengchandala), IWMI (particularly Guillaume Lacombe), the Swiss National Centre of Competence in Research (NCCR) North-South (and particularly Dr. Andreas Heinimann), Dietmar Brautigam, the GTZ projects in Attapeu, Sayabouri, Luang Namtha, other CIAT colleagues working in the Lao PDR, and lastly, but not least, the farmers in Attapeu, Luang Namtha, and Sayabouri who shared their time and experiences with us generously.

1 Introduction

1.1 Background

In the last 40 years, issues related to Climate Change have shifted from being the concern of a small number of environmental activists and specialized scientists to being the focus of broad scientific, political, and community interest and activity.

Many specialised institutions and organisations have been established at international and national levels to research climate change, predict likely changes, assess likely impacts, and propose responses in terms of adaptation to climate change and mitigation to reduce the likely rate of change, and all from scientific, economic, social, and political stand points. Perhaps the most influential of these international organisations is the Intergovernmental Panel on Climate Change (IPCC), which was established in 1988 by two United Nations organizations, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The IPCC monitors the research undertaken by a wide range of scientific groups and publishes reports that tend to drive the social and political debates, especially those associated with the United Nations Framework Convention on Climate Change (UNFCC), which was a treaty that came out of the 1992 Earth Summit. Under the UNFCC the annual Conference of Parties (COP) has been organised since 1995, with perhaps the best known being that held in 1997 in Kyoto Japan, which yielded the Kyoto Protocol to the initial treaty. The 15th COP was held in December 2009 in Denmark and it was in the build up to COP 15 that interest in agriculture and forestry increased dramatically, both in terms of the adaptations necessary and the mitigation potential of agriculture and forestry.

In the end, there was a great deal of disappointment in COP 15. The main outcome of the conference was a non-binding political agreement, known as the Copenhagen Accord, which included recognition of the objective of keeping the maximum global average temperature rise below 2°C, outlined the commitment to additional funding for adaptation and mitigation in developing countries, and called for greater transparency between developed and developing countries in dealing with the consequences of global warming and climate change. The next challenge will be to turn this political agreement into an effective and legally binding agreement by COP16, which will be held in Cancún, Mexico, in November/December 2010.

It is not long ago that many developing economies considered that the issue of climate change was not of particular importance as they had far greater challenges in terms of economic development to consider. For many, economic growth and profligate use of fossil fuels during the industrialization of the developed world were the cause of the problem, thus it was a developed world problem, and especially as far as mitigation was concerned. The realization that sea level rise associated with climate change was going to affect a disproportionate number of people in the developing world , especially island nations and countries with large populated delta areas, such as Bangladesh and Vietnam, alerted many countries to the problems of climate change. More recently, the likely impact of climate change on agriculture and forestry has meant that even more countries in the developing world have started to take a greater interest in climate change.

Like many countries at similar stages of development, the Lao PDR did not have a particular interest in climate change until recently, but this has changed quickly. In May 2008, the Climate Change Office was setup under the Department of Environment within the Water Resource and Environment Administration (WREA) and they have actively pursued issues related to climate change. A series of working groups have been established on related topics and the development initiated of a National Climate Change Strategy and Action Plan, a National Adaptation Programme of Action to Climate Change (NAPA) (WREA, 2009), and a Strategy on Climate Change of the Lao PDR (WREA, 2010). According to some observers, the situation in the Lao PDR has changed so quickly that interest in and responses to climate change issues in the Lao PDR has now overtaken the situation in some similar economies that initiated a response to climate change somewhat earlier.

A number of studies have already been undertaken or are on-going in the Lao PDR, or have included the Lao PDR. For instance, the MRC-GTZ Watershed Management Project undertook a study on “Climate Change Adaptation in the Lower Mekong Basin” (MRC-GTZ, 2008), the Swedish International Development Cooperation Agency (Sida) commissioned the International Water Management Institute (IWMI) to undertake a “Scoping Study on Natural Resources and Climate Change in Southeast Asia with a Focus on Agriculture” (IWMI, 2009), Norwegian Church Aid commissioned a smaller study, with a focus in northern Lao PDR (Foley, 2009), and the Asian Development Bank (ADB) has an on-going study commissioned through Risk Management Solutions India (RMSI) to undertake a pilot study entitled “Climate Change Impacts and Adaptation Strategies for the Rural Infrastructure Sector in Lao PDR”, with a focus on the economic impacts in the five southern provinces, which is part of a larger study across a number of countries.

Agriculture, forestry, and natural resources are of critical importance to the Lao PDR, both at the level of the whole country and for individual Lao, especially for poor farming households. Consequently, the potential effects of climate change on the Lao people need to be assessed carefully and possible adaptation and mitigation strategies developed.

Temperature and rainfall patterns are almost certain to change in the Lao PDR in the next few decades, although the nature of these changes and the likely impacts on agriculture and the environment are not well understood at the national level, let alone at the level of the farmer. Resultant changes in agricultural productivity will affect income, with concomitant impacts on livelihoods. Potential changes in agricultural production, the natural resource base, and livelihoods need to be understood, and they need to be understood in the context of on-going change resulting from other drivers, such as population growth, migration and resettlement, and economic growth.

Understanding how climate change may cause impacts at the local scale, on land, and on land use, is crucial for the development of long-term adaptation and mitigation strategies that may minimize any negative impacts of climate change within the context of a country and a people undergoing rapid development.

The Lao-German Land Management and Registration Project (LMRP) (formerly the Land Policy Development Project) has funded 14 land policy studies that aimed to collect relevant data, describe the present status, and analyse policy matters of land management and administration. This study on impacts of climate change on land and land use is part of this series.

1.2 Objectives of this study

The study was designed to have a primary focus on the following key points:

1. Assess the status quo and draw scenarios of climate change impacts on land and land use in the Lao PDR, with a specific interest in the provinces of Sayabouri, Luang Namtha, Luang Prabang, and Attapeu.
2. Predict potential impacts of climate change on land and land use.
3. Predict the use/conversion of farm/forest land as a result of climate change and change in CO_2 level and draw consequences of potential shifts of agro-ecological zones on the agro-industry and agro-forestry sector. Assess the potential economic effects and consequences for the provinces as a result of such changes.
4. Assess the vulnerability-level of local rural people to those impacts (including aspects like food security, water resource, access to the commons, NTFPs, etc.)
5. Draw climate change scenarios (based on IPCC emission scenarios) over time and conceptualize potential responses by Lao farmers and Policy makers along two time horizons (short-term (2020) and medium -term (2050)).

6. Summarize and assess existing adaptation and mitigation-strategies and assess preparedness level with a specific focus on the four provinces (including national adaptation strategies and actions needed to increase adaptation-capacity).
7. Give clear advice on the prioritization/improvement of intervention initiatives and mitigation measures (including governance structure, economical instruments).
8. Advise on meaningful actions to strengthen the integrity of ecological services that are vital for maintaining agricultural productivity.
9. Advise on ways to improve the capacity of adeptness and potential coping mechanism.
10. Give clear recommendations for further policy development on land management and use in relation to climate change.

2 The past and future climate of the Lao PDR

2.1 Introduction

As agriculture remains a major component of the Lao economy and the major activity of the majority of the Lao people, so climate is a major driver of the economy and of the livelihoods of the Lao people, especially the marginalized rural poor for whom agriculture is extremely critical. The potential for agricultural production is set by many biophysical factors, including climate, soil quality, topography, latitude and altitude, but the main factor affecting to what degree potential production is achieved each year is the climate and most particularly the amount and distribution of rainfall.

In assessing the likely impacts of climate change over the next few decades it is critical to assess how much climate has changed and then predict how much climate is likely to change before relating to agricultural production and land use. The natural variation in climate, both cyclical and non-cyclical, on an intra-annual, inter-annual, and on a longer-term basis (e.g. the Hale cycle related to sun-spot activity), means that variations in climate need to be assessed over an extended period for there to be any confidence that the changes are real and not just part of natural variation. This requires extensive records.

The IPCC has coordinated and assessed the results of climate change research and produced regular reports. The IPCC Third Assessment Report (IPCC, 2001) indicated that globally, the average diurnal temperature increased by 0.6ºC in the 20th century. This overall trend was observed as a significant increase form 1910 to 1945, a slight decrease from 1945 to 1965, and a marked increase from 1976 to 2000. Generally, there was a reduction in low temperature extreme events and an increase in high temperature extreme events. For rainfall, it was concluded that there had been geographically differentiated increases and decreases in precipitation of at least 1% per decade. There was an increases in the frequency and the intensity of heavy rainfall events and an increase in cloud cover. A consequence of these various changes was an increase in sea level of between 0.1 and 0.2 meters.

Whilst the potential for anthropogenic global warming was proposed more than a century ago, it is only in the last decade or so that the evidence has looked very strong and only in their Fourth Assessment Report (IPCC, 2007) did the IPCC concluded that “Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations”.

Although extensive datasets of climate records exist in many countries, which have contributed greatly to the conclusion that there is anthropogenic global warming, for many countries, such as for the Lao PDR and many of its neighbours, long-term and reliable climate records do not exist and so a combination of data are required to assess the evidence for climate change in the Lao PDR.

2.2 Methods for assessing climate and climate change

2.2.1 Method of analysis of past climate trends

With limited historical records of climate in the Lao PDR, and in neighbouring countries, analysis of long-term trends in the Lao climate requires the reconstruction of a climate dataset for the country based on all available data. The dataset and methodology of New *et al*. (2000) was used to reconstruct the Lao climate from 1901 to recent times. This reconstructed climate was then analysed for spatial and temporal changes in a range of climate parameters.

The CRU TS2.1 Climate Dataset has been produced by the Climatic Research Unit (CRU) of University of East Anglia, and reformatted by Antonio Trabucco of the International Water Management Institute (IWMI) for the CGIAR-CSI into ArcInfo Grid format, to provide for easy access (http://cru.csi.cgiar.org) and use for geospatial analysis using common GIS software. The creator of this dataset and CRU retain full ownership rights (Mitchell and Jones, 2005).

The CRU TS 2.1 Global Climate dataset is comprised of 1224 monthly time-series of climate variables, for the period 1901 to 2002, covering the global land surface, excluding Antarctica, at 0.5 degrees resolution. For this study, the data from 103 data points, each representing 0.5° by 0.5°, were required to cover the full extent of the Lao PDR (Figure 2.1), a total area of 236,800 km^2. The 0.5° by 0.5° represent areas that are approximately 55.45 km from east to west and range from between about 53.9 to 51.5 km from north to south, whether in the south or the north of the country, respectively (approximately 14° to 22° N). Thus each data area represents between 2,850 to 3,000 km^2.

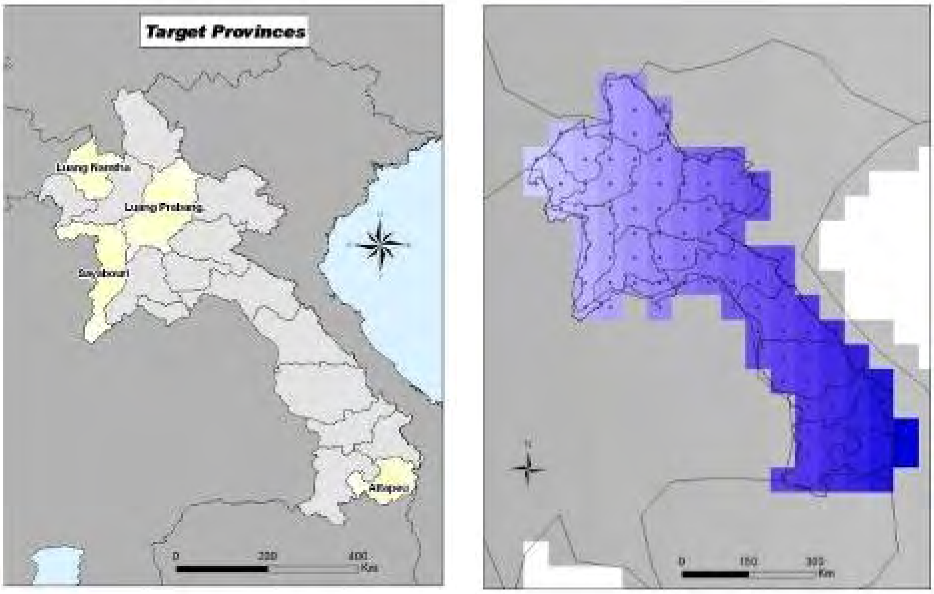


Figure 2.1. Maps of Lao PDR showing the provinces, including the four target provinces, and the 103 data areas used from the CRU dataset

The nine climate variables available through the CRU dataset are daily mean, minimum and maximum temperature, precipitation, wet day frequency, diurnal temperature range, frost day frequency, vapour pressure and cloud cover. In this study the analysis was carried out on the annual mean, minimum, and maximum temperature, the annual rainfall, the monthly rainfall in April, May, and October, and the wet day frequency. The months of April, May, and October were selected as these are the critical and more variable months for rainfall at the beginning and the end of the wet season.

The annual temporal variation in climate parameters is large, especially for variables such as rainfall. For this reason, analysis and more particularly depiction of such time series data must first be smoothed otherwise any trends may less obvious. The most common technique for smoothing is moving average smoothing, in which the non-systematic variations are cancelled by replacing each data point of the series by an average of the point and a number of surrounding (before and after) data points (Box and Jenkins, 1976; Velleman and Hoaglin, 1981). In this study, the CRU data for 1901 to 2002 was smoothed using a 10 year moving average for depiction of the data and trends in graphs. For the statistical analysis, however, the unsmoothed data was used as if the smoothed data is used the effective period of analysis is reduced to 1905 to 1997, which can make a difference, albeit slight, in the analysis of trends. For most variables, the unsmoothed and smoothed data are presented.

2.2.2 Methods for projection of the Lao climate to 2020 and 2050

Assessing how much the climate is likely to change involves the projection of data from climate models on to the same 103 0.5° by 0.5° areas that cover the Lao PDR. The data used in this study are based on the mean of seven Global Climate Models (GCM) that are used in the IPCC 4th Assessment Report (IPCC, 2007) for two time periods, namely for 2020 (short-horizon) and for 2050 (medium horizon).

The datasets used are part of the International Centre for Tropical Agriculture (CIAT) climate change downscaled data, developed in the Decision and Policy Analysis (DAPA) program of CIAT. The data were downloaded originally from the IPCC data portal and re-processed using a spline interpolation algorithm of the anomalies and the current distribution of climates from the WorldClim database developed by Hijmans *et al.* (2005a). It is assumed that the geographies of changes in climate variables do not vary too much at regional scales and that the relationships between the different variables will remain basically the same in the future. The data surfaces used were generated using an empirical downscaling approach, which is the method preferred by CIAT and many others, rather than re-modelling the climate patterns using an RCM (Regional Climate Model), especially where the local/regional climate dataset is limited, either spatially, temporally, or, as in this case, both.

The downscaling process includes the following: (i) calculation of anomalies (if they are not provided directly by IPCC) by simply subtracting the future value of each variable with the baseline, (ii) interpolation of anomalies to a 30 arc-seconds resolution (approx. 1km) and (iii) addition of the interpolated anomalies to the current distribution of climates in WorldClim (www.worldclim.org). For temperature an absolute sum is used, but for precipitation the relative differences are used, as there are differences between the GCM baseline and the WorldClim baseline.

The IPCC Special Report on Emission Scenarios (SRES) (2000) included scenarios grouped into four families of scenarios, namely, A1, A2, B1, and B2, with a total of 40 scenarios developed under these four families. The different scenarios produce large differences in the patterns of greenhouse gas (GHG) emissions during the 21st century (Figure 2.2).

The A1 scenario family describes a future world of very rapid economic growth, global population that peaks around the middle of the 21st century and then declines, and the rapid introduction of new and more efficient technologies. This scenario assumes a substantial reduction in regional differences in per capita income, based on increased cultural and social interaction between and within nations. The A1 scenario family includes three sub-groups that describe alternatives in terms of energy systems. A1FI takes a fossil intensive pathway, A1T relies more on non-fossil energy sources, while A1B involves a balance between fossil and non-fossil fuel sources.

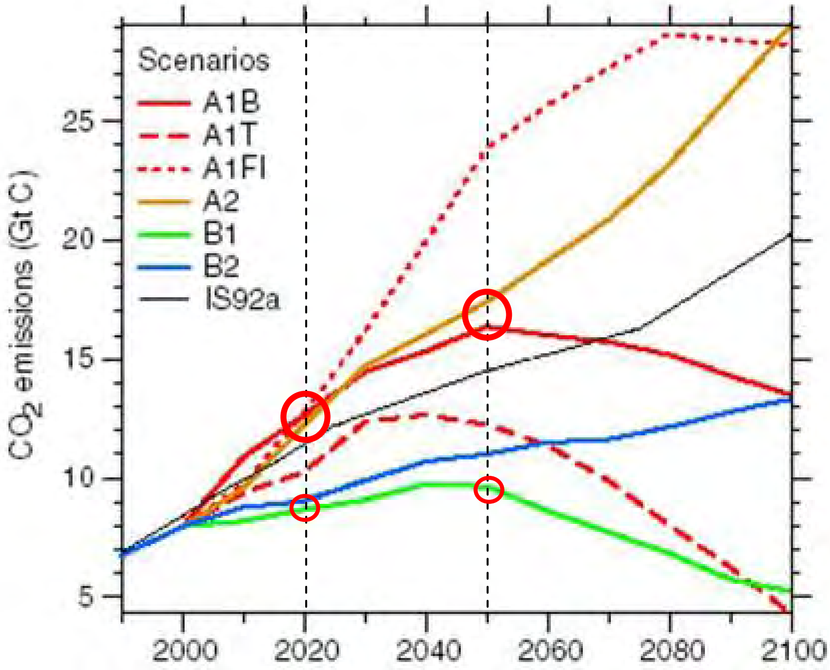


Figure 2.2 Six of the IPCC SRES emission scenarios from 2000 compared to the earlier, 1992, IPCC IS92a “business-as-usual” scenario

The A2 scenario group describes a very heterogeneous world that maintains regional differences in population growth and economic development, and thus large regional differences are maintained in per capita income and in technological change. The B1 scenario follows a similar line to the A1 scenario in population growth, but with a rapid change in economic structures toward more service and information oriented economies and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity. Finally, the B2 scenario group describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. Global population increases at a rate lower than the A2 scenario, with intermediate levels of economic development, and slower and more diverse technological change than in the B1 and A1 scenarios.

The majority of climate change research groups have focused on three emission scenarios, namely A1B, A2, and B1, and these are the three for which large datasets exist. Of these three scenarios, B1 already looks way too optimistic, considering the trends in global GHG emissions, which have continued to follow something like a business as usual scenario since 2000. While A1B and A2 have very different outcomes in terms of expected GHG emissions, and thus impacts on climate change, most of these differences do not occur until after 2050. Even the A1FI scenario, which involves much greater emissions than A1B and A2 by 2050, does not differ greatly from these two scenarios by 2020. Consequently, and for reasons of space, the projected climate of the Lao PDR is presented for two periods, 2020 and 2050, with the reasonably, but not too optimistic A1B scenario, all compared to the average of climate for the 20 year period from 1982 to 2002.

2.3 Reconstruction of the 20th century climate of the Lao PDR

The climate of the Lao PDR for the 20th century, from 1901 to 2002, was reconstructed according to the methods outlined in section 2.2.1 for eight climate variables, namely annual mean, minimum, and maximum temperature, annual precipitation and wet days, and monthly precipitation for April, May, and October. Time series data of the variables are presented, as real and smoothed data, along with maps of the country that depict the average value of the variable for the period 1982 to 2002 and as the net changes in the climate variable from 1901 to 2002. The period from 1982 to 2002 was used to represent a recent period, but averaged over a sufficiently long period (20 years) to represent a reasonable average for recent times.

2.3.1 Annual mean temperature

The annual mean temperature for the 103 data points that cover the Lao PDR indicate a range across the country of about 7°C (Figure 2.3). Comparison of the real data with the smoothed 10-year moving average data highlights the significant inter-year variation. Both datasets, but more easily with the smoothed data, show the trend for increased mean temperature from 1901 to 2002, particularly in the last decade.

The increase in mean temperature over this period is not even across the country, with greater increases observed in the south of the country (Figure 2.4), which is clear in the maps of mean temperature for 1982 to 2002 and the change in mean temperature from 1901 to 2002. In most of the north and central part of the country the increase in mean temperature was between 0.1° and 0.5°C, whereas the change in the southern part of the country, covering most of the lower four provinces, including Attapeu, was between 0.5° and 1.0°C.

2.3.2 Annual minimum temperature:

The minimum temperature can be an important factor in controlling which plant species grow where and how well. The incidence of frost is a well recognized determinant of species suitability and even survival, but the general minimum temperature also has broad impacts on many aspects of plant physiology, especially with regard to reproduction and product quality. In many cases, because of the impact on reproduction, the tolerance of heat is as much defined by the tolerance of higher minimum temperatures as it is by tolerance of higher maximum temperatures.

The smoothed moving average annual minimum temperature for the Lao PDR for the 20th century indicates a greater variation within country (approximately 10º C) and across time than the mean temperature for the same period. There was a general decrease in the minimum temperature from 1900 to 1960 and then a reasonably steady increase in the minimum temperature for the remainder of the century (Figure 2.5). Across much of the country, the increase in the minimum temperature during the 20th century, and particularly in the latter part of the century, was between 0.1 to 0.5º C for the whole period (Figure 2.6). In some limited areas, primarily, but not exclusively, in the south, the increase was greater, at between 0.5 to 1.0º C.

A: Real data

B: Smoothed Moving Average

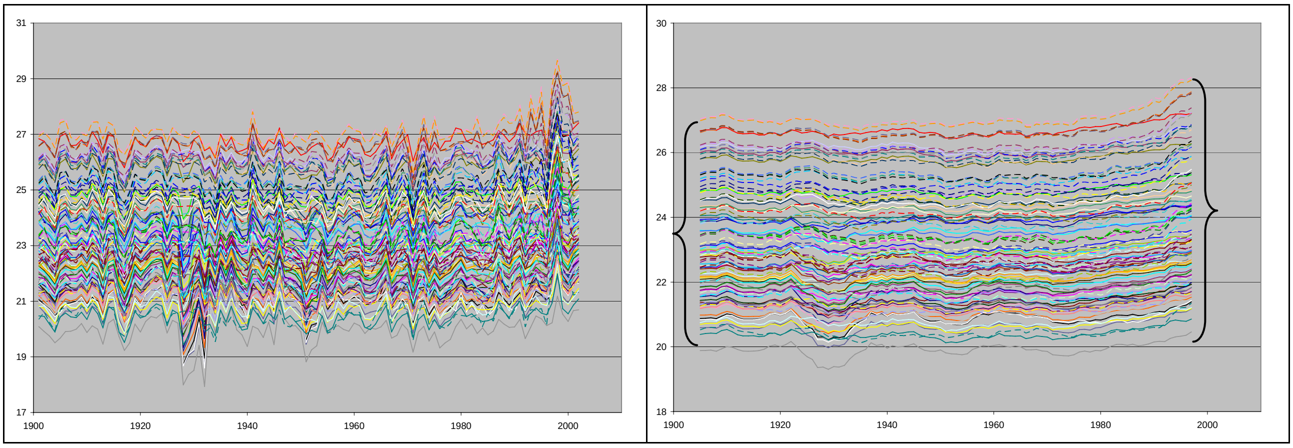


Figure 2.3 Annual Mean Temperature 1901-2002 for the 103 pixels that cover the Lao PDR

A: Average for 1982-2002

B: Change from 1901 to 2002

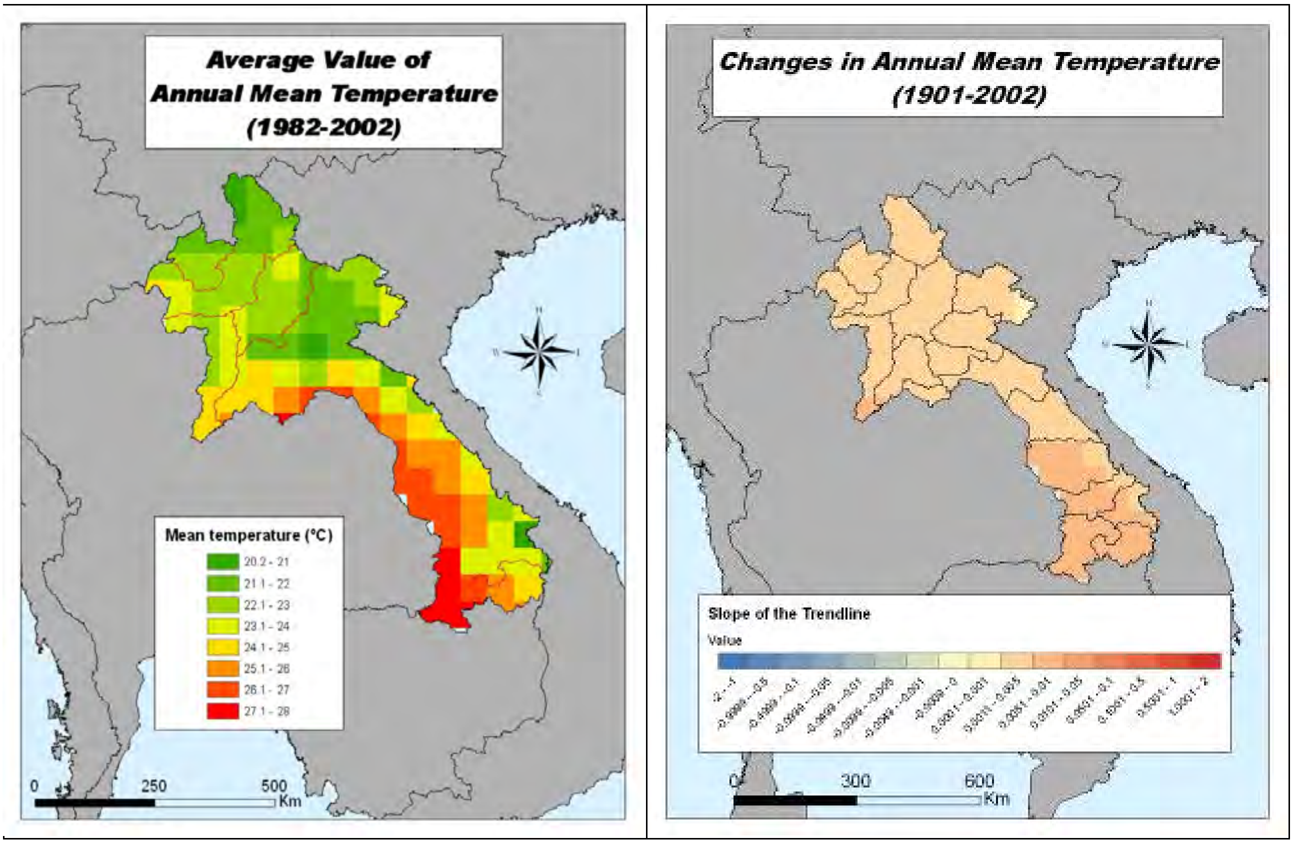
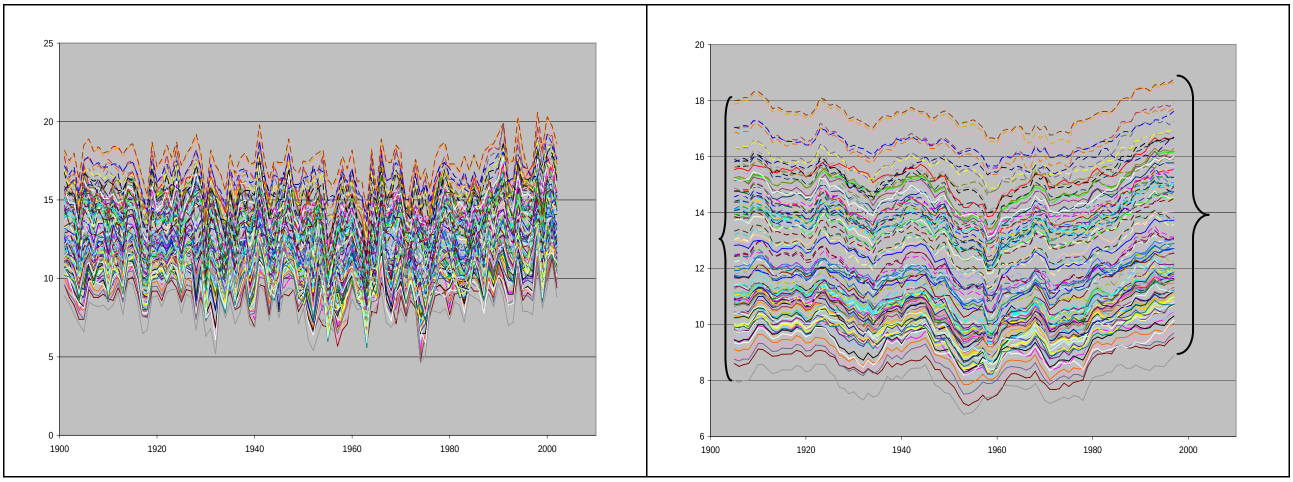
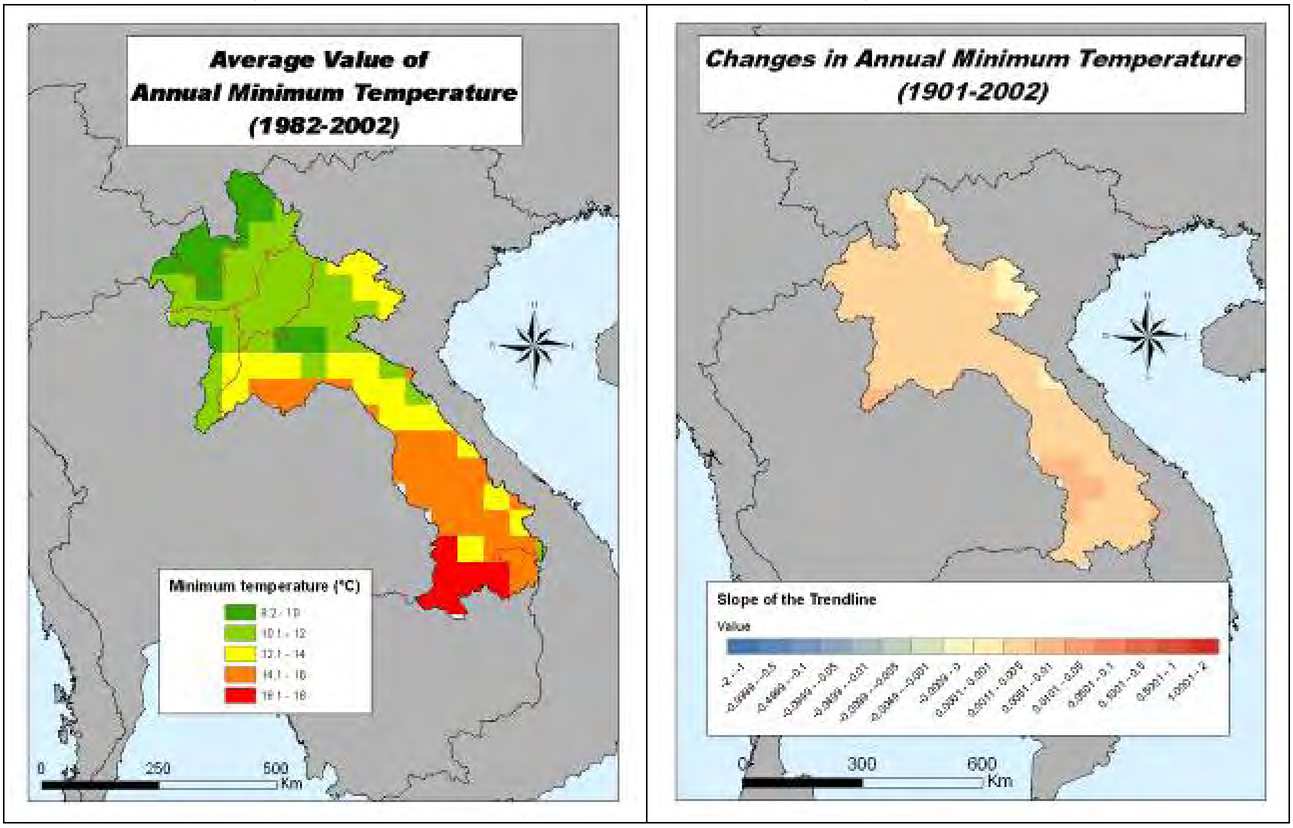


Figure 2.4 Average Annual Mean Temperature for the period 1982 to 2002 and the change in Annual Mean Temperature from 1901 to 2002


A: Real data

B: Smoothed Moving Average

Figure 2. 5 Smoothed moving average of the Annual Minimum Temperature from 1901-2002 for the 103 pixels that cover the Lao PDR


A: Average for 1982-2002

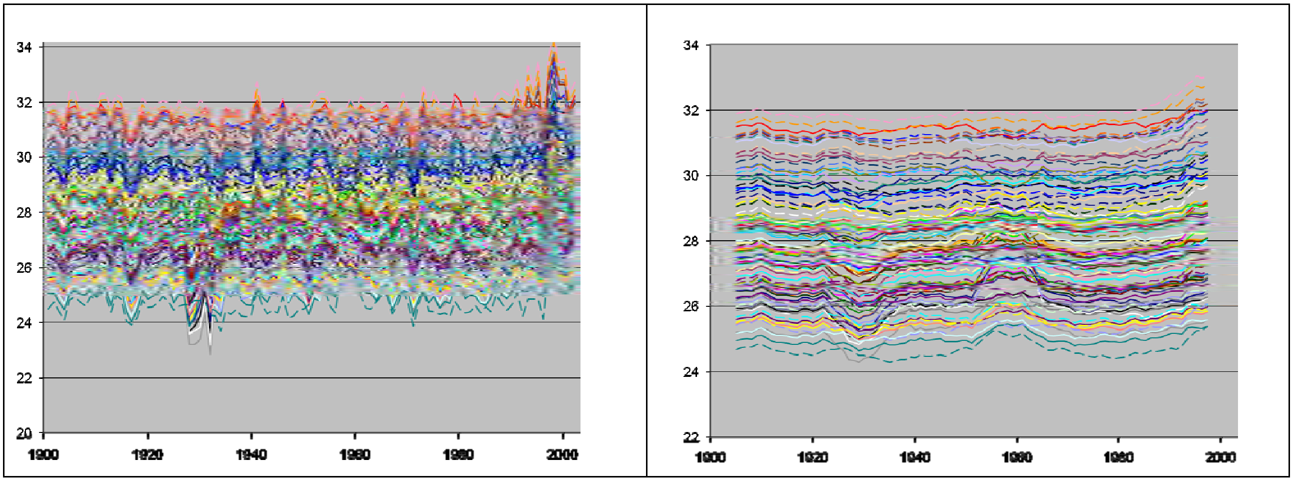
B: Change from 1901 to 2002

Figure 2.6: Average Annual Minimum Temperature for the period 1982 to 2002 and the change in Annual Minimum Temperature from 1901 to 2002

2.3.3 Annual maximum temperature:

The maximum temperature is another important determinant of species suitability, with major impacts on physiology, particularly on enzyme reactions and on water relations. During the 20th century there was a general increase in the maximum temperature. Both the real and smooth data show a slight increase in the maximum temperature up to 1990, then a significant increase in temperatures in the 1990s, particularly in the latter part of the decade (Figure 2.7).

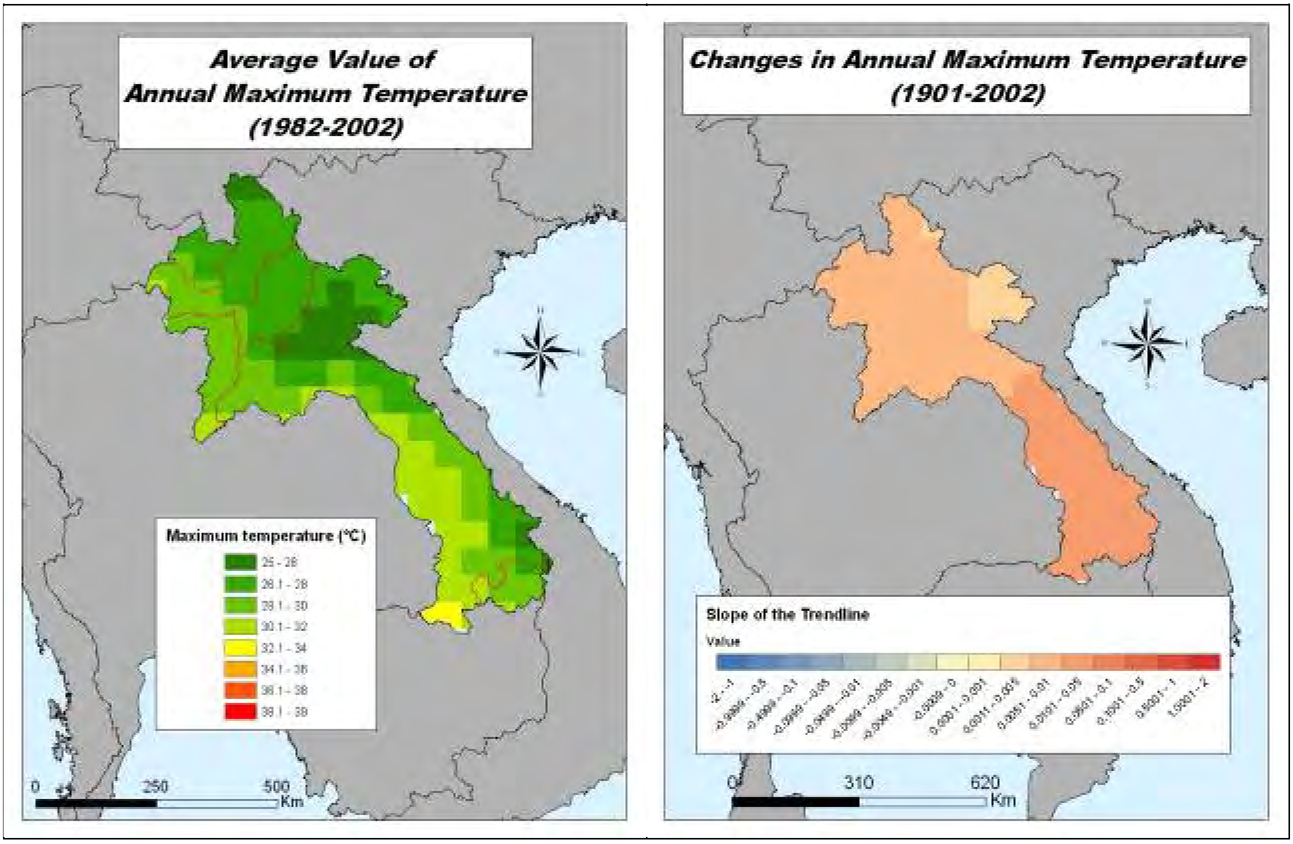
Once again, there is a clear difference in the change in maximum temperature from 1901 to 2002 across the country. For most of the north of the country there was an increase of 0.5 to 1.0º C, whereas in the south and lower central part of the country the increase ranged from 1.0 to 4.5º C (Figure 2.8), with most of this change in the last decade of the century (Figure 2.7)



A: Real data

B: Smoothed Moving Average

Figure 2.7 Annual Maximum Temperature 1901-2002 for the 103 pixels that cover the Lao PDR



A: Average for 1982-2002

B: Change from 1901 to 2002

Figure 2.8 Average Annual Maximum Temperature for the period 1982 to 2002 and the change in Annual Maximum Temperature from 1901 to 2002

2.3.4 Annual Precipitation

The first thing that is clear from the plots of annual precipitation for the period from 1901 to 2002 is the enormous variability between years (Figure 2.9), which is much greater than for the temperature variables. This is something that every Lao farmer knows and expects, and they know that this variation poses the major challenge for them in developing sustainable and relatively risk-free livelihoods.

A: Real data

B: Smoothed Moving Average

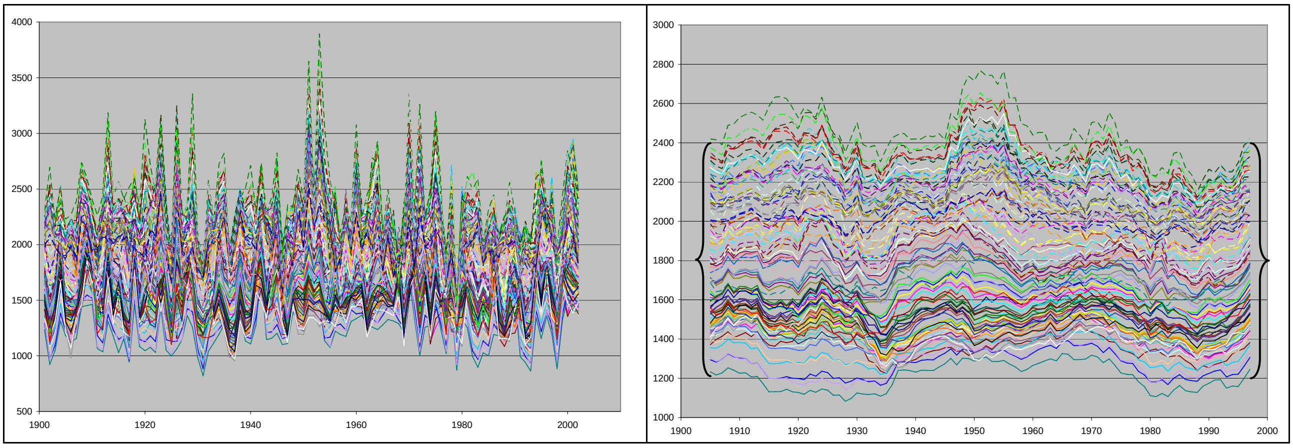


Figure 2.9 Annual precipitation 1901-2002 for the 103 pixels that cover the Lao PDR

A: Average for 1982-2002

B: Change from 1901 to 2002

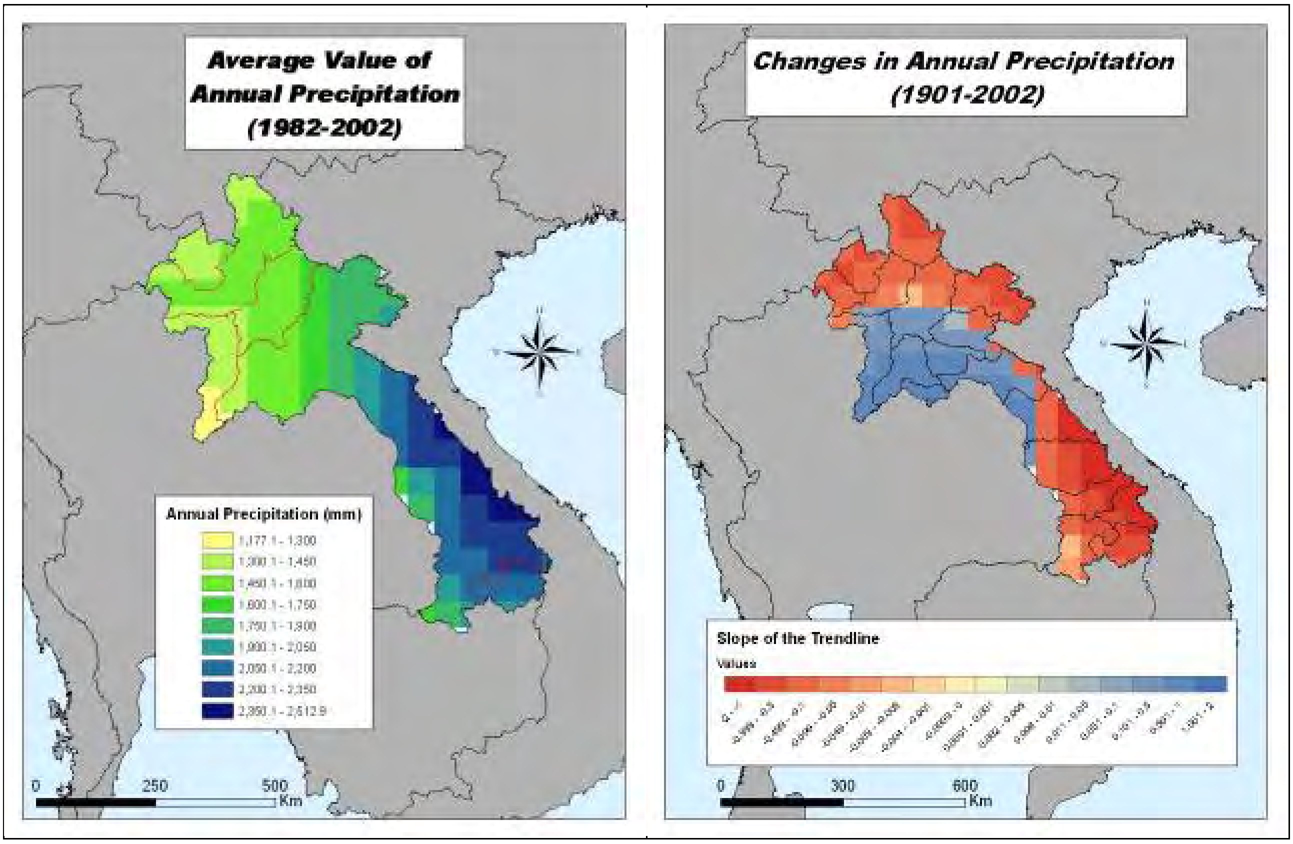


Figure 2.10 Average Annual Precipitation for the period 1982 to 2002 and the change in Annual Precipitation from 1901 to 2002

The smoothed data (Figure 2.9) clearly shows the large range in the average annual precipitation, from about 1200mm per year to more than 2400mm per year, with the highest average rainfall being along the border with Vietnam in the south of the country (Figure 2.10). The overall trend in rainfall for the 101 years is not clear from the plot of individual data areas (Figure 2.9), although the map of change in precipitation over this period shows some clear trends, which are quite contrasting for different parts of the country (Figure 2.10). The highest rainfall in much, although not all, of the country occurred in the 1950s, with the highest data point indicating 3895mm in 1953 (Figure 2.9).

In the far north, the south, and some of the central part of the country there was a decrease in rainfall across the century, with a net decrease of up to 200mm in annual rainfall across the century. By contrast, a smaller part of the country, in the lower north and upper central part of the country showed a net increase in annual precipitation of up to 115mm over the century.

The largest decreases in rainfall occurred in the southern part of the country, affecting in particular the target province of Attapeu. A large decrease in rainfall was also seen in the very north, thus affecting the target province of Luang Namtha. By contrast, most of Sayabouri province experienced an increase in precipitation, while Luang Prabang province showed a relatively minor increase in part of the province and a relatively minor decrease in other parts.

It must be pointed out, however, that these trends for increased and decreased annual precipitation are still less than the annual variation in rainfall, and much less than the extreme variations. Once again, this highlights the extremely high variability in rainfall as well as why long-term analyses are required to identify clear trends.

2.3.5 Annual wet days frequency

The absolute amount of rainfall is critical, but so is the distribution of rain. One measure of distribution is the number of days on which rain occurs throughout the year. The smoothed data for the number of wet days annually confirm a tendency for a general decrease in the frequency of wet days across the century, and especially for the wetter areas, but they also show the very large variation from year to year and in particular periods (Figure 2.11). For the first three decades, and particularly the 1930s, and for the last two decades much of the country showed a marked decline in the frequency of wet days, whereas for other periods there were increases or little change.

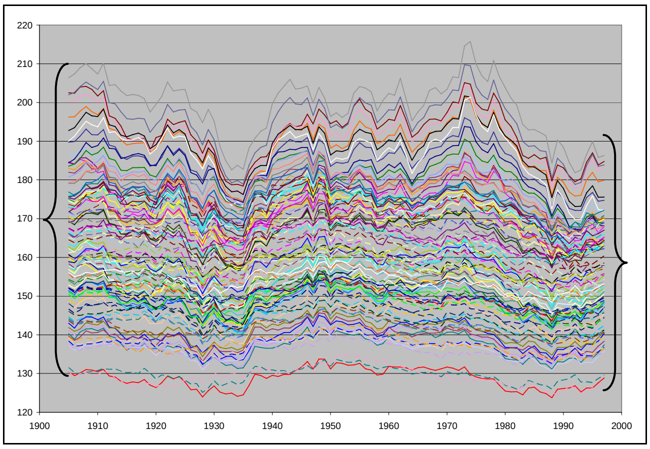
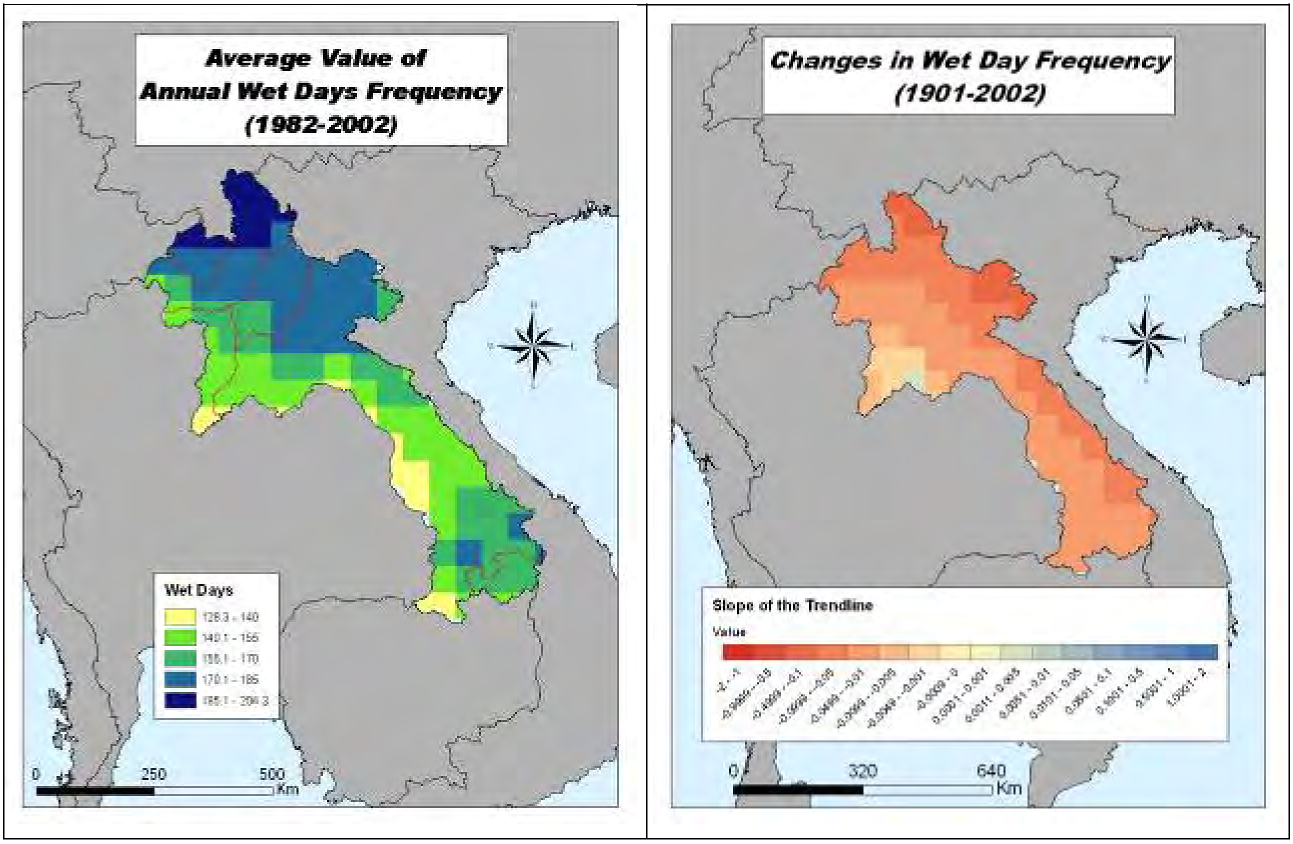


Figure 2.11 Smoothed moving average of the Annual Number of Wet Days from 1901 to 2002 for the 103 pixels that cover the Lao PDR

The overall trend for the century was that most of the country showed a net decrease on the number of wet days, with the difference over the 101 years being as little as one day and as much as 10 days. One small area, near Vientiane, is analysed as having a net increase in wet days over the century, but this net increase was by less than one day.

2.3.6 Seasonal variation in rainfall

The year to year variation in annual rainfall is a major problem for farmers throughout the world, and the Lao PDR is no exception. The risk associated with the variation in rainfall is partially the variation in the total amount of rain during the growing season, however, another major risk is associated with the distribution of the rainfall throughout the wet season. The number of wet days is an indicator of distribution, but it is more important to understand the month by month, week by week, or even day by day variations in rainfall at critical times during the growing season as this can have a critical affect on plant growth. For all crops, but especially for annual crops, the rainfall and overall moisture regime (the balance of rainfall, soil moisture, and evaporation potential as driven by temperature and humidity) during crop establishment is very critical. During the early growth of plants their limited root system, the lack of ground-cover shading, and the high demand of a young growing plant means that they are very susceptible to relatively short periods of water shortage. In areas where there is not capacity for irrigation farmers need to minimized water stress on the crops, which in many cases means avoiding planting until rainfall is reasonably assured. There are other times of crop growth that are critical for water, but the other very important time for most crops will be during grain, seed, or fruit fill, when water is required to drive the movement of carbohydrates to the reproductive or storage bodies, such as during the maturation of rice. Unfortunately, it is exactly these periods, at the beginning and the end of the wet season, when the greatest variation in rainfall occurs.


A: Average for 1982-2002

B: Change from 1901 to 2002

Figure 2.12 Average Annual Wet Day Frequency for the period 1982 to 2002 and the change in Annual Wet Day Frequency from 1901 to 2002

Analysis of daily rainfall from Luang Prabang during the period from 1953 to 2004 serves to highlights this problem (Figure 2.13). Eight years were selected to demonstrate the variation in rainfall between and within seasons and they are compared to the mean cumulative daily rainfall over this period (smooth solid line). It is clear that there is a large range in total annual rainfall recorded during this period, with more than a three-fold difference between the driest and wettest years. Secondly, the variation between seasons in rainfall distribution is evident, particularly in April, May, and even June, when the season is getting started, and then at the end of the season, in October. In some seasons there is a steady increase in cumulative rainfall from early April, whereas in the worst case, the rains only get started in late June. Similarly at the end of the season, in some years the rains stopped, or at least there was a critical break, in September or early October.

The mean monthly rainfall for April, May, and October were analysed for trends across the whole country in the beginning and the end of the wet season during the period from 19901 to 2002.

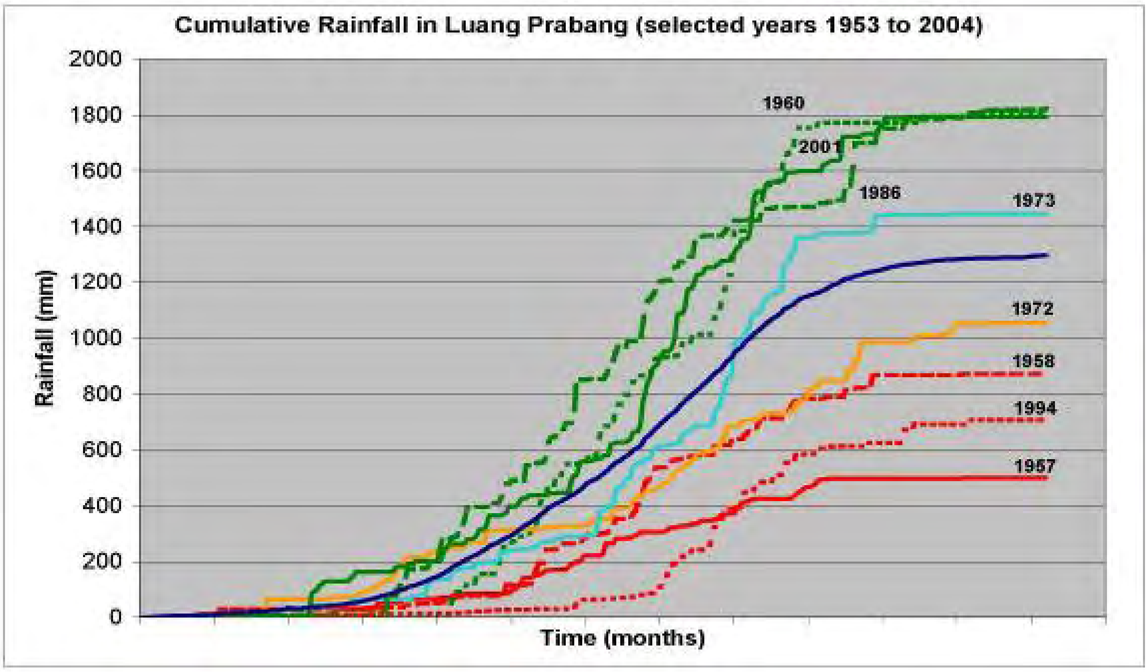


Figure 2.13 Cumulative Daily Rainfall for Luang Prabang for eight representative years selected from the period 1953 to 2004. (Mean for the period is the smooth blue line)

Monthly precipitation at the beginning of the wet season (April and May)

A comparison of the smoothed mean monthly rainfall in April and May for the whole of the 20th century indicates some interesting trends (Figure 2.14). Firstly, while there is substantial variation between years, there is greater uniformity across the country in the rainfall patterns in April compared to the pattern in May. Secondly, despite the substantial year-to-year variation, there was a trend for increasing rainfall in April from 1901 to 2002 and a trend for a decrease in the monthly rainfall in May. This suggests that the slight bimodality in rainfall across the country, with a small early peak followed by a drier period before the main rains, may have increased.

The maps of mean rainfall for 1982 to 2002 and the change in monthly rainfall across the century for both April (Figure 2.15) and May (Figure 2.16) add further complexity. The general increase in April rainfall seen in the plot of smooth data for the century (Figure 2.15) hides a marked difference between the north and the south of the country, with April rainfall increasing in the north, especially the far north, by up to 20mm, and April rainfall decreasing in most, but not all, of the south by as much as 10mm. For rainfall in May there was a decline across the whole country, particularly in the north, of from 4 up to 50mm.

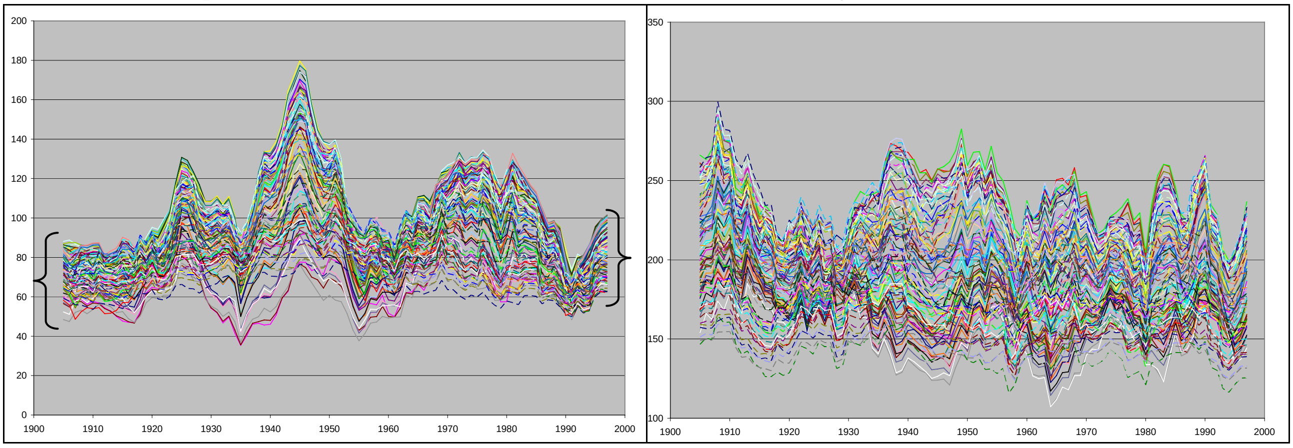
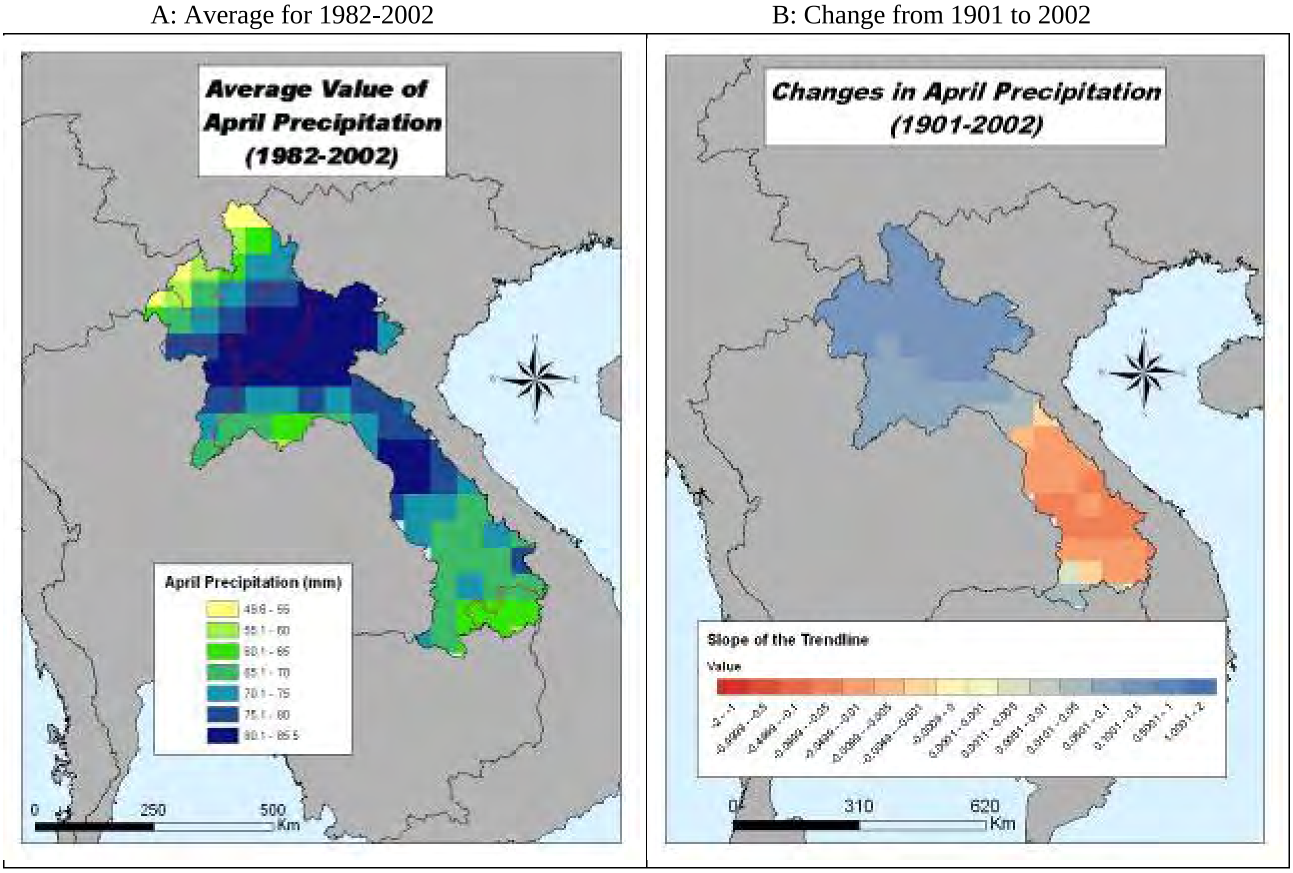

A: April B: May

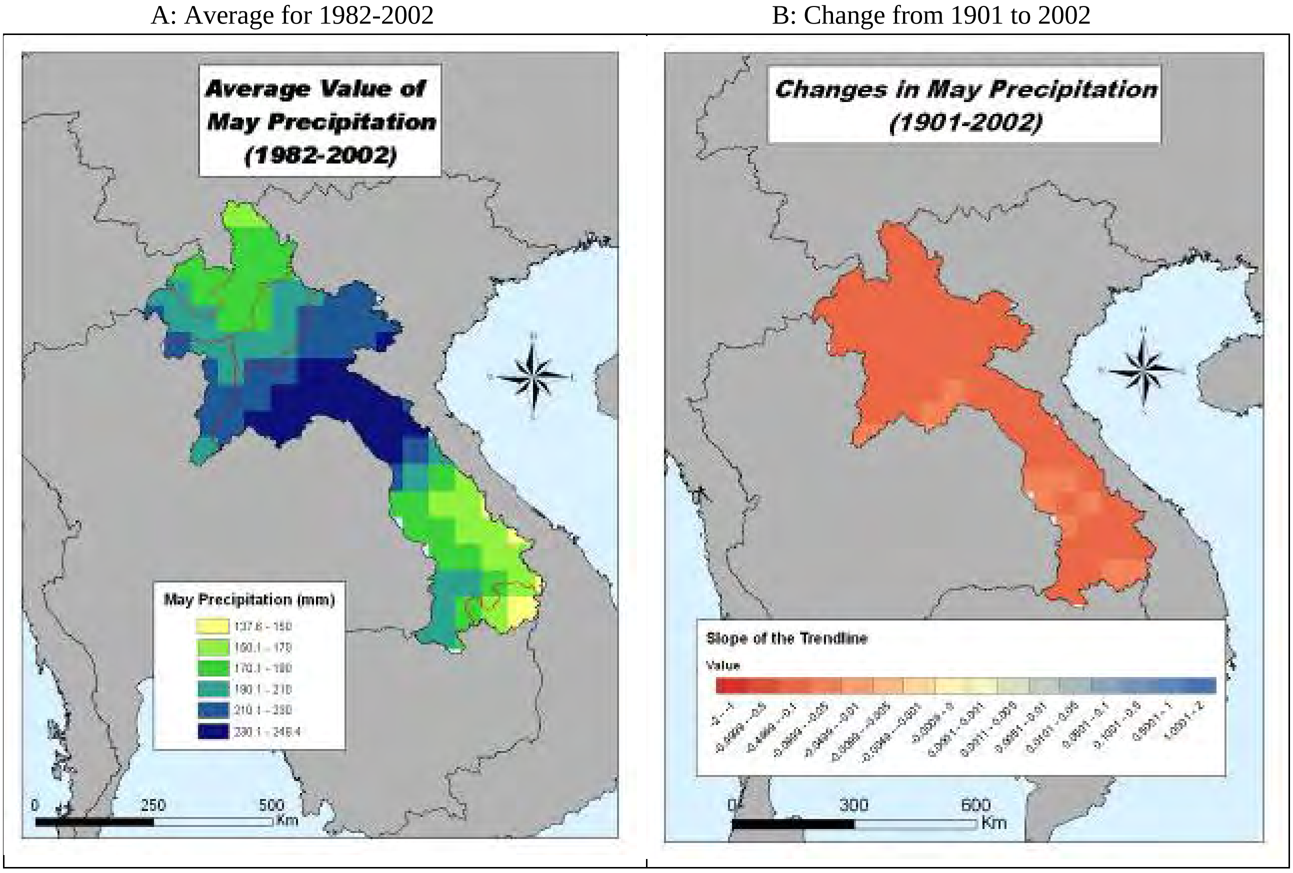
Figure 2.14 Smoothed Moving Average for monthly precipitation for (A) April and (B) May from 1901-2002 for the 103 pixels that cover the Lao PDR



A: Average for 1982-2002

B: Change from 1901 to 2002

Figure 2.15 Average monthly precipitation in April for the period 1982 to 2002 and the change in April precipitation from 1901 to 2002



A: Average for 1982-2002

B: Change from 1901 to 2002

Figure 2.16 Average monthly precipitation in May for the period 1982 to 2002 and the change in May precipitation from 1901 to 2002

Monthly precipitation of October (end of wet season)

The time series data of October rainfall (Figure 2.17) and the map of average October rainfall for 1982 to 2002 (Figure 2.18) show the marked spatial differences across the country. About three-quarters of the area of the Lao PDR receives approximately 100mm of rain in October, whereas 25 of the 103 pixels that cover the country are shown to received higher rainfall in October, up to approximately 400mm, with the highest of these being in the southeast of the country. Across the country there has been a trend towards an increase in October rainfall of between 4 and 20mm from 1901 to 2002, particularly in the north and upper central part of the country (Figure 2.17).

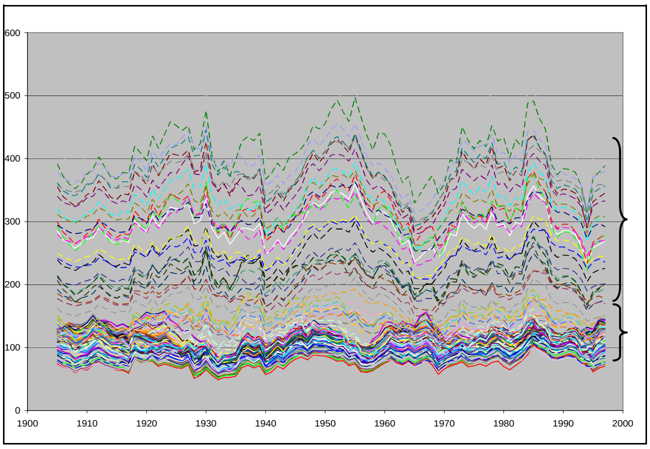


Figure 2.17 Smoothed moving average of monthly precipitation in October from 1901 to 2002 for the 103 pixels that cover the Lao PDR

A: Average for 1982-2002

B: Change from 1901 to 2002

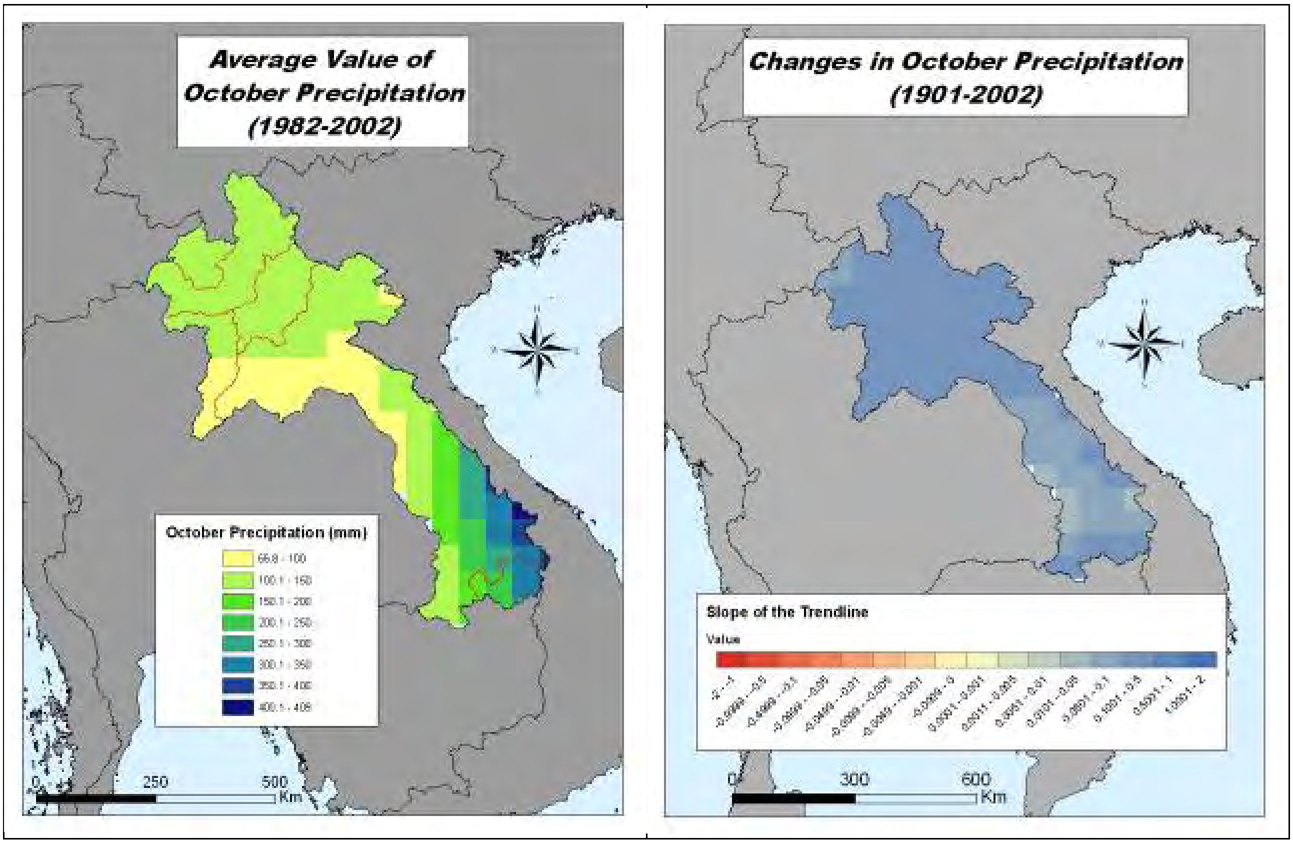


Figure 2.18 Average monthly precipitation in October for the period 1982 to 2002 and the change in October precipitation from 1901 to 2002

2.4 Projected changes in the climate of the Lao PDR to 2020 and 2050

The projections of the likely change in climate for the Lao PDR were based on the mean results of seven GCMs and were projected for the period to 2020 and 2050. There were differences between the results of the different GCMs, which are discussed below, although the depicted data are the mean values from all seven models.

Of the three main scenarios in which modellers have been interested, SRES scenarios A1B, A2, and B1, it is clear that the B1 scenario is too optimistic and that, at least up until 2050, A1B and A2 are very similar. After 2050 the A2 scenario diverges, on a higher emission pathway. Due to this comparative lack of difference, as well as to save space, only the A1B projections are presented. Some people suggest that even the A1B scenario is too optimistic, considering how much GHG have continued to rise, and that the A1FI scenario may be more appropriate, but A1FI is definitely on the pessimistic end.

For all seven climate variables studied (number of rainy days is not predicted by the GCMs), the results are presented in the same format. This includes three maps of the country to represent the mean value of the parameter projected to 2020 and projected to 2050 and the mean value for the period from 1982 to 2002. The fourth map depicts the change in the particular climate variable between the mean value for 1982 to 2002 through to the values in 2050. The situation for the four provinces of particular interest (Figure 2.1) can be seen from these maps.

While the analysis of climate in the 20th century indicated that there were significant changes, especially in temperature, between 1982 and 2002, it is necessary to use reasonable average values (in this case for 20 years) as the point of comparison to reduce the problem of year-to-year variations. As such, at least some of the projected change from this mean (1982-2002) through to 2020 or 2050 would have occurred by 2002, let alone by 2010. To use a shorter period, such as the five year period from 1997 to 2002, would reduce this affect, however, would introduced a larger year-to-year variation and thus may have made comparisons harder or at least less valid.

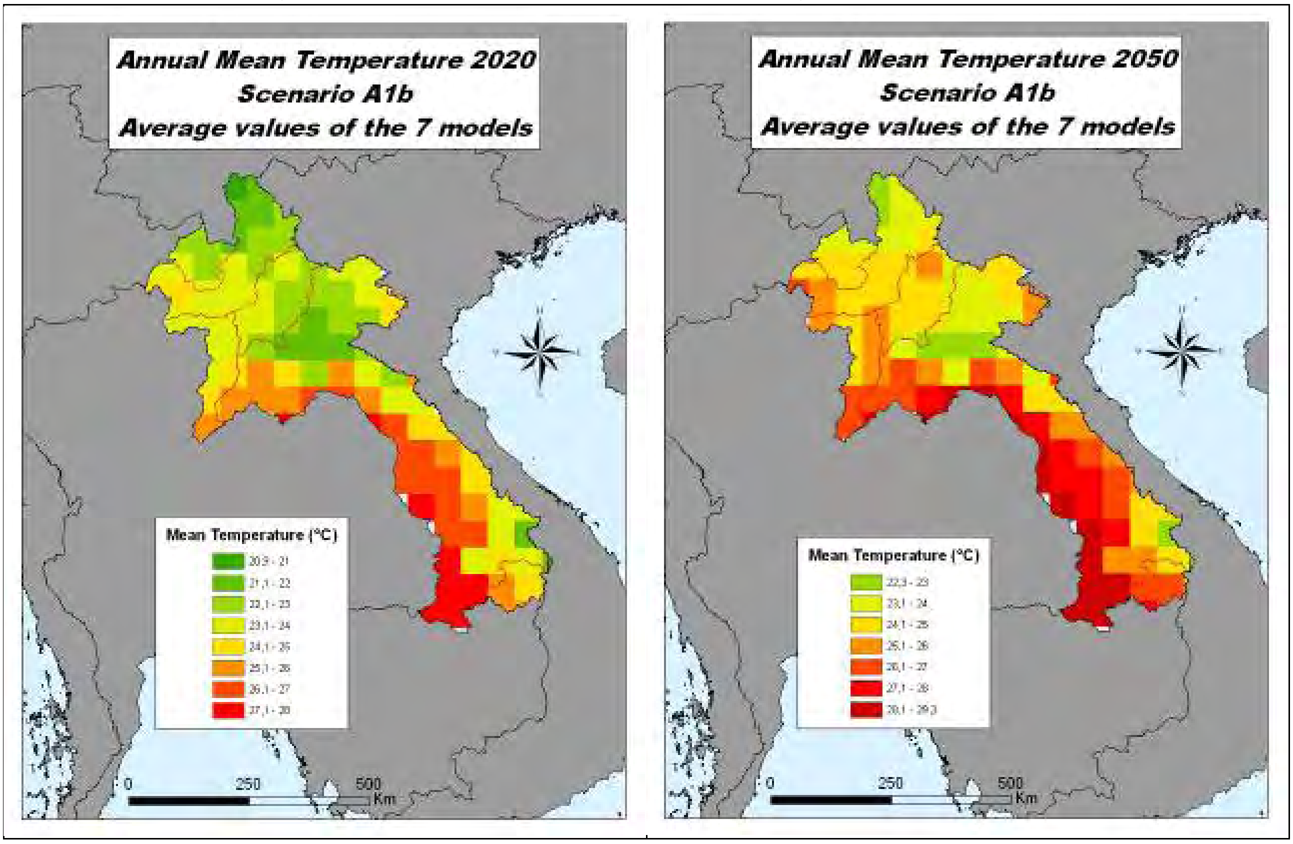
2.4.1 Projected changes in Temperature

The seven GCMs produced similar predictions of annual mean temperature for 2020 and 2050. The maximum differences between models for a particular data point, or pixel, are 0.37°C in 2020 and 0.89°C in 2050.

The reconstructed data for the 20th century indicates that temperatures started to increase from about the 1970s, although this increase became particularly clear in the 1990s. The projections to 2020 and 2050 indicates that temperatures will continue to increase, with the mean temperatures reaching levels never seen in the 20th century. The mean temperatures in 2050, on average, will be 1.62°C higher than the values in the 1990s. Across the country, the increase in mean temperature ranges between 1 and 2°C, with higher temperatures in the south but bigger increases in the north (Figure 2.19). As an example of the predicted change, the mean temperature for 1982 to 2002 in Sayabouri was 23.7°C, but it is projected to be 24.4°C in 2020 and 25.7°C in 2050; some 2°C above the 1982-2002 temperature.

The models differed in the prediction of minimum temperature. The greatest difference in minimum temperature between models for a pixel is 1.08°C in 2020 and 2.57°C in 2050. Across the country there was an increase in the minimum temperature (Figure 2.20). In 2020, a large area in the south and center of the country will have minimum temperature higher than 16°C and by 2050, all of the south will be above 16°C, and over 18°C in the extreme south. Although the temperatures remain lower in the north, the increase in minimum temperature is likely to be higher in the north (Figure 2.20). The mean minimum temperature for Sayabouri is predicted to increase from 11.3 °C in 1982 – 2002 to 12.5°C in 2020 and 13.9°C in 2050; an increase of 2.6°C.

A: 2020 Projection B: 2050 Projection



C: Average for 1982-2002 D: Change from 1982-2002 average to 2050 projection

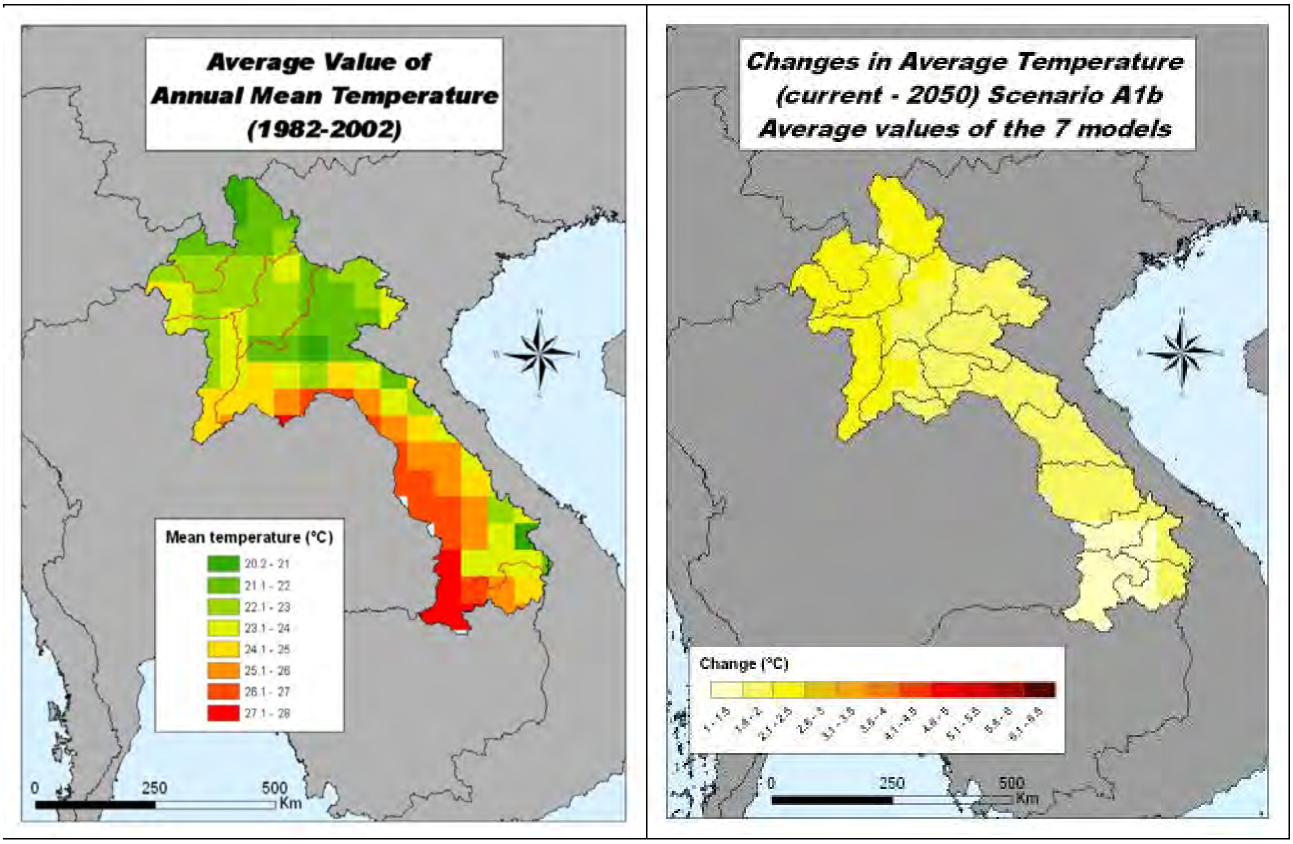
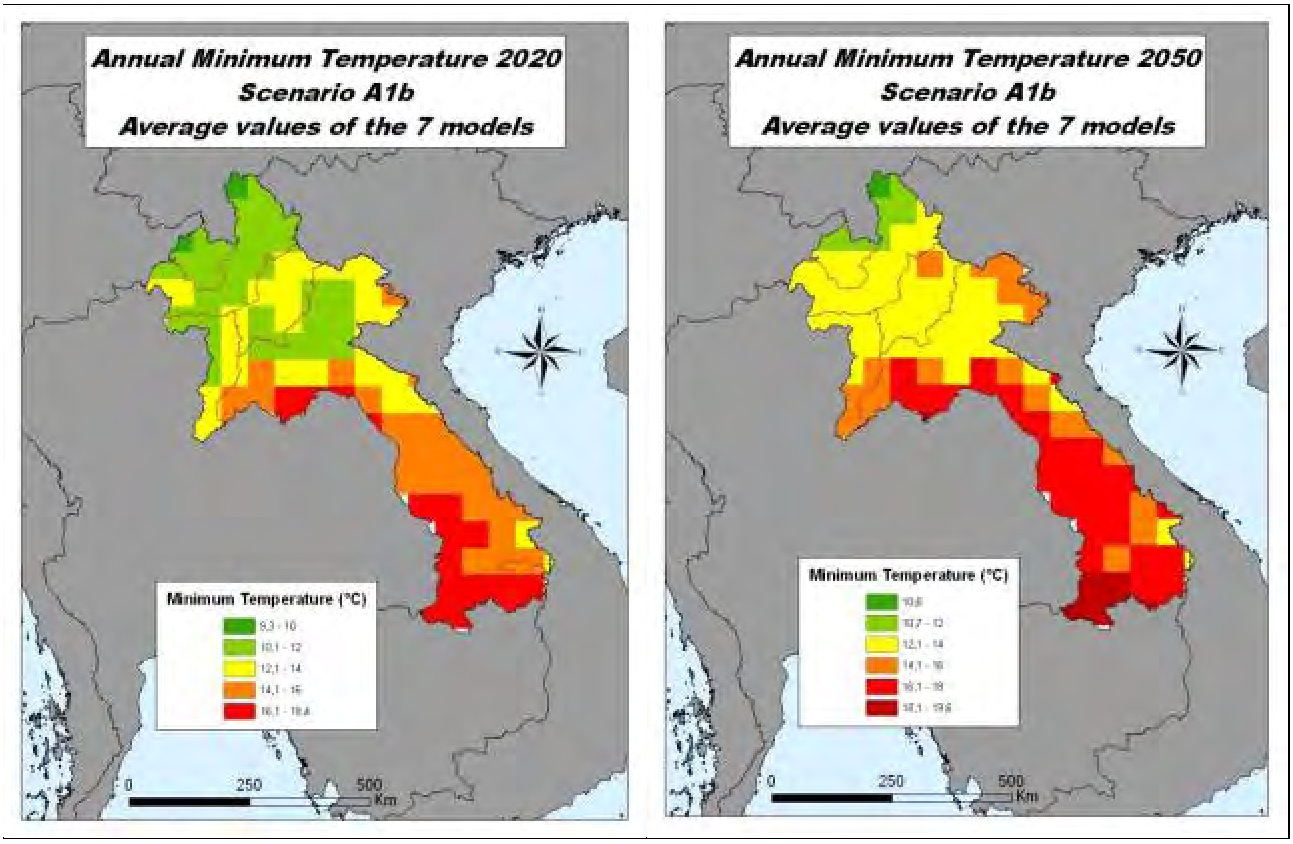


Figure 2.19 Projected changes in Annual Mean Temperature to (a) 2020 and (b) 2050 based on 7 GCMs and the A1B emission scenario, compared to (c) the mean vale for 1982 to 2002 and with (d) and map of change from 1982-2002 through to 2050

A: 2020 Projection B: 2050 Projection



C: Average for 1982-2002 D: Change from 1982-2002 average to 2050 projection

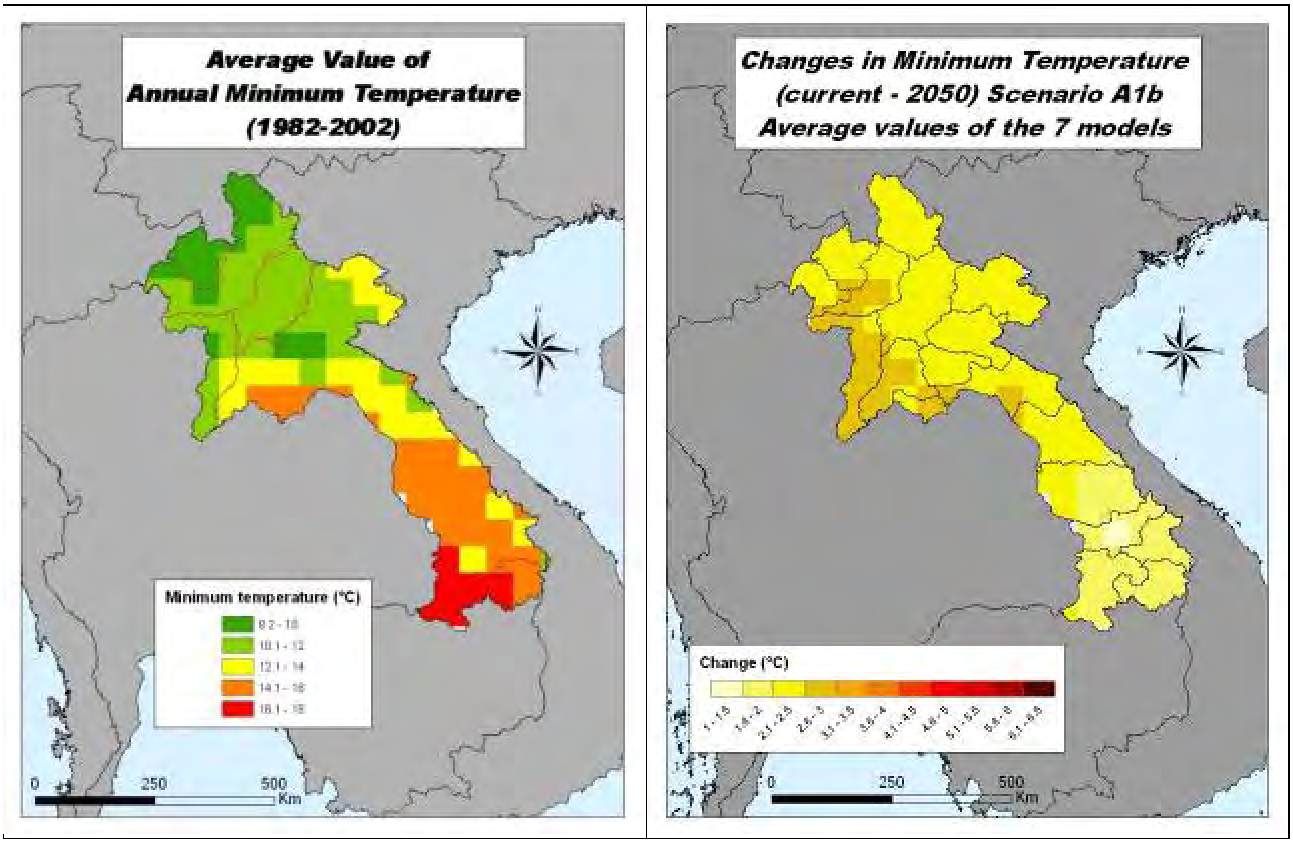
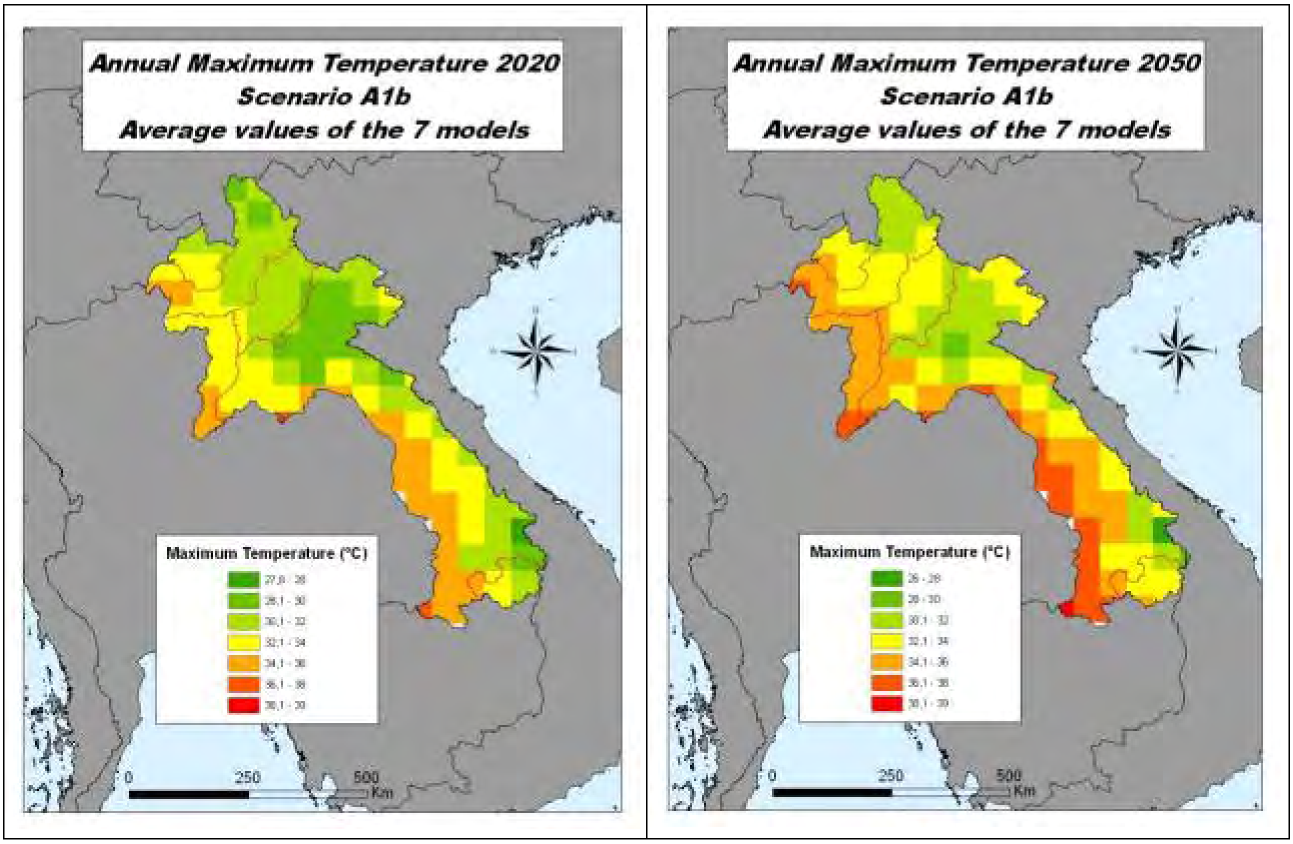


Figure 2.20 Projected changes in Annual Minimum Temperature to (a) 2020 and (b) 2050 based on 7 GCMs and the A1B emission scenario, compared to (c) the mean vale for 1982 to 2002 and with (d) and map of change from 1982-2002 through to 2050

A: 2020 Projection

B: 2050 Projection



C: Average for 1982-2002

D: Change from 1982-2002 average to 2050 projection

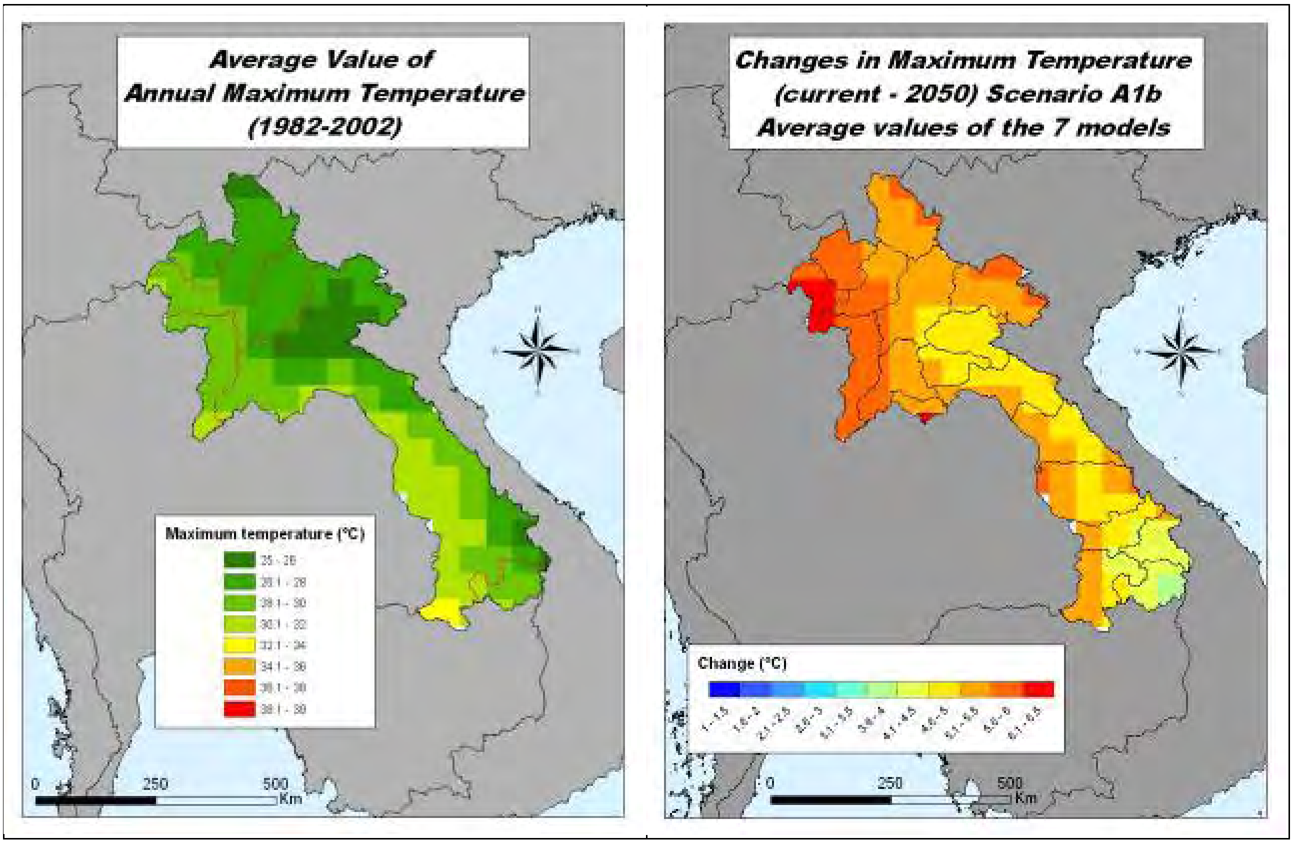


Figure 2.21 Projected changes in Annual Maximum Temperature to (a) 2020 and (b) 2050 based on 7 GCMs and the A1B emission scenario, compared to (c) the mean vale for 1982 to 2002 and with (d) and map of change from 1982-2002 through to 2050

The difference between models is even greater with the maximum temperature, with the greatest difference for the same pixel being 1.17°C in 2020 and 2.77°C in 2050 (Figure 2.21). Generally, there is an increase in maximum temperature across the country for both 2020 and 2050, compared to the current maximum, with the overall change being between 3 and 6 °C. While the south remains the hottest area, the increase in maximum temperature was even greater in the north.

2.4.2 Projected changes in Rainfall

Generally, the differences in predicted precipitation values for the different models in 2050 was greater than in 2020. The maximum difference between modelled values of annual rainfall for a pixel in 2020 was 219mm and in 2050 it was 511mm. As for the mean of the seven models, there was a general trend for rainfall to increase to 2020 and 2050, but all values stayed within the range of values of the 20th century, which, as was observed, do varied substantially from year-to-year.

The distribution of average annual rainfall data modelled in 2020 and 2050 looks quite similar to the current average (Figure 2.22). The highest rainfall is in the south, while the driest areas are in the north. Analysis of the predicted change in rainfall from now to 2050 indicates that there was a tendency for precipitation to increase in the north and decrease in the south, although the wetter areas still remained the south. As an example of the change in rainfall, the mean value in 1982 – 2002 of annual rainfall in Sayabouri was 1,351mm, whereas in 2020 it is predicted to be 1,421mm and in 2050 it is predicted to be 1,458mm.

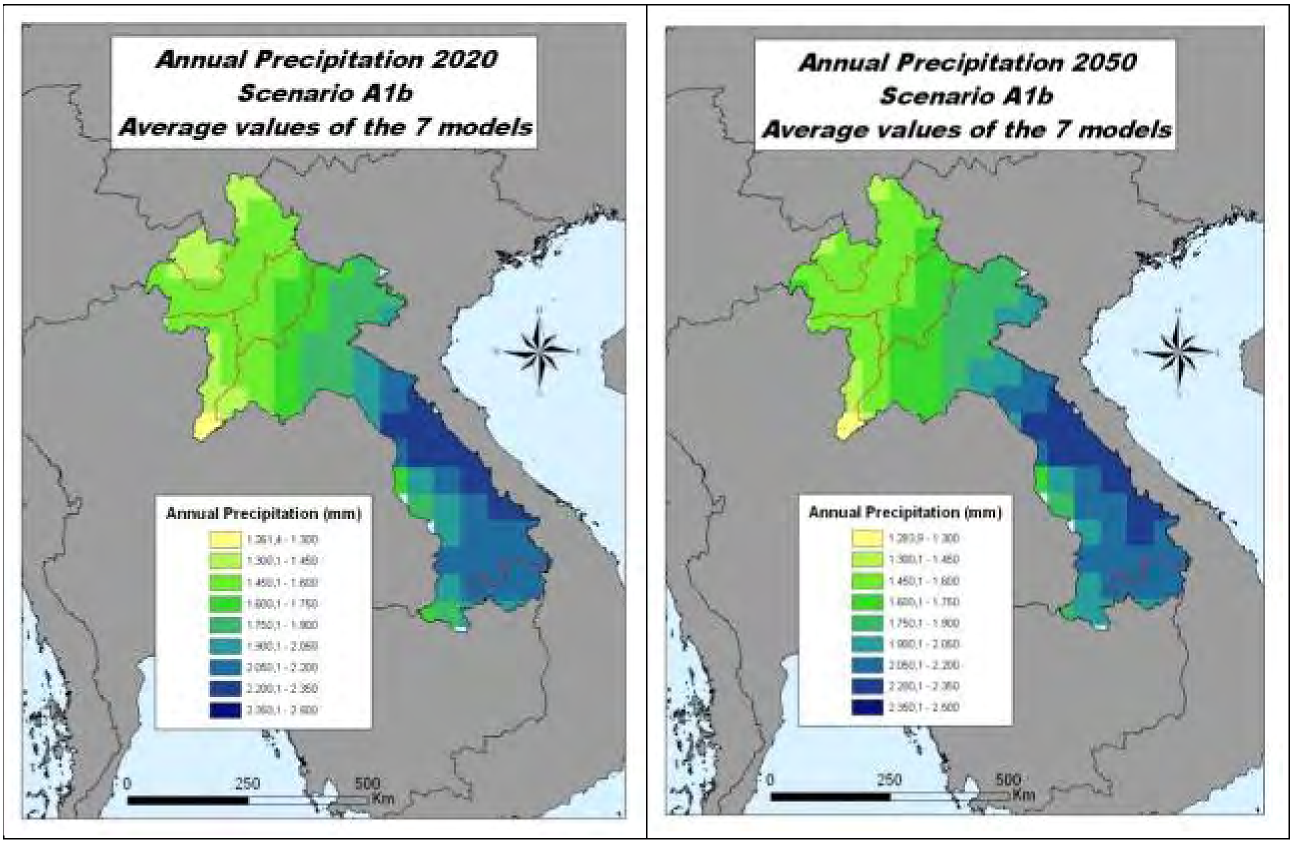
The seven models showed reasonable similarity for monthly rainfall, although more so for April and October than May. The maximum difference between the models for a pixel were 34mm in 2020 and 78mm in 2050 for April, 55mm in 2020and 123mm in 2050 for May, and 41mm in 2020 and 97 mm in 2050 for 2050.

The monthly precipitation for April increased in much of the country, and especially the north, from the 1982-2002 average through to 2020, with a slight decline from 2020 to 2050 (Figure 2.23). Across the country, the amount of April rain showed a similar pattern in 2020 and 2050 as now, with more rain in April in the north. The change in April rain from 1982-2002 to 2050 was a slight reduction in the very south and a slight increase in much of the north. The range of April rainfall values in 2020 and 2050 are similar to those in the 1980s and the mean projected values always remain less than the maximum values observed in the 1940s. As an example of the change, the values for Sayabouri province were 76 mm in 1982 – 2002, 107mm for 2020, and 105mm in 2050.

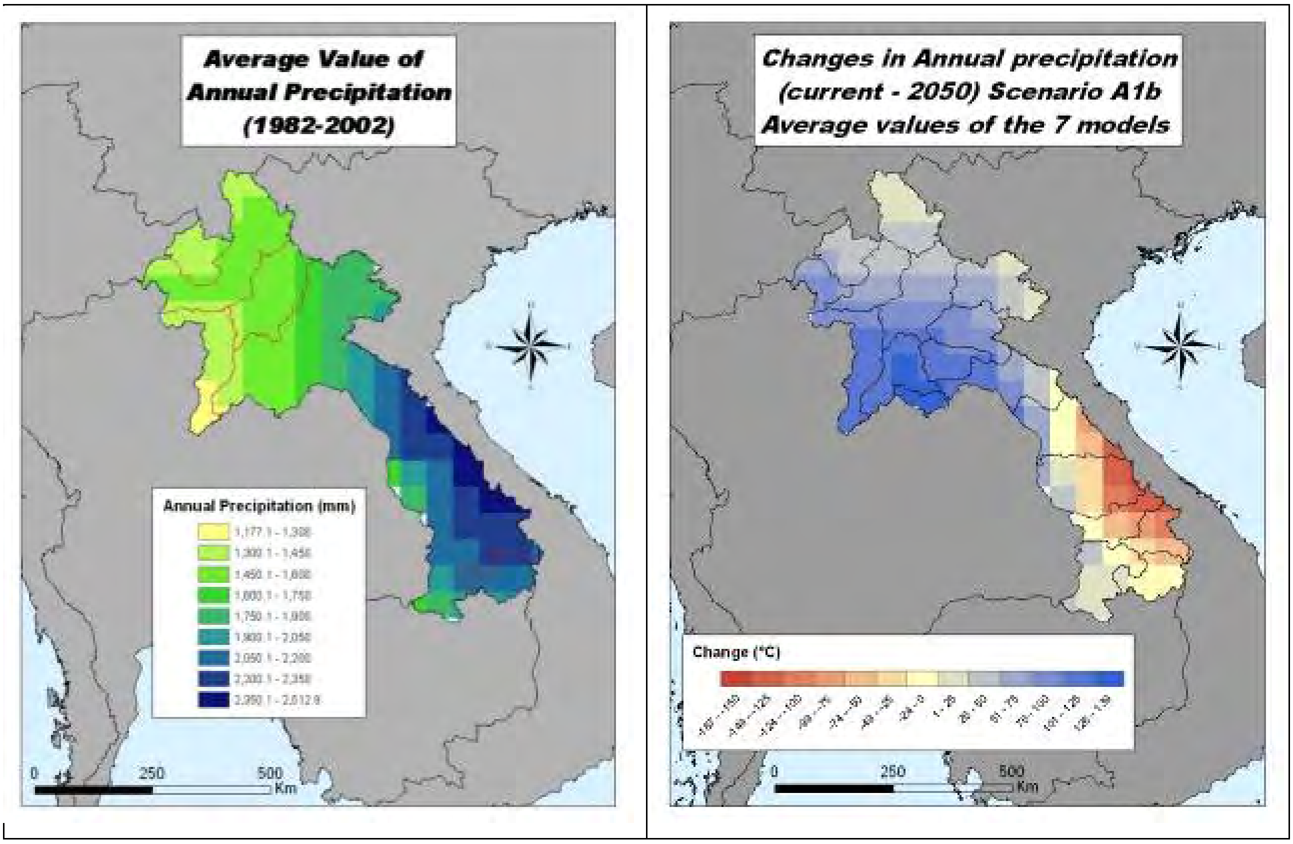
The rainfall in May is two to three times more than in April, with a similar spatial distribution, being wetter in the north, although not as uniform across the north, being wetter in the lower north and upper central part (Figure 2.24). The progression from 1982-2002 to the projected values for 2020 and 2050 show relatively little change. The map of change from 1982-2002 to 2050 projects a small decline in the north and a small increase in the south. The values for Sayabouri province are 211mm in 1982 – 2002, 196mm in 2020, and 199mm in 2050.

There is a larger variation in October rainfall across the country, with low values in the north and center of the country (from 85 to 150mm) and higher precipitation in the south (from 300 to 450mm). The trend from the 1982-2002 value to the projected value in 2050 is an increase in October rainfall across the country, with a slightly larger increase in the south and east and lower in the northwest (Figure 2.25). The values projected for Sayabouri province are 114mm in 2020 and 122 mm in 2050, compared to the value of 102 mm for 1982 – 2002.

Annual Precipitation


A: 2020 Projection

B: 2050 Projection


C: Average for 1982-2002

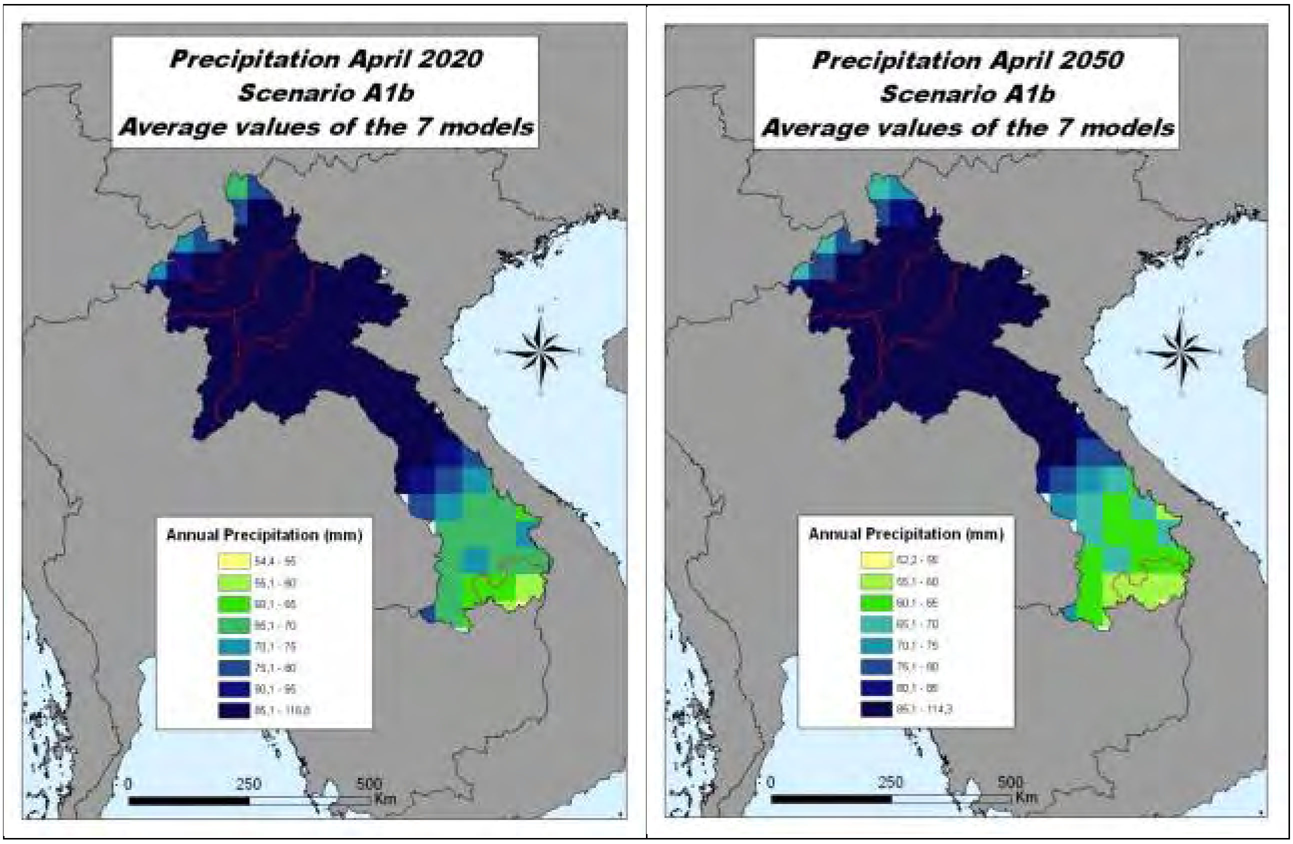
D: Change from 1982-2002 average to 2050 projection

Figure 2.22 Projected changes in Annual Precipitation to (a) 2020 and (b) 2050 based on 7 GCMs and the A1B emission scenario, compared to (c) the mean vale for 1982 to 2002 and with (d) and map of change from 1982-2002 through to 2050

April precipitation

A: 2020 Projection

B: 2050 Projection



C: Average for 1982-2002

D: Change from 1982-2002 average to 2050 projection

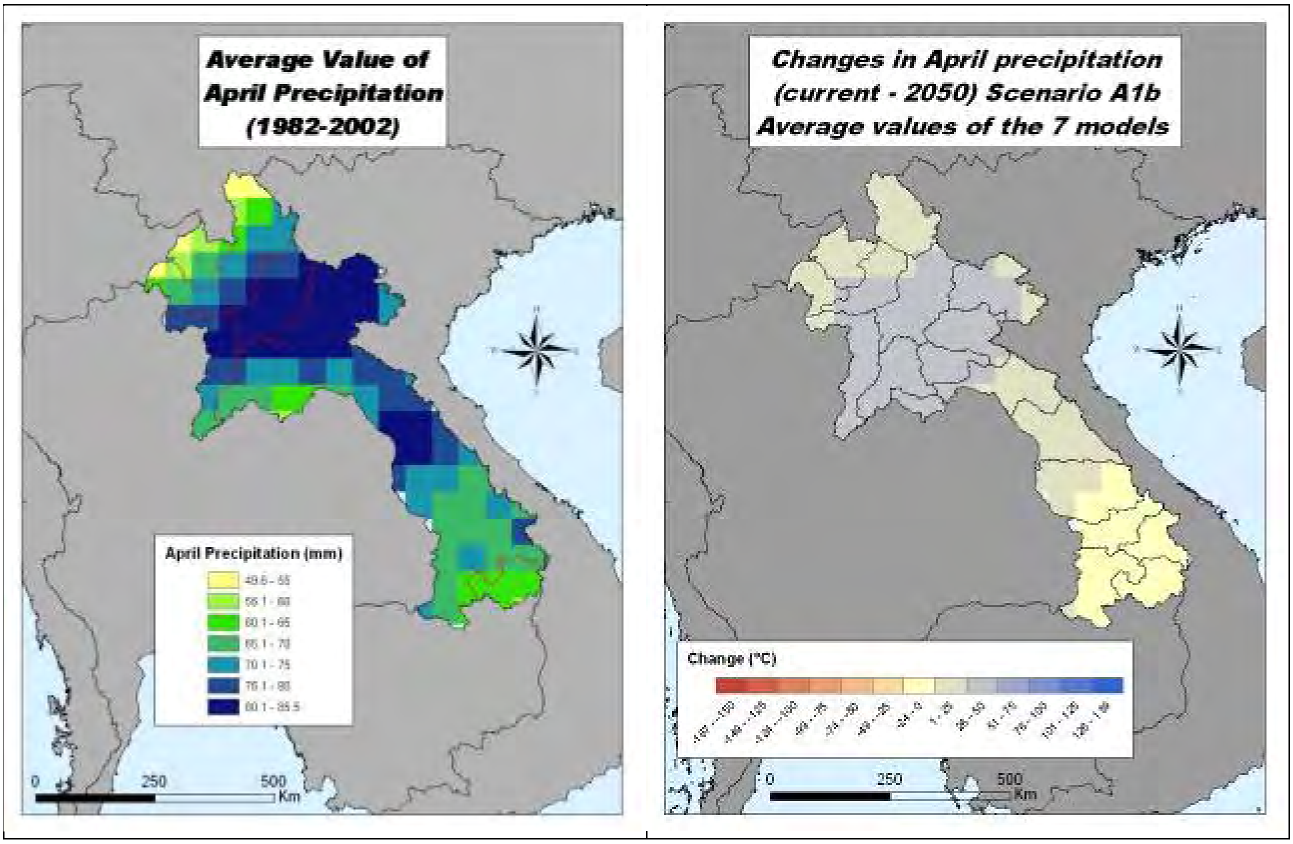
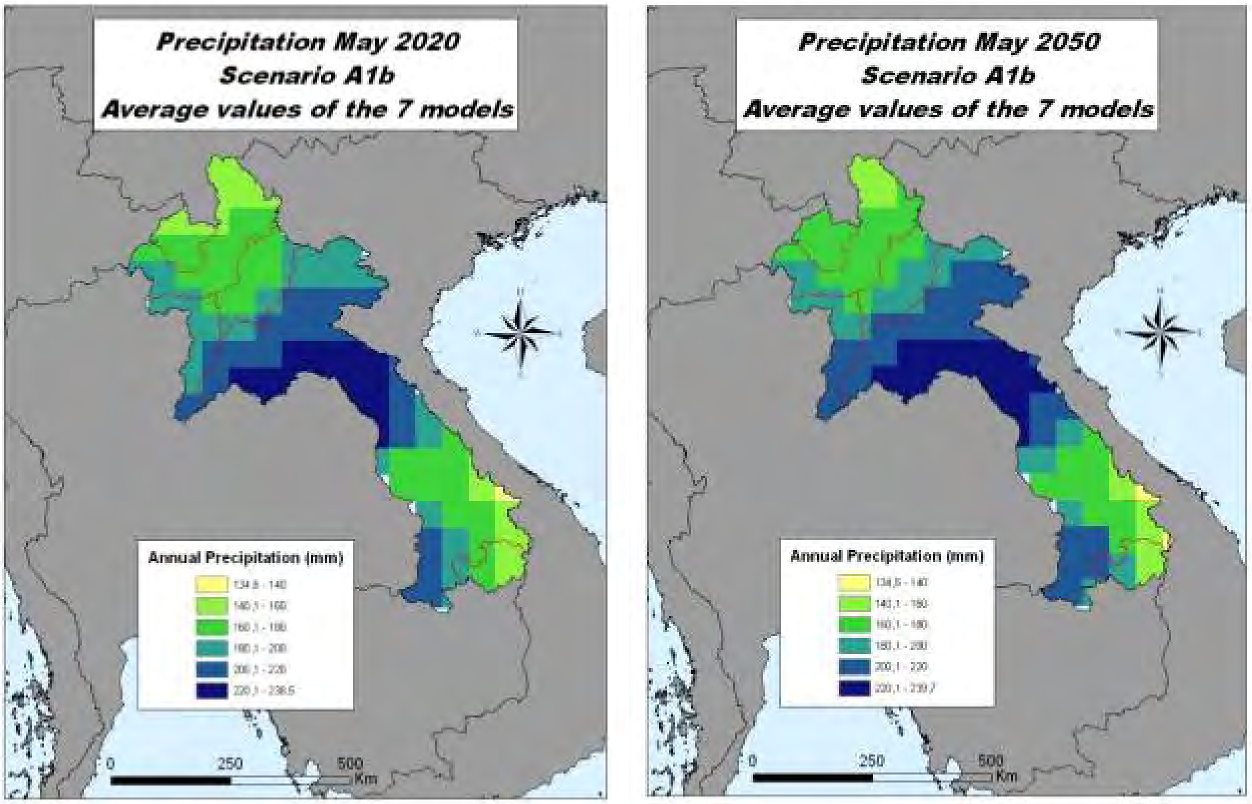


Figure 2.23 Projected changes in April Precipitation to (a) 2020 and (b) 2050 based on 7 GCMs and the A1B emission scenario, compared to (c) the mean vale for 1982 to 2002 and with (d) and map of change from 1982-2002 through to 2050

May precipitation



A: 2020 Projection

B: 2050 Projection

C: Average for 1982-2002

D: Change from 1982-2002 average to 2050 projection

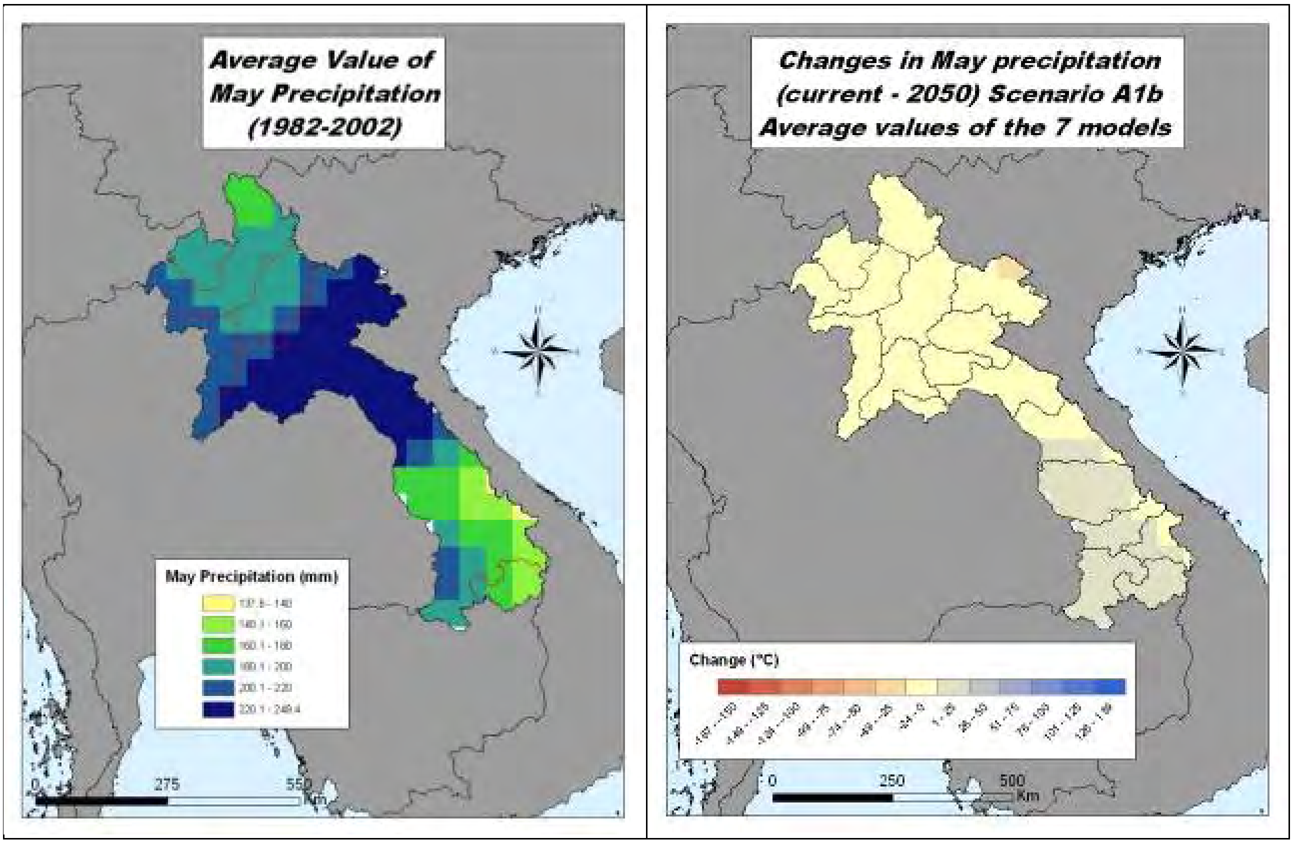
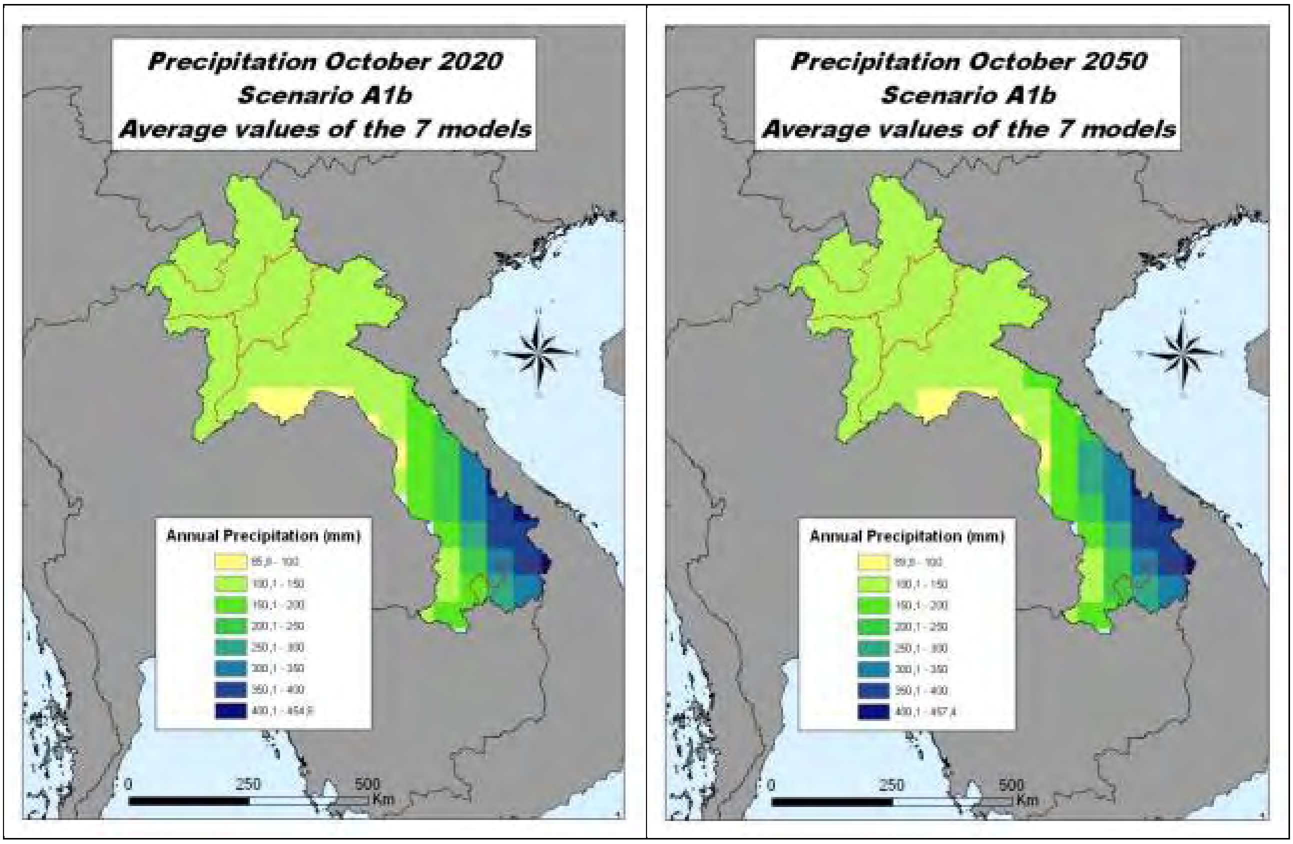


Figure 2.24 Projected changes in May Precipitation to (a) 2020 and (b) 2050 based on 7 GCMs and the A1B emission scenario, compared to (c) the mean vale for 1982 to 2002 and with (d) and map of change from 1982-2002 through to 2050

October precipitation

A: 2020 Projection B: 2050 Projection



C: Average for 1982-2002 D: Change from 1982-2002 average to 2050 projection

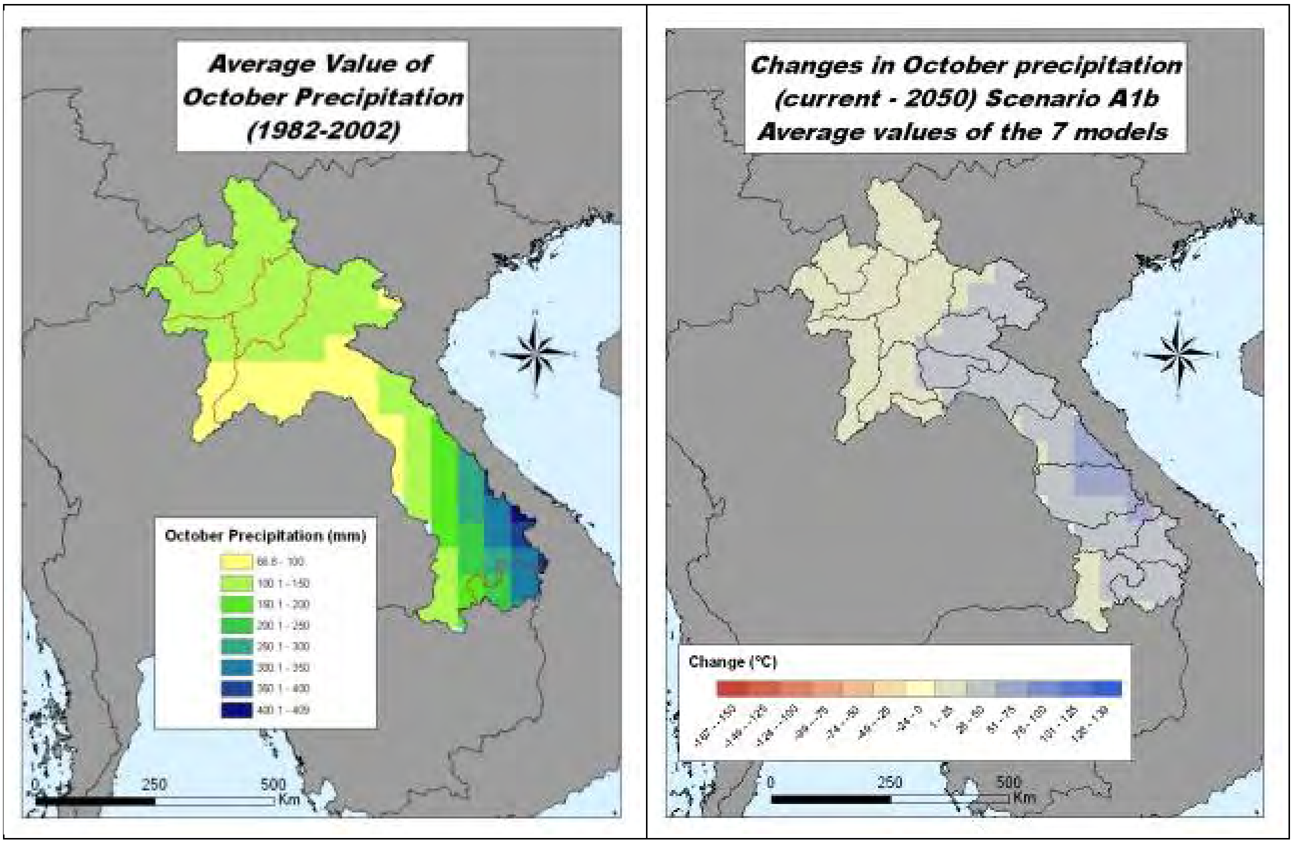


Figure 2.25 Projected changes in October Precipitation to (a) 2020 and (b) 2050 based on 7 GCMs and the A1B emission scenario, compared to (c) the mean vale for 1982 to 2002 and with (d) and map of change from 1982-2002 through to 2050

2.5 Summary of 20th century climate change and predictions to 2020 and 2050

Temperature

Based on analysis of the re-constructed 20th century climate data for the Lao PDR, there was a significant increase in the annual minimum, mean, and maximum temperatures throughout the country, but particularly in the south. Minimum temperatures increased by between 0.1 and 1.0ºC, mean temperatures increased by between 0.1 and 1.0ºC, and maximum temperatures increased between 0.5 to 4.5ºC.

Based on the mean of projections of seven Global Circulation models (GCMs), and using the reasonably optimistic IPCC SRES A1B scenario, it was predicted that there will be a significant increase in annual minimum, mean, and maximum temperatures throughout the country, but particularly in the south. By 2050, the minimum and mean temperatures are predicted to increase across the country by up to 2ºC, while the maximum temperatures are predicted to increase by up to 5ºC. It must be remembered that the changes by 2050 are in comparison to the mean of 1982 to 2002 and yet during this period, particularly the final decade, there was already a significant rise in temperature, so the increase compared to 2002 or 2010 should be quite a bit less.

Discussions with villagers indicated that they felt that from the early 1990s there had been an increase in temperature, particularly in the south. Some said that the hottest days were now hotter and others that the cooling affect of rain did not last as long. Interestingly, their comments matched the time when the reconstructed data indicated quite sharp increases in temperature, from around 1993. Some, but not all, of the limited provincial and district data that could be compared with the reconstructed data showed these increases.

Rainfall

During the 20th century there were significant trends in mean annual and monthly rainfall, but with some areas and times increasing and others decreasing. None of these changes were large compared to the large inter-annual variations. The changes in rainfall during the 20th century for different parts of the country ranged from increases of up to 115mm in annual rainfall, mainly in the lower north and upper central part of the country, to decreases of up to 200mm in the upper north, lower central and south. For April rainfall there were increases of up to 20mm, mainly in the north, and decreases of up to 10mm in the rest of the country. The rainfall in May showed a trend of decreasing by between 4 and 50mm across the country and the October rainfall tended to increase by between 4 and 20mm.

The predictions for rainfall to 2020 and 2050 from the mean of seven GCMs and with the A1B scenario suggest that annual rainfall will increase, that rainfall in May will decrease while the rainfall in April and October will increase, generally suggestion that the main wet season will be delayed slightly.

While there were significant trends in rainfall during the 20th century and further significant changes are predicted, particularly for a slight delay in the main wet season, all of these changes are of the same order of magnitude as the variation between years, which means that the main aspect of rainfall that farmers will be aware of is the variability.

During discussions with villagers there were no extremely clear perceptions of change in the rainfall patterns, which fits the observations that variability was at least as large as the statistical trends. There was a feeling by some that the wet season tended to be delayed – starting and ending later. In some cases farmers commented on wet and dry years when even the local rainfall data did not indicate these trends. In further discussions, when it was pointed out that this did not match the local rainfall data, it was clear that they were talking as farmers, about water availability and about flooding and drought, rather than about rainfall *per se*. They agreed that these wet and dry years did not match the rainfall patterns and, when challenged for an explanation, suggested it was more to do with land management issues. For instance, they suggested that flooding was not due to higher rainfall, but to sedimentation of the streams and rivers due to land clearing. While this seems very likely, it appears that the flooding could have been in combination with increased runoff due to land management practices, rather than just through sedimentation of the streams.

In addition to changes in mean values of weather variables, there is a need to consider the extreme events, which often are the most serious in terms of impacts on farming systems and thus livelihoods. There is very limited capacity for prediction of extreme events in the Global Climate Models, either in terms of the frequency with which they occur, the spatial distribution within which they occur, and the level or intensity. Despite this weakness in the models, there is good evidence that the changes observed in mean values are driven, in part, by changes in the extreme values. In particular, where increases in temperatures have been observed, the trend has been for less cold nights and more hot nights, and to a lesser extent less cold days and more hot days, rather than a general increase in mean values. For rainfall, even where there has been limited change in the amount of rainfall, the incidence of heavy and very heavy rainfall appears to have increased. While the incidence of tropical storms and hurricanes is highly variable, as influenced by such factors as the El Nino-Southern Oscillation, there is evidence that the number and intensity of storm events has increased significantly in the last few decades of the 20th century, and this trend appears likely to continue and increase. Thus it is likely that the calendar of extreme events may continue to be of greater threat to the livelihoods of smallholder farmers in the Lao PDR.

In summary, the climate has become and is likely to continue to become hotter and with a slightly delayed wet season. The variations in rainfall, even if the trends are for significant change in rainfall patterns, are within the order of the normal year to year variations, so the climate change induced variations in rainfall patterns are unlikely to be observed easily, at least for some time, which may lead to some complacency. The incidence of extreme events, such as hotter nights and days and heavy storms, is likely to increase.

Climate variability, and in particular rainfall variability, irrespective of climate change, will remain a major challenge for farmers, especially as the current farming systems are susceptible to less than ideal rainfall patterns, whether too dry or too wet.

3 Climate and crop suitability

3.1 Background and methodologies

Changes in temperatures and in the amount and distribution of rainfall can be expected to affect the productivity of plants and thus of agricultural crops and forests. The complex physiology of plants means that they have the ability to adapt to some level of change, but only up to a point. Estimating the likely responses to changes in temperature and rainfall patterns is complex and there are several approaches that can be taken.

There are three basic approaches that can be taken to modelling the likely changes in plant productivity. The first is to develop full mechanistic models of plant and crop growth. These have to be complex otherwise they cannot be expected to mimic the behaviour of the crop. While the quality of mechanistic models is improving there remain several major drawback in using this approach for estimating the impacts of climate change in such a study. Firstly, mechanistic models do not exist for a very wide range of crops, although they do exist for the main staple crops. Secondly, the degree of parameterization required to run these models effectively is very large and this requires a lot of site-specific data that either does not exist or is too difficult to collect.

The second approach is to take a more empirical approach. This does not require detailed understanding of the mechanisms by which different plants respond to and adapt to changes in temperature and rainfall, but it does require a great deal of data on plant growth under a very wide range of conditions, and in most cases this does not exist, especially when the aim is to predict how plants grow under conditions that they do not experience regularly.

The third approach is to take a partially mechanistic approach based on understanding the specific bioclimatic niches in which a plant species grows and being able to set the limits and responses to different conditions.

CIAT, with the support of Bioversity International and the International Potato Centre (CIP), developed a simple mechanistic model based on the FAO Ecocrop database of crop ecological requirements (http://ecocrop.fao.org/ecocrop/). Ecocrop is mechanistic in terms of the climatic niches to which a species is suited or less-well suited. The model, which uses the same name as the FAO database, Ecocrop, uses temperature and precipitation thresholds in order to evaluate the suitability of a certain place for a particular crop species by using the WorldClim database of world climate data (Hijmans et al., 2005a). The model was developed to run from within the DIVA-GIS software (Hijmans et al., 2005b). The main use has been to predict the suitability of various crops under different climatic conditions, and thus at different locations. The aim is to assess suitability, rather than productivity or yield per se. In situations where there is a lot of information about yields under different conditions and locations, then it is possible that the suitability assessment can be interpreted in terms more closely related to yield.

The model requires ten different parameters (Figure 3.1): Tkill (the temperature at which the crop will die), Tmin (the minimum temperature at which the crop will grow), Topmin (the minimum temperature for optimal growth), Topmax (the maximum temperature for optimal growth), Tmax (the maximum temperature at which the crop will grow), Rmin (the minimum amount of rain required for the crop to grow), Ropmin (the minimum amount of rain required for optimal growth), Ropmax (the maximum amount of rain for optimal growth), Rmax (the maximum amount of rain below which the crop grows), Gmin (the minimum length of the growing season), and Gmax (the maximum length of the growing season), with measurements of temperature, rainfall, and growing season being in °C, mm, and days, respectively. Using these parameters, the Ecocrop model computes separate suitability indices for temperature and rainfall and then a combined suitability rating is computed by multiplying the two indices.

The Ecocrop model is a very convenient way to assess plant species suitability to a particular location or environment, although, like all such models, it needs to be interpreted carefully. The main limitations are that it is based purely on bioclimatic variables. Although these bioclimatic variables are extremely important for plant suitability and productivity, such a suitability rating ignores specific soil requirements, problems of pests and diseases, and their interactions with climate. Both soils requirements and the presence of pests and diseases can be considered as fairly simple modifiers of the suitability, although both will have important interactions with climatic factors. For instance, the upper and lower limits for rain will be affected by the soil type in terms of differences in soil water holding capacity, at the dry end of the scale, and infiltration rates when waterlogging is a risk, and both of these will be further affected by topography and crop management. As far as crop management is concerned, relatively small differences in the maintenance of ground cover, the use of mulch, the degree of tillage, the use of raised beds, and of course the use of irrigation, can all affect the soil moisture regime of a soil, and in different ways under different rainfall regimes. Another issue is that the parameters are input from the FAO dataset, and thus represent the mean values for major varieties, yet we know that there can be quite a range in varieties in terms of adaptation to specific environments. Careful selection of varieties can increase crop suitability, and inappropriate selection can reduce the crop suitability. Despite the requirement for care in interpreting the results of Ecocrop, the results can provide a very useful start to assessing likely suitability and eventually productivity.

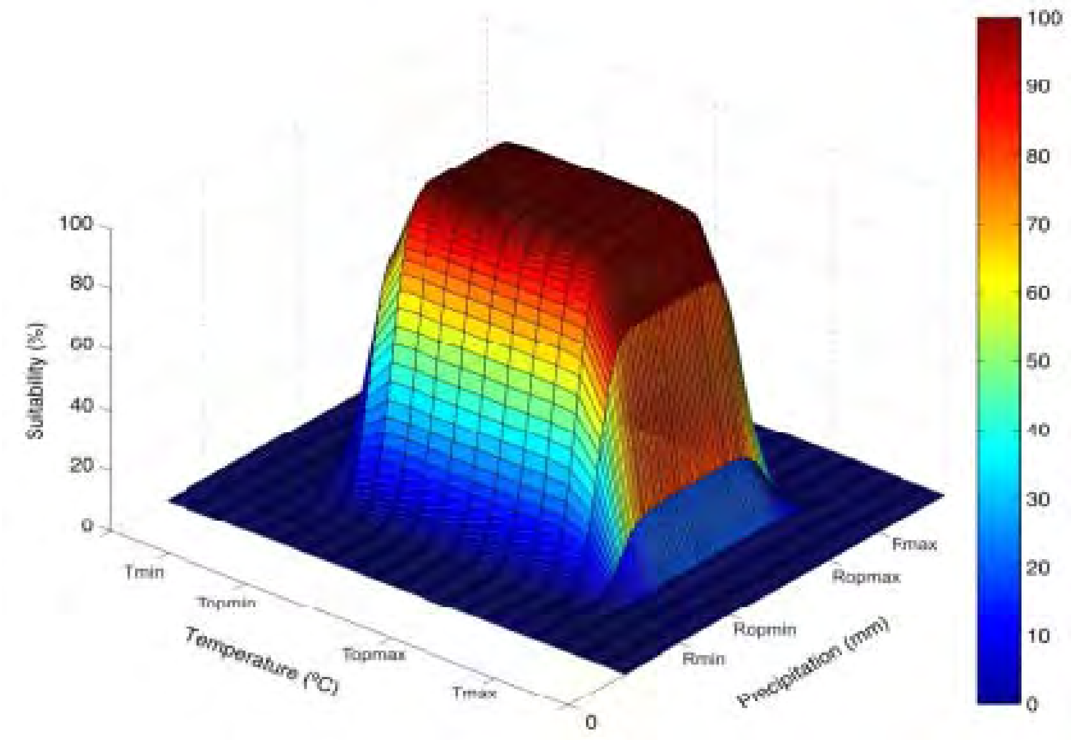


Figure 3.1 The use of climatic parameters to set the suitability of plant species to particular climates in the ecological niche-based Ecocrop model

In this study, Ecocrop was used to assess the suitability of a range of plant species to the current climate of the Lao PDR and then to the mean climate predicted by seven GCMs for 2050 under the IPCC SRES A1B emission scenario. The plant species assessed were a range of staple crops, cash crops, and important tree species, namely: maize, sugarcane, paddy and upland rice, cassava, peanuts, common bean, soybean, chilli, sweet corn, robusta coffee, arabica coffee, banana, rubber, jatropha, teak, and eucalyptus.

3.2 Current suitability of crops and comparison with current cropping patterns

Assessing the current bioclimatic suitability of crops using Ecocrop and then comparing suitability with current production statistics on a provincial basis allows assessment of the accuracy and usefulness of Ecocrop in understanding bioclimatic suitability and thus the value of Ecocrop in predicting changes in crop suitability with projected climate change. The comparison of provincial production data and assessed suitability is presented in this section for maize and sugarcane, and Ecocrop assessment for the current and future climates is presented for 17 crops in the next section (Section 3.3).

Maize

The suitability for maize under the current climate was assessed using Ecocrop (Figure 3.2). It was surprising to see that a relatively small proportion of the country was assessed as highly suitable for maize production when maize has become such an important crop in recent years. When compared to the areas cultivated with maize in each province, however, the areas planted (Table 3.1) match quite closely to the suitability map, with the two provinces with the highest suitability assessment, Sayabouri and Huaphanh, making up nearly approximately 45% of total production in the country. A further 45% of the maize production of the country occurred in the four provinces with the next most suitable rankings, Luang Prabang, Oudomxay, Bokeo, and Xieng Khuang, thus about 90% of the national production is observed in the areas assessed to be of high to medium suitability and thus indicating that Ecocrop worked well for maize in the Lao PDR.

Table 3.1 Area of maize planted (ha) in different provinces/regions in 2008

Location	Area (ha)	% Total
Northern Region	169,020	
Phongsaly	2,715	1.3
Luang Namtha	3,335	1.6
Oudomxay	21,815	10.6
Bokeo	21,695	10.5
Luang Prabang	27,725	13.4
Huaphanh	33,655	16.3
Sayabouri	58,080	28.1
Central Region	34,470	
Vientiane C.	3,800	1.8
Xieng Khuang	23,120	11.2
Vientiane	5,895	2.9
Borikhamxay	1,285	0.6
Khammuane	-	0.0
Savannakhet	370	0.2
Southern Region	3,280	
Saravan	305	0.1
Sekong	605	0.3
Champasack	1,770	0.9
Attapeu	600	0.3
Total	206,770	

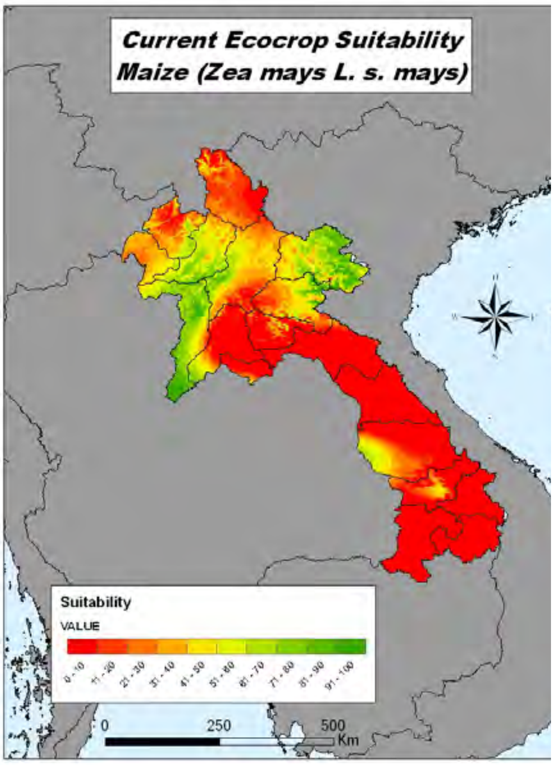


Figure 3.2 Suitability of maize in the current environment as assessed by Ecocrop

Sugarcane

Between a quarter and a third of the country, primarily in the south, was assessed as being suitable for sugarcane through Ecocrop (Figure 3.3). The major production areas, primarily in Savannakhet, do fall within these areas of highest suitability (Table 3.2). There are some areas that are highly suitable, especially in Saravan, Champasack, and Attapeu, that do not have large areas of sugarcane production, but this is presumably because there is poor or no access to processing plants. This emphasises that Ecocrop is only about bioclimatic suitability, with final assessment of production potential having to be assessed with knowledge of other biophysical constraints, such as soils and pest and diseases, and combined with logistic factors such as access to processing facilities and markets, with the importance of such factors varying with crops depending on their processing needs, perishability, and market values.

Table 3.2 Area of sugarcane planted (ha) in different provinces/regions in 2008

Location	Area (ha)	% Total
Northern Region	4,275	
Phongsaly	1,555	9.1
Luang Namtha	1,920	11.3
Oudomxay	250	1.5
Bokeo	-	0.0
Luang Prabang	215	1.3
Huaphanh	280	1.6
Sayabouri	55	0.3
Central Region	12,300	
Vientiane C.	80	0.5
Xieng Khuang	70	0.4
Vientiane	260	1.5
Borikhamxay	675	4.0
Khammuane	365	2.1
Savannakhet	10,850	63.6
Southern Region	480	
Saravan	-	0.0
Sekong	145	0.9
Champasack	335	2.0
Attapeu	-	0.0
Total	17,055	

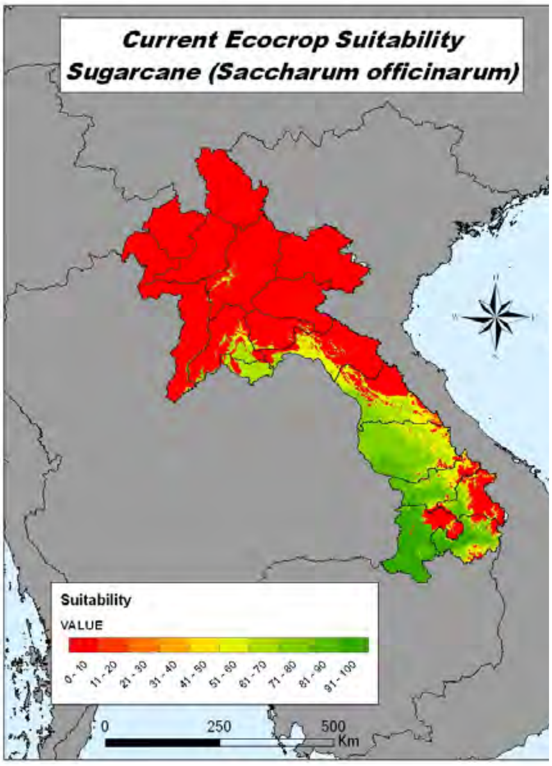


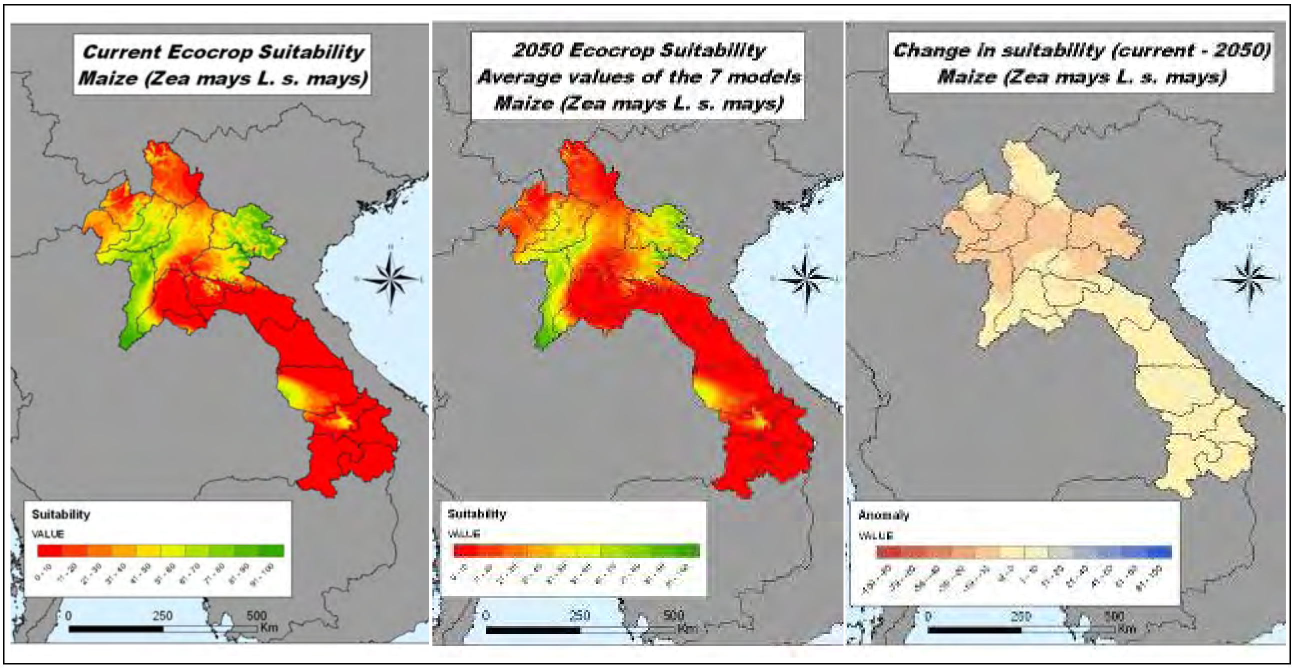
Figure 3.3 Suitability of sugarcane in the current environment as assessed by Ecocrop

3.3 Current and future suitability of different crops

For all the crops assessed, the Ecocrop assessments are presented as maps of the suitability under the current climate, the suitability under the climate predicted for 2050 according to the mean of seven GCMs using the A1B emission scenario, and then a map of the change in suitability between the current and 2050 assessments.

Maize

With the exception of some very small areas, which showed slight improvements in suitability, the bioclimatic suitability for current maize varieties remains the same or is reduced by 2050, especially in much of the north (Figure 3.4). The current favourable areas are still the most suitable, although their suitability is reduced slightly. While the major current production areas do match the high suitability areas (Table 3.1), some current production is in areas that are ranked as having a low suitability. In some of these areas maize is grown under supplementary irrigation. Production of maize in other less suitable areas may be very poor or it may be reasonable as a result of access to better adapted varieties. Better varieties and better management practices may help to increase production in some of the less suitable areas and similar approaches could be a strategy for the future as suitability declines further.

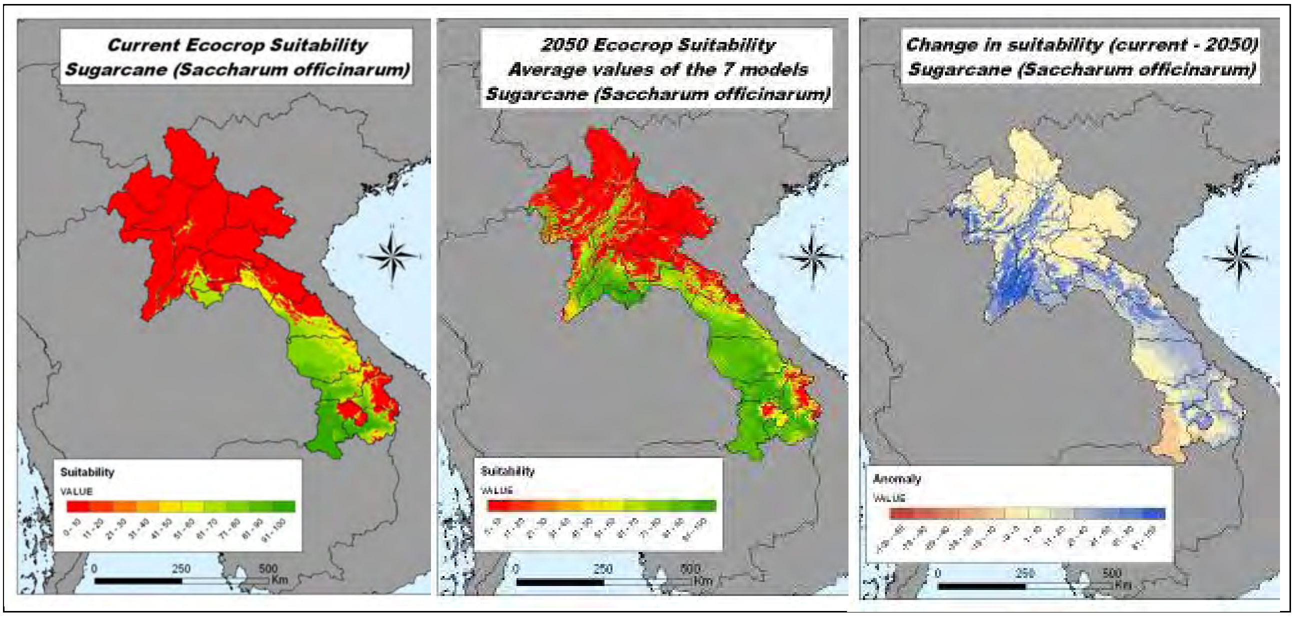


A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.4: Current and future bioclimatic suitability for maize in the Lao PDR

Sugarcane

The suitability for sugarcane production is predicted to increases in the country as the predicted changes in climate to 2050 occur, especially in the lower north, in Sayabouri and Vientiane provinces, and through an increase in the suitable areas in the south (Figure 3.5). Only a small part of the south, in Champasack, is predicted to experience a significant decline in suitability, and yet the area will still remain quite suitable. There appears to be significant potential for expansion of sugarcane production in the future, given the right infrastructure provision for processing.



A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.5: Current and future bioclimatic suitability for sugarcane in the Lao PDR

Rice

Approximately three-quarters of the area planted to rice is planted to rainfed lowland rice and this produces just over three-quarters of the national production (MAF, 2008). The remainder of the area planted is split between upland rice and irrigated lowland rice, with upland rice making up the larger area but irrigated rice accounting for more production. Most of the rice varieties used in the Lao PDR for lowland rice are of the Indica type. By contrast, much of the rice used for upland rice is regarded as a tropical Japonica type, often referred to as the Javanica type. There are limited quantities of the true Japonica type and there are many examples of forms that are intermediate between Indica and Javanica (Appa Rao *et al.*, 2006). With this diversity of races and cultivation types, Ecocrop was run for both Indica and Japonica types and under lowland and upland conditions (Figure 3.6 to 3.9). Not surprisingly, the suitability for rice was high, but with some interesting changes in suitability.

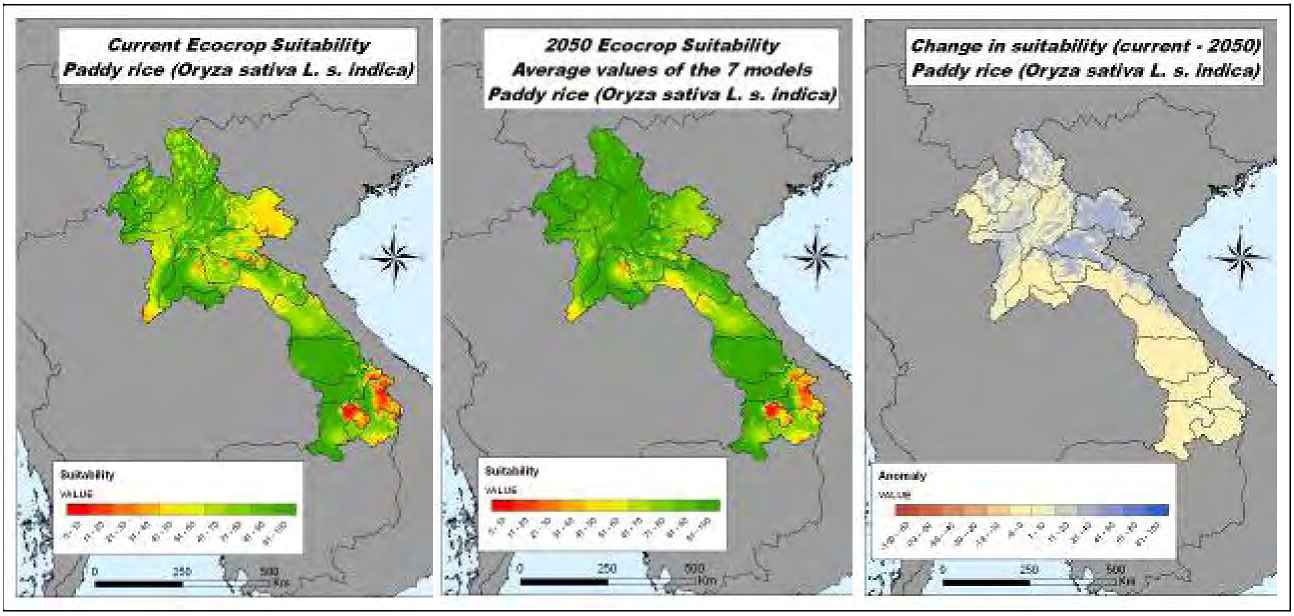

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.6 Current and future bioclimatic suitability for Indica-type lowland rice in the Lao PDR

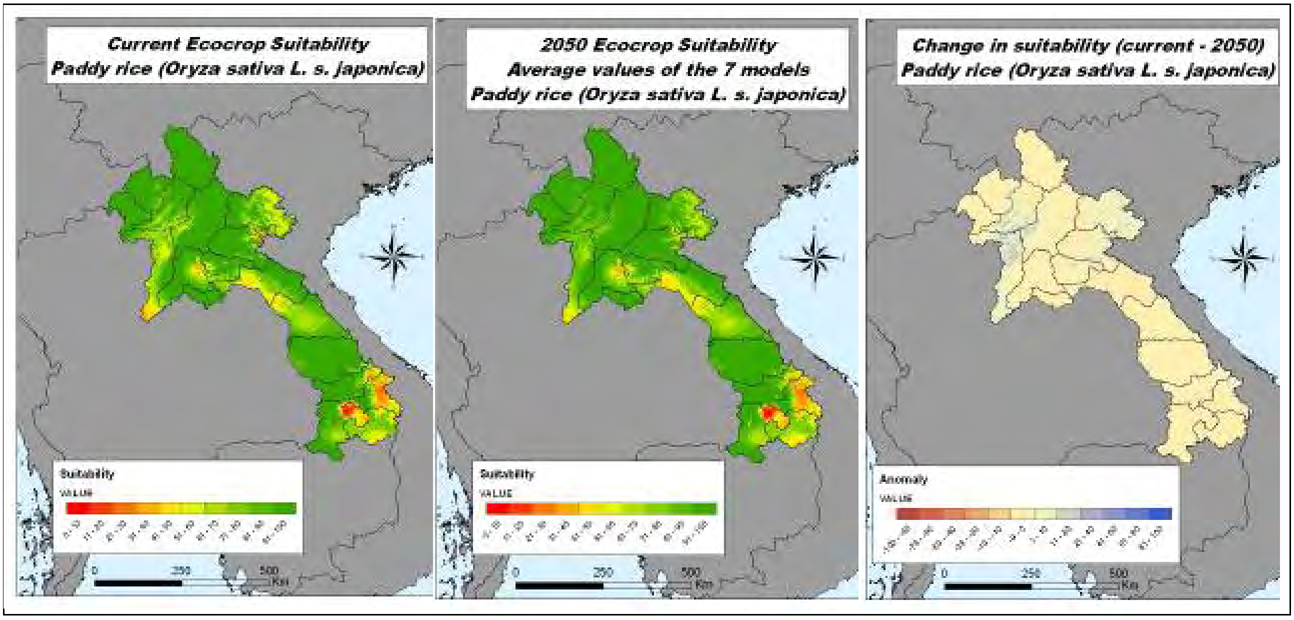

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.7 Current and future bioclimatic suitability for Japonica-type lowland rice in the Lao PDR

Paddy rice: The suitability for Indica-type lowland rice, which should best match current rainfed lowland rice production systems, is rated as high across much of the country (Figure 3.6). The suitability is predicted to increase by 2050 in the much of the north and particularly in Xieng Khuang and Huaphanh. The suitability for Japonica-type lowland rice is rated as quite high over much of the country, with a slight increase in suitability by 2050 in parts of the north, particularly in Sayabouri, Huaphanh, and Oudomxay (Figure 3.7).

Upland rice: The suitability for Indica-type upland rice is quite high over much of the country and should increase by 2050 in the north, particularly in Huaphanh and Xieng Khuang (Figure 3.8). The suitability for Japonica-type upland rice, which is arguably the best match for current upland rice production, is rated as higher than the Indica-type and is not predicted to change by 2050 (Figure 3.9).

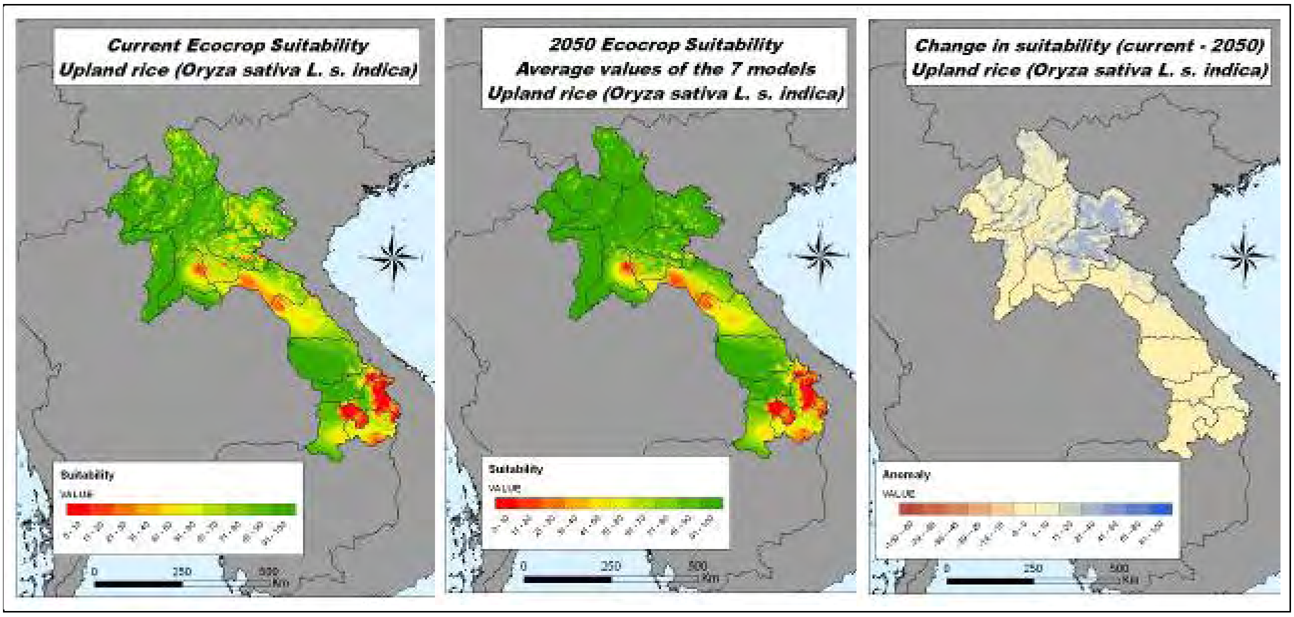

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.8 Current and future bioclimatic suitability for Indica-type upland rice in the Lao PDR

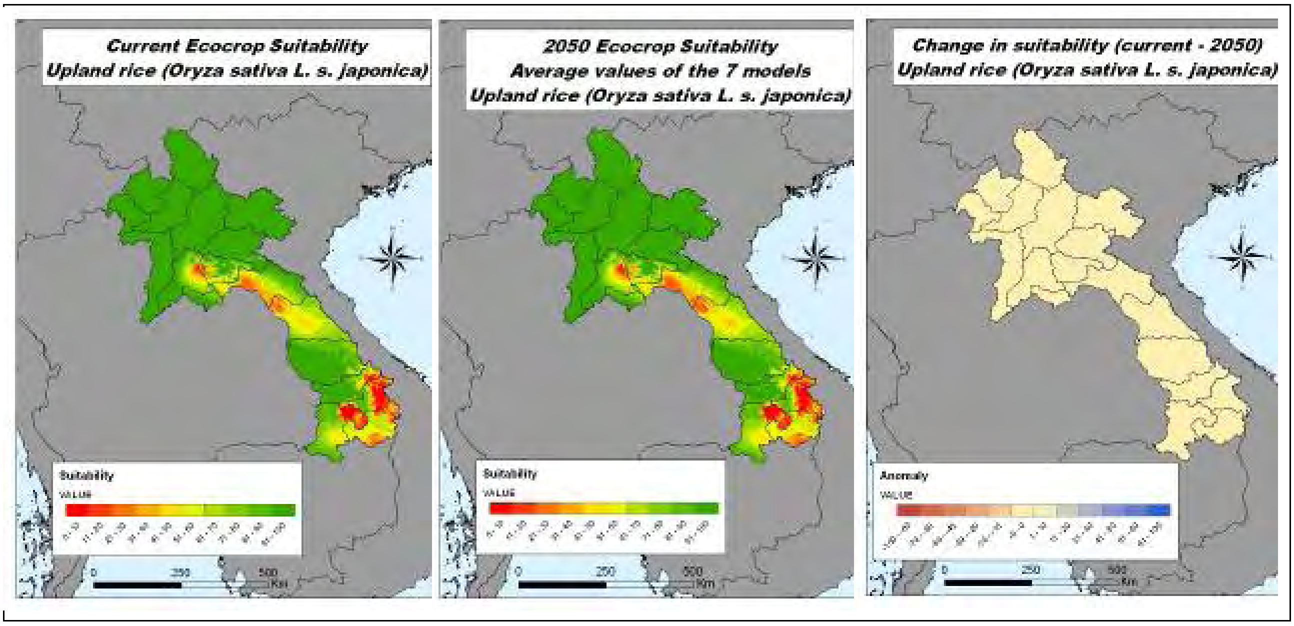

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.9 Current and future bioclimatic suitability for Japonica-type upland rice in the Lao PDR

Cassava

The current suitability for cassava is high over much of the country, although with pockets assessed as unsuitable (Figure 3.10). The 2050 climate looks more suitable for cassava in the north east of the country, especially in Huaphanh, Xieng Khuang, and Phongsali. As a crop with increasing market potential and good tolerance to water stress, there appears to be high potential for expansion of cassava production, both now and in the future.

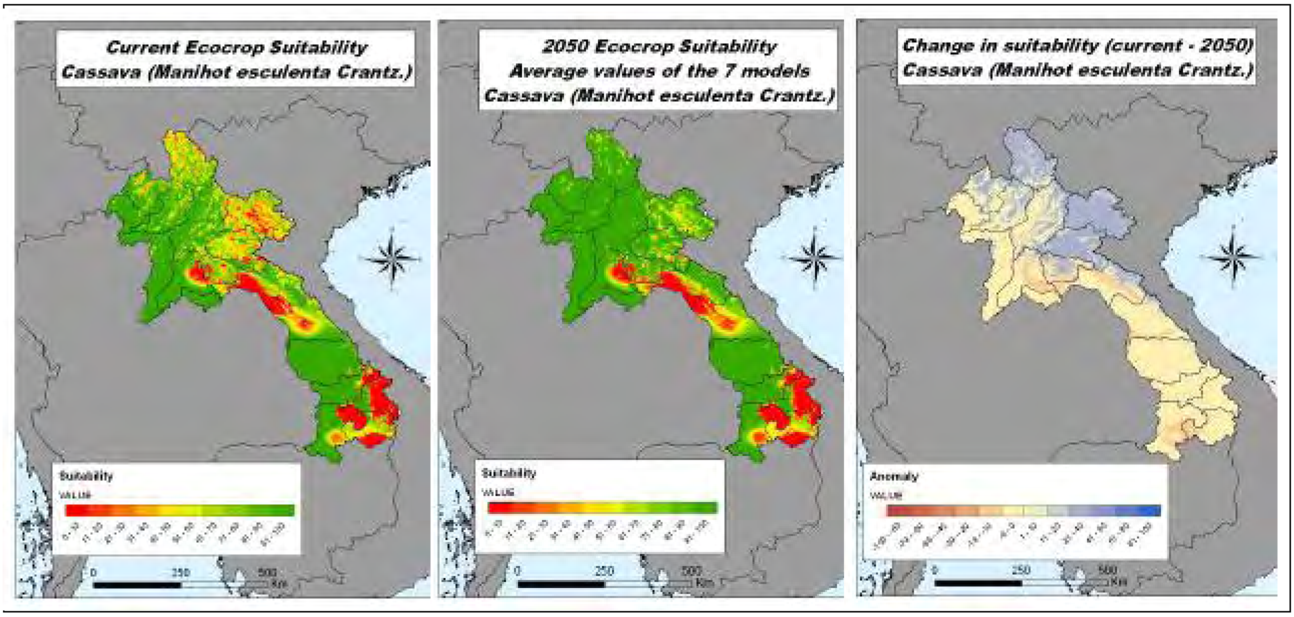

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.10 Current and future bioclimatic suitability for cassava in the Lao PDR

Peanuts

The current suitability for peanuts is high and there is very little change in suitability with the predicted 2050 climate, except in very isolated areas in the northeast (Figure 3. 11).

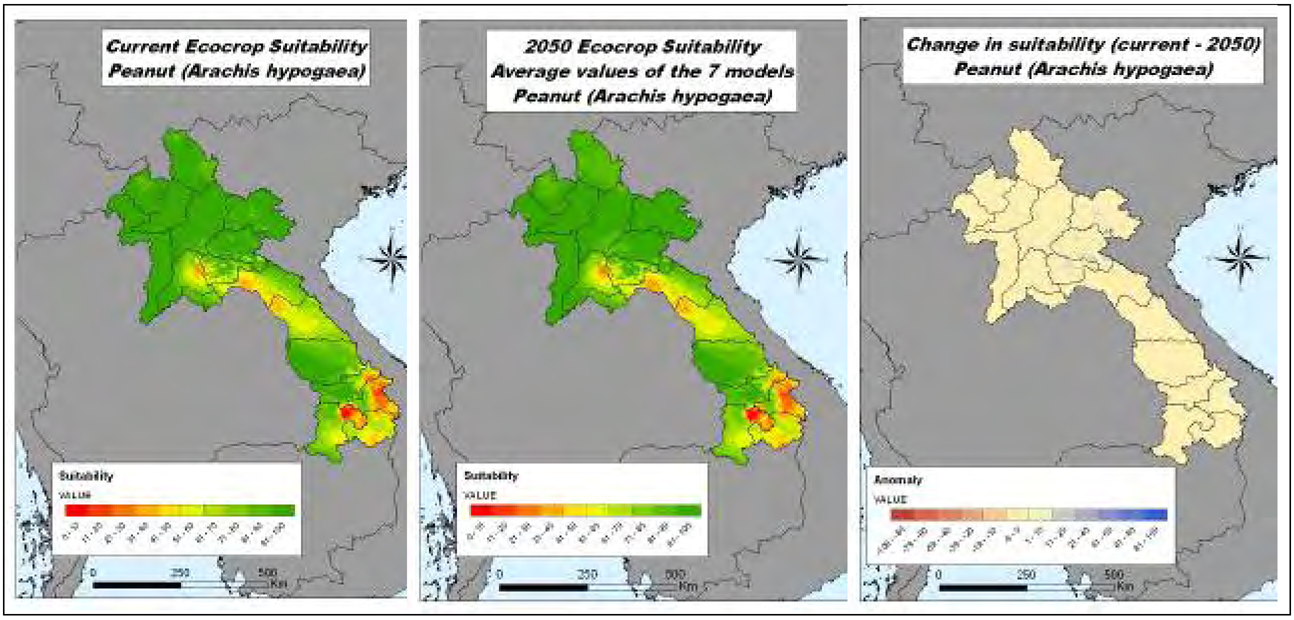
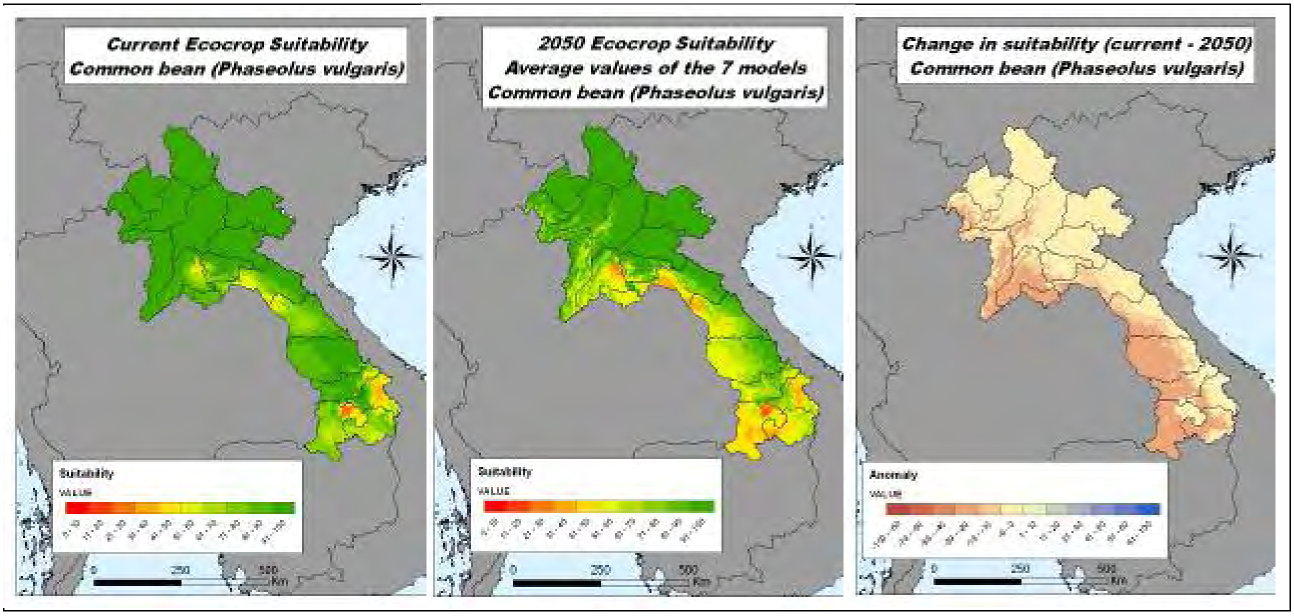

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.11 Current and future bioclimatic suitability for peanuts in the Lao PDR

Common bean

The common bean, *Phaseolus vulgaris*, is not a major crop in the Lao PDR, or in much of SE Asia, except in parts of Burma/Myanmar and China. The Ecocrop assessment suggests that it is well suited to the current Lao climate (Figure 3.12). This matches the comments of bean experts from Latin America and China, who have suggested common bean could be well suited to the region, especially in mountain areas, for improved nutrition and as a marketable crop. The suitability under the predicted 2050 climate is somewhat reduced, although not in the mountainous areas.

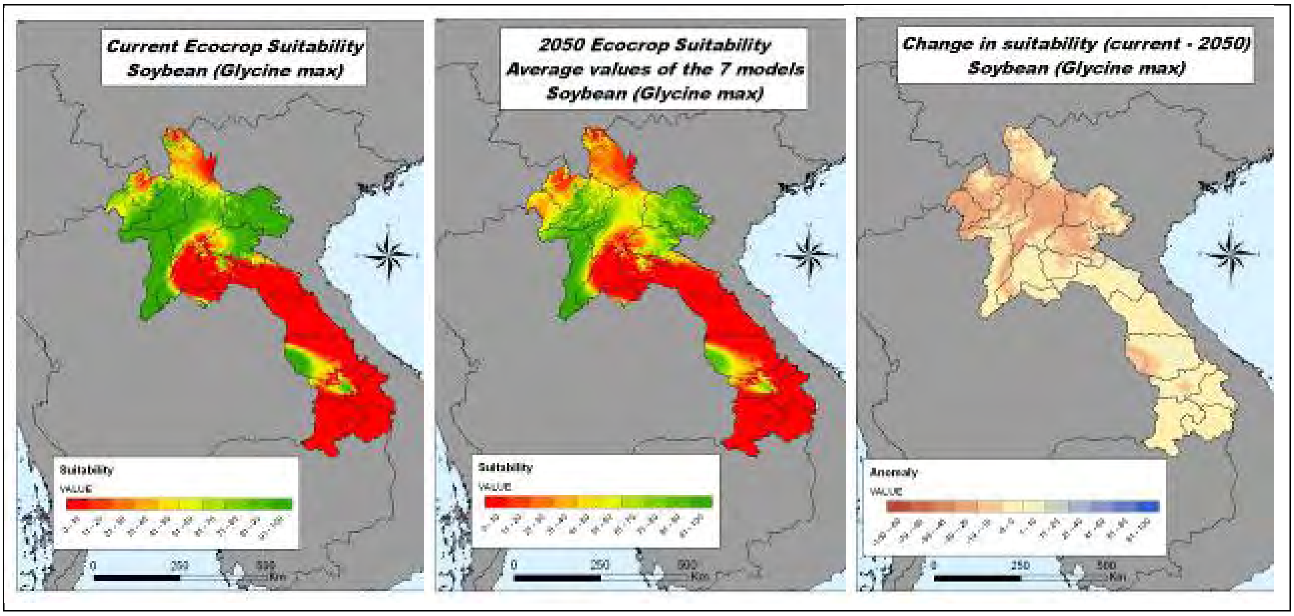


A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.12 Current and future bioclimatic suitability for common bean in the Lao PDR

Soybean

The map of current suitability for soybean cultivation indicates that a large proportion of the country is unsuitable, although a large part of the north, where two-thirds of production takes place, are rated as highly suitable (Figure 3.13). The suitability under the predicted 2050 climate is somewhat reduced, especially in some of these areas of current high suitability in the north. This may be a reason to seek more heat-tolerant soybean varieties.



A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.13 Current and future bioclimatic suitability for soybean in the Lao PDR

Chilli

The map of current suitability for chilli, or hot pepper, indicates that the most suitable areas, as for soybean, are across quite a large part of the north and in part of Savannakhet (Figure 3.14). The suitability under the predicted 2050 climate is somewhat reduced in these areas of current high suitability, although not to the same extent as for soybean.

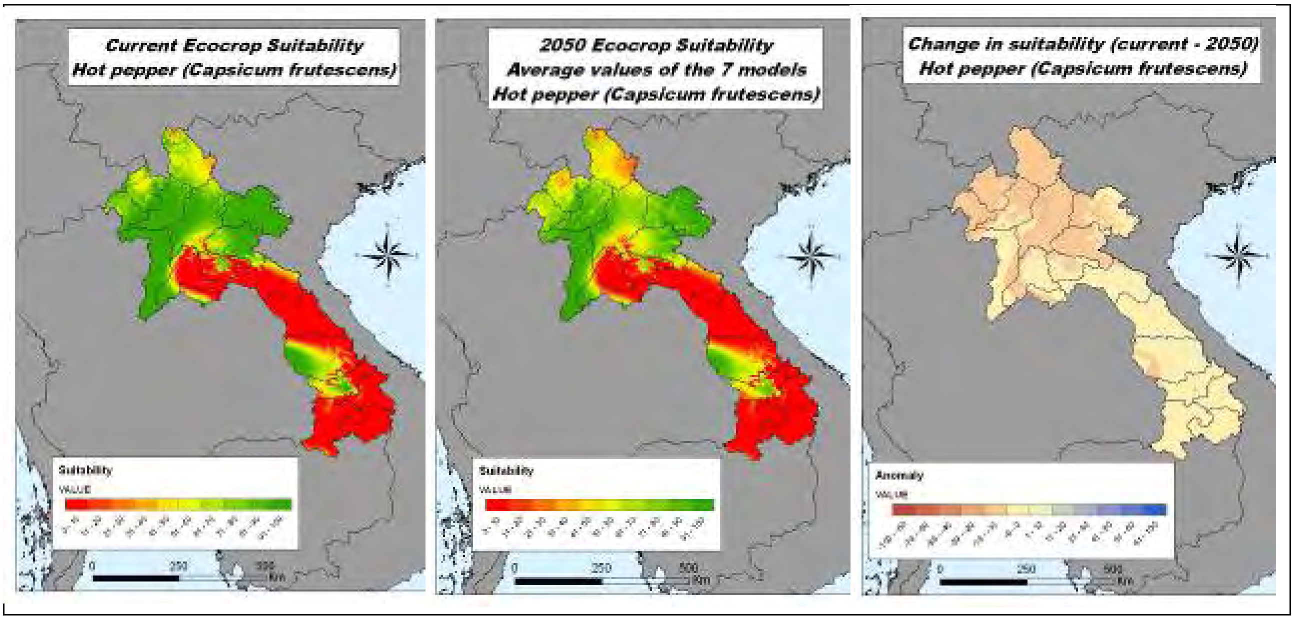

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.14 Current and future bioclimatic suitability for chilli in the Lao PDR

Sweet corn

The map of current suitability for sweet corn (Figure 3.15) is similar, although not exactly the same, as for maize (Figure 3.4). The suitability map may not be so relevant for sweet corn as much of the sweet corn is grown as an irrigated crop in the dry season. The suitability under the predicted 2050 climate is somewhat reduced, especially in some of the areas of current high suitability in the north and in Savannakhet.

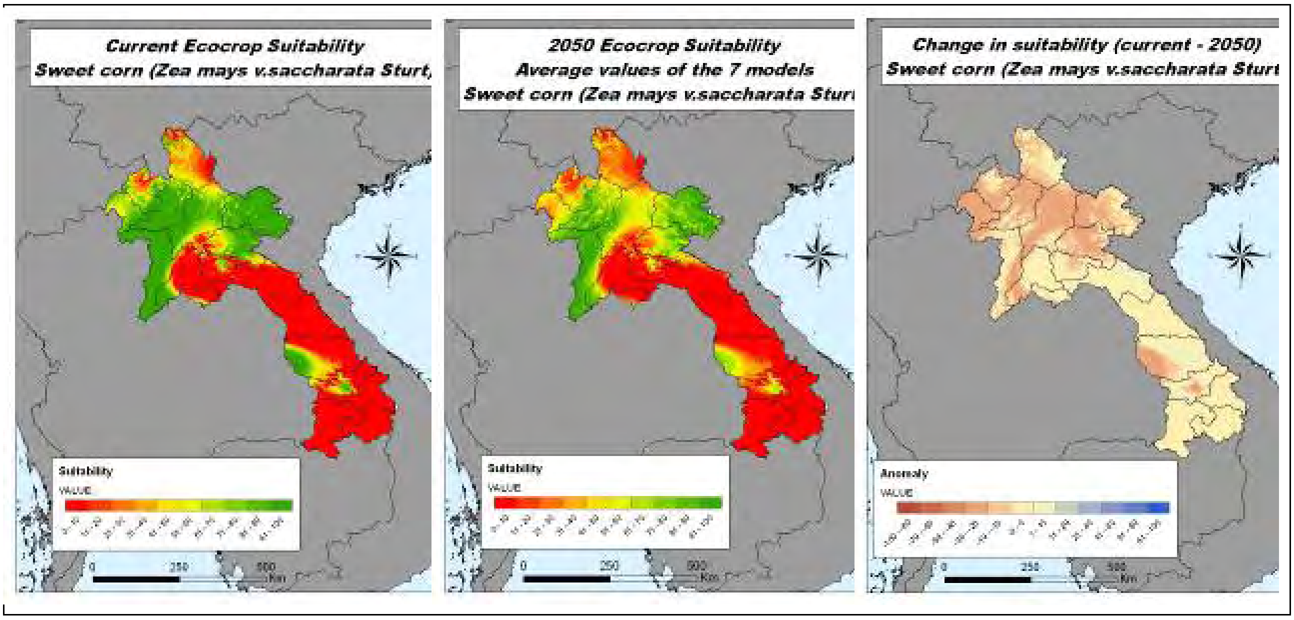
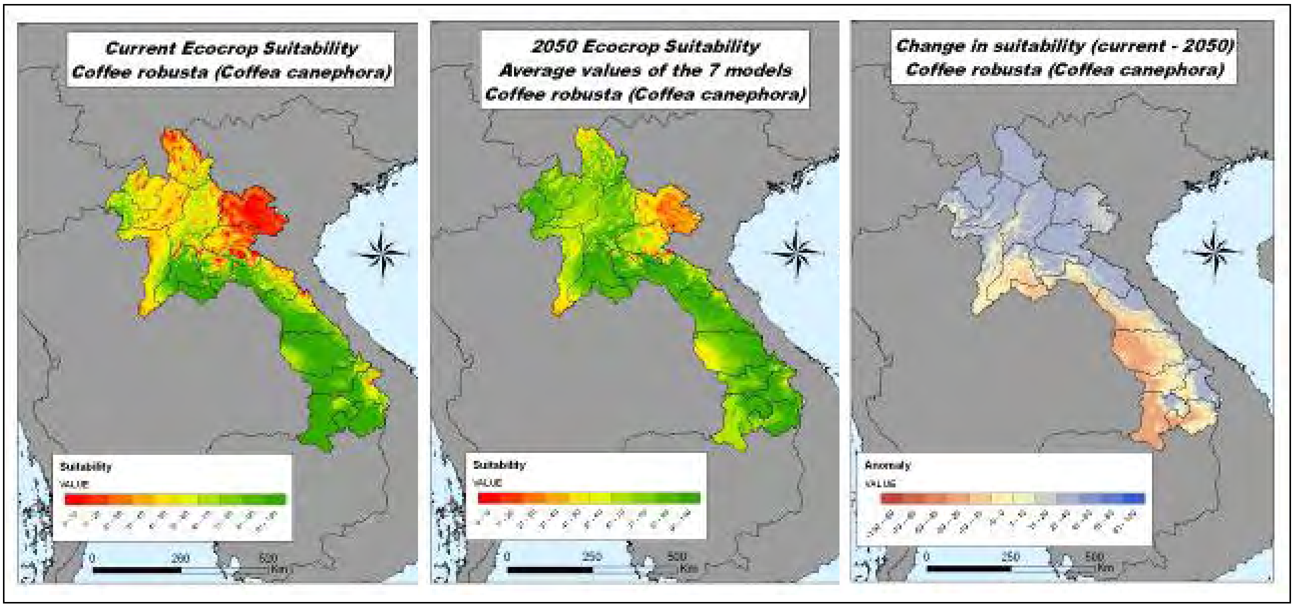

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.15 Current and future bioclimatic suitability for sweet corn in the Lao PDR

Robusta coffee

The majority of coffee grown in the Lao PDR is Robusta and it is grown almost exclusively in the south, which is included in the area shown to be most suitable (Figure 3.16). The top of the Bolovens Plateau is indicated as having sightly lower suitability, which is due to the lower temperature and the higher rainfall. This is not necessarily a problem as the negative impact of lower temperatures can be reduced through shade management and high rainfall may not be an issue if the soil is very free draining. Under the predicted climate for 2050, the suitability is expected to decline in much of the south, but increase in a larger area, both in the north and at higher altitudes in the south, as temperature in these areas becomes more favourable.

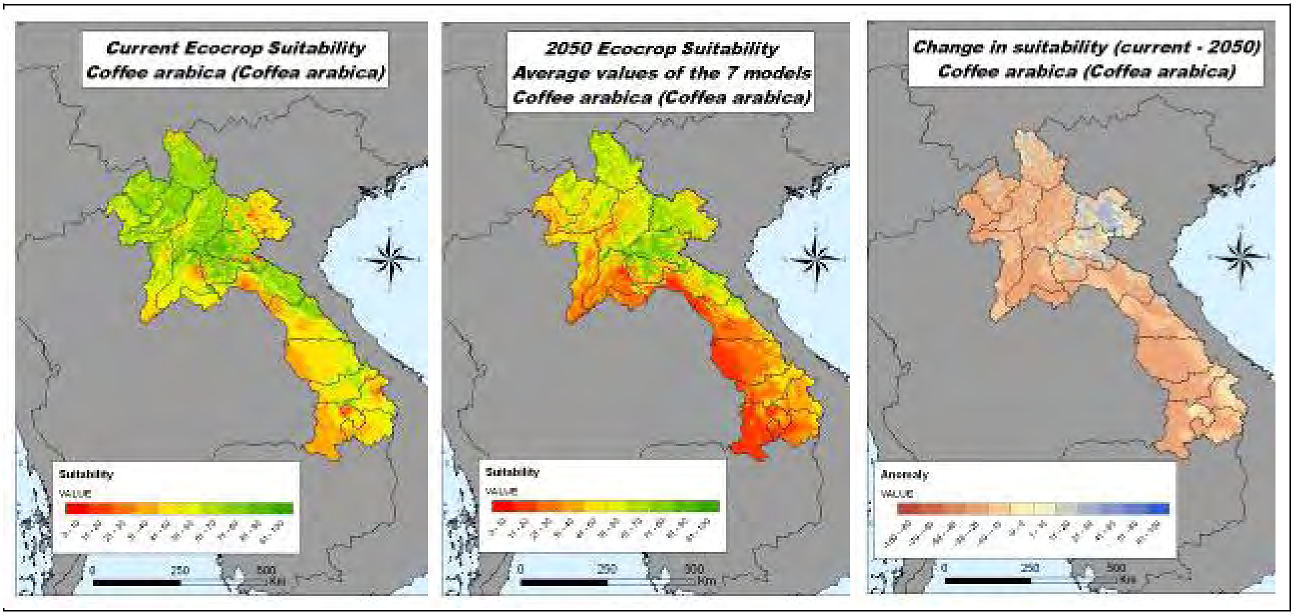


A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.16 Current and future bioclimatic suitability for Robusta coffee in the Lao PDR

Arabica coffee

Arabica coffee is not rated as particularly suitable for production in the Lao PDR, largely due to higher temperatures, and the suitability declines quite markedly under the predicted 2050 climate, with the exception of a small area in Huaphanh, where it will still not be particularly well suited.



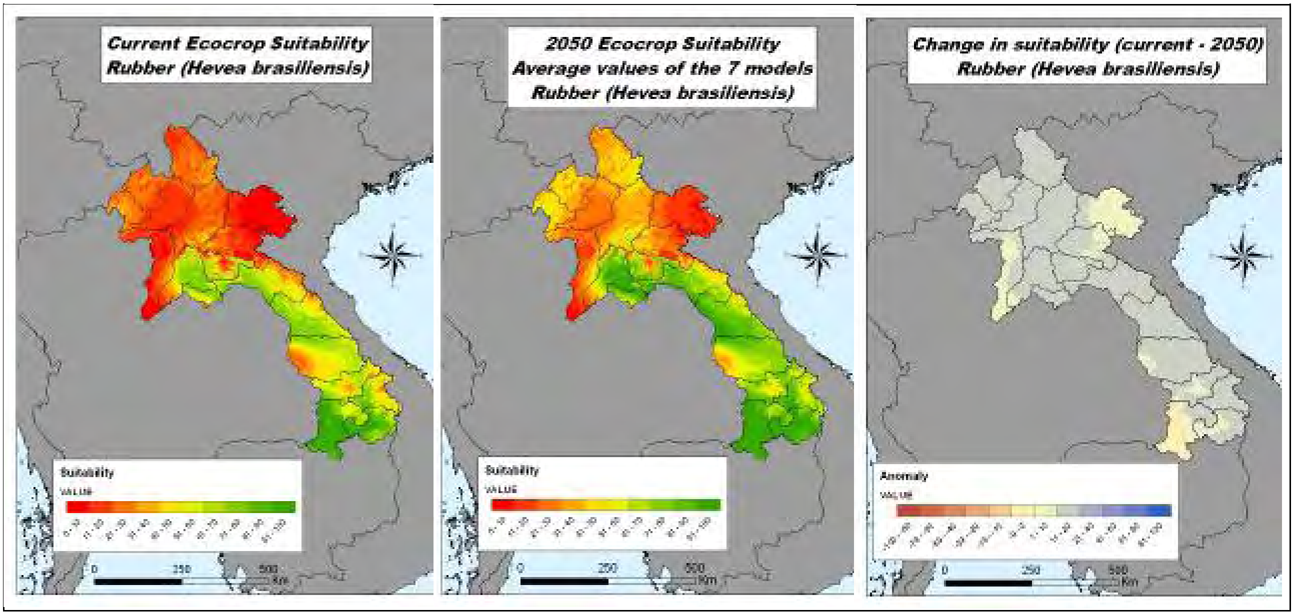
A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.17 Current and future bioclimatic suitability for Arabica coffee in the Lao PDR

Rubber

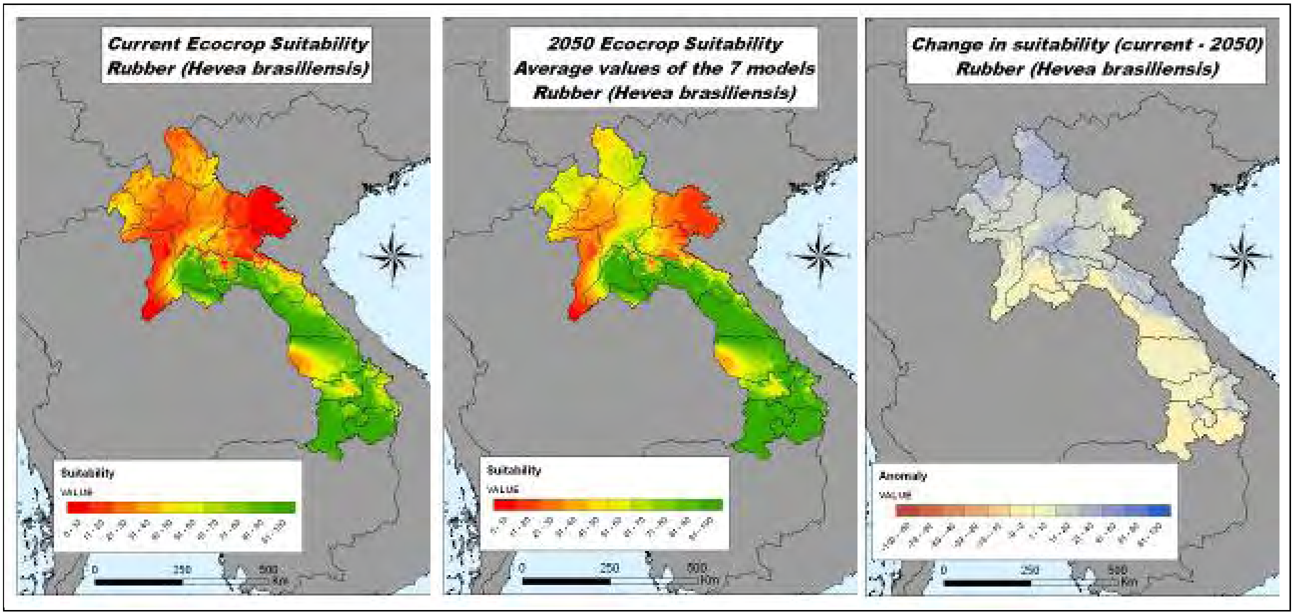
Planting of rubber in the Lao PDR has increased markedly in recent times. When compared to most rubber cultivation areas and to the site of origin in the Amazon., however, the climate is rather cool, at least in the north where there has been a lot of interest in rubber production. The map of current suitability supports this assertion, with relatively low suitability across much of the country (Figure 3.18). The predicted climate in 2050 results in improved suitability across almost all of the country, although most of the north is still rated as marginal at best.

Both acclimatization and breeding can improve the tolerance of rubber to cool conditions, as seen in Yunnan, China (Jiang, 1988). Consequently, Ecocrop was re-run with adjusted temperature parameters, which yielded improved suitability, both currently and in 2050. These suitability maps are probably better suited to the lower temperature acclimatized material from Yunnan that are used in the Lao PDR, although the suitability is still rated as low in most of the north.



A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.18 Current and future bioclimatic suitability for rubber in the Lao PDR



A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.19 Current and future bioclimatic suitability for lower-temperature acclimatized rubber in the Lao PDR

Banana

Over 50% of bananas produced in the Lao PDR are produced in the southern provinces, particularly Saravan, although significant production does occur in Luang Prabang as well. The current suitability for bananas is favourable across much of the country, but most particularly in the south (Figure 3.20). The predicted climate for 2050 is more favourable for banana production in the north and suitability in the south remains the same of increases in some higher altitude areas.

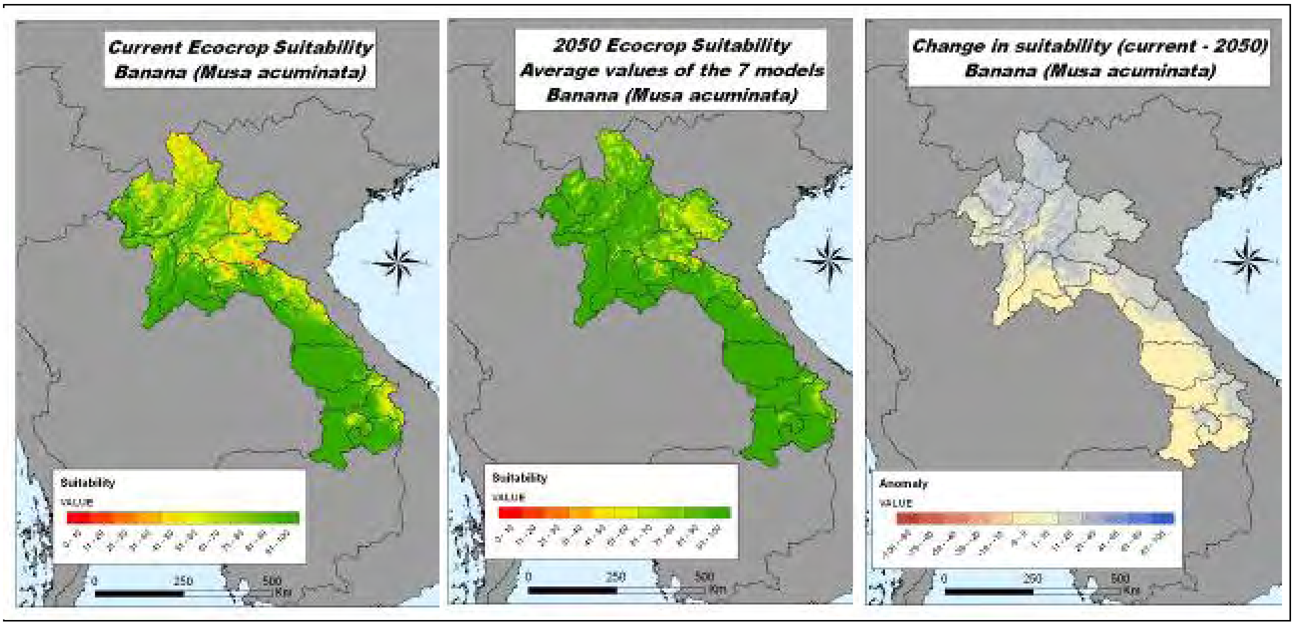

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.20 Current and future bioclimatic suitability for banana in the Lao PDR

Jatropha

Jatropha has been used traditionally in the north as a living fence and, in the past, as a source of oil for lamps and as an emetic against poisoning. The areas in which it grows widely are the areas indicated as highly suitable for the current climate (Figure 3.21). The 2050 climate is assessed as much less suitable for jatropha. Interest in jatropha as a biofuel has been built, at least in part, on excessive projections for yield. According to these Ecocrop analyses, interest in the south are misplaced, and many of the areas in the north are likely to be less suitable in the future.

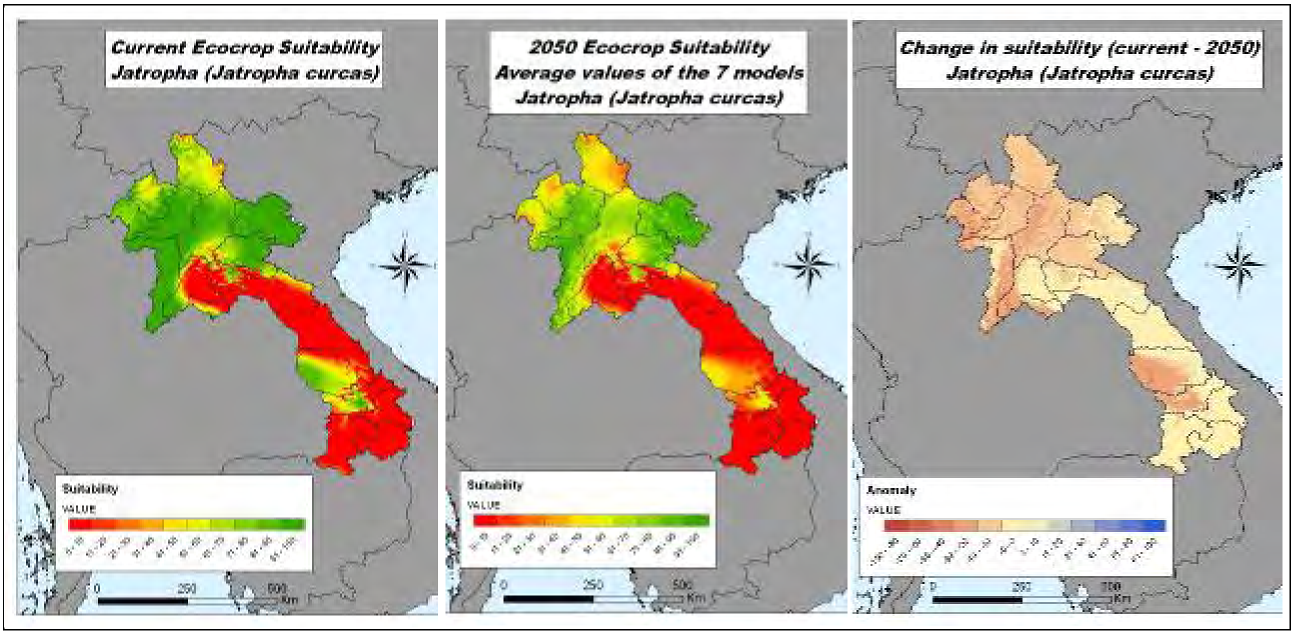

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.21 Current and future bioclimatic suitability for jatropha in the Lao PDR

Teak

The climatic data used in these Ecocrop analyses may not match the main accessions used commercially (for example around Luang Prabang), but it does show reasonable suitability across much of the country, especially in the south (Figure 3.22). The increase in suitability under the 2050 climate is one of the largest improvements of any of the plant species analysed.

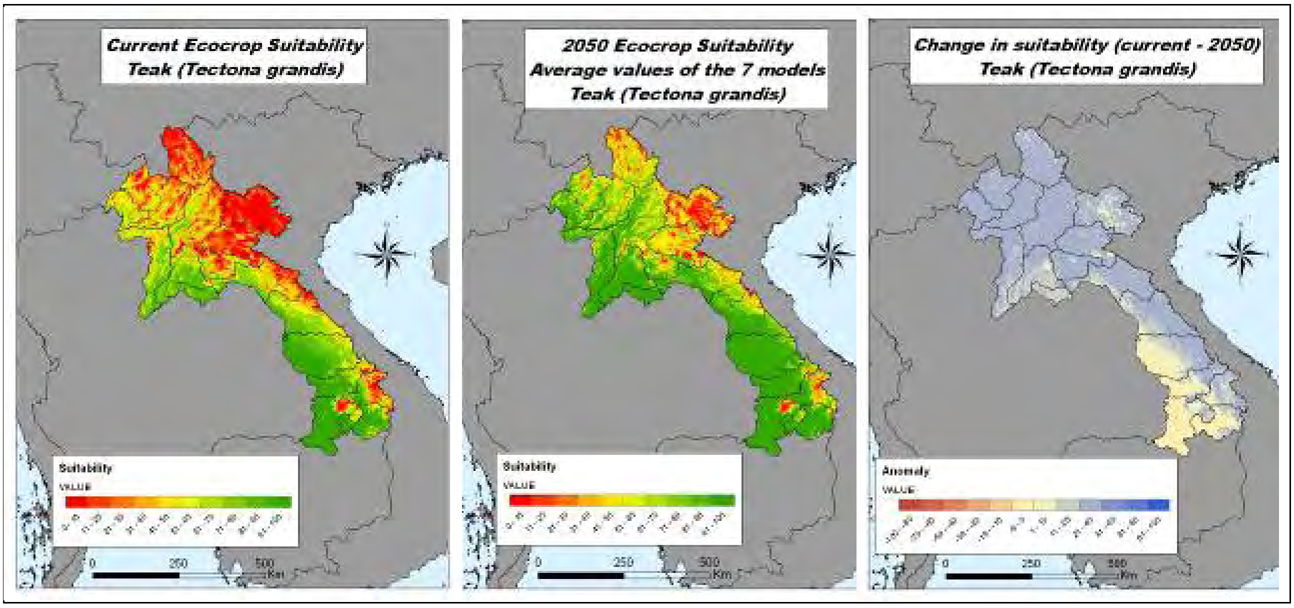

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.22 Current and future bioclimatic suitability for teak in the Lao PDR

Eucalyptus

Eucalyptus globulus is commonly used in commercial forestry, although other species and hybrids are perhaps more important in the Lao PDR. As with teak, it is far from clear if the climate parameters used in this suitability assessment apply to the accessions used locally, but hopefully they do not as these analyses indicate that it is not well suited to the current climate and that it will be less so in the predicted 2050 climate (Figure 3.23). Even with more appropriate parameters and greater current suitability, it is likely that the direction of change, to become less suitable in the future, will remain the same.

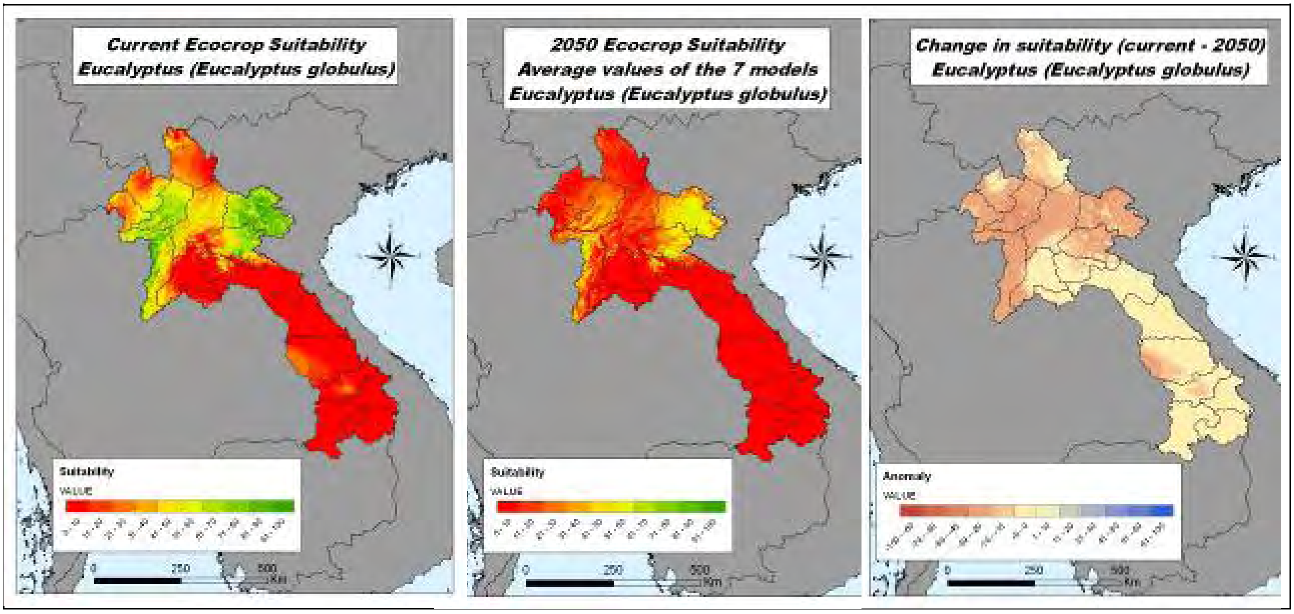

A: Current suitability B: 2050 projected suitability C: Change to 2050

Figure 3.23 Current and future bioclimatic suitability for *Eucalyptus globulus* in the Lao PDR

3.4 Summary of crop suitability assessment

According to the Ecocrop analysis of bioclimatic suitability of these 17 crops, under the current climate and under the climate in 2050 as projected using the mean of seven GCMs under the A1B emission scenario, there was a wide range of responses in suitability with the projected climate change. Of the 17 crops (with upland rice and paddy rice treated separately) and 19 separate analyses (including Indica-type and Japonica-type upland and lowland rice treated as separate crops), eight showed a decline in suitability (maize, common bean, soybean, chilli, sweet corn, Arabica coffee, jatropha, and eucalyptus), three show little change (paddy rice (Japonica-type), upland rice (Japonica-type), peanuts), seven show increased suitability (sugarcane, paddy rice (Indica-type), upland rice (Indica-type), cassava, banana, rubber, and teak), while Robusta coffee showed some areas of the country with a marked increase in suitability and other areas with a marked decrease in suitability.

Across all of these crops, the net change in suitability was a decrease in suitable land of 50,000 km^2. This is a difficult figure to interpret as it is not weighted according to the current importance of the different crops and it will include multiple counting of the same land. It does, however, indicate areas of concern, particularly for maize and soybean, in either seeking alternative crops or at least the need to breed for or select varieties and accessions that are well suited to a changing climate.

If the climate parameters used for the different species in this study could be verified with the specific varieties and accessions being used currently in the country, then a more accurate assessment of suitability could be made. Such a study could even build in assessments for the different varieties and accessions that are being used in different parts of the country. The results of such an improved study would allow for a more accurate assessment of potential productivity under future climates and would indicate the greatest challenges and potential greatest benefits that would accrue from efforts to identify new varieties that are better suited to the current and future conditions.

Further localized studies on suitability would also allow for a better appreciation of the interactions between bioclimate and soil type, as well as between agronomy, crop management, pests and diseases, and bioclimate. With such information, it may be possible to increase the suitability for different crops through cultural practices related to land preparation, mulching, ground cover, intercropping, irrigation, fertilizer application, and other aspects of management.

4. Changes of Land Use and Drivers

4.1 Background and Methods

In sections 2 and 3, the change in climate and the likely impacts on crop production through changes in bioclimatic suitability were quantified. These are essential steps to determining whether and how climate change may affect land use. Another crucial aspect of determining the impact is to understand the current land use, how land use is and has been changing, and the drivers of land use change. An understanding of these factors is critical for drawing conclusions about the magnitude of the impact of climate change in terms of changes in crop suitability and productivity compared to, or in addition to, other drivers of land use change. Such land use change analysis puts the change in crop suitability analysis in a wider context and allows for the development of appropriate strategies to address the issues of adaptation.

The period 2000 to 2009 was chosen as the period for which land use change was analysed and the drivers behind these changes assessed. The approach involved the examination of remotely sensed data, agricultural statistics, and other economic information. The following description of methodology focuses on the analysis of remote sensing satellite imagery.

The MODIS NDVI (Moderate Resolution Imaging Spectroradiometer Normalised Difference Vegetation Index) product is state-of-the-art for studying environmental change. Measuring vegetation with this index allows the determination of the density of plant growth by using satellite information of visible and near-infrared sunlight reflected across the spectrum of wavelengths. For healthy and dense vegetation, the reflection in the visible wavelengths is low and the reflection of the near-infrared wavelengths is high, for unhealthy or degraded vegetation it is the opposite.

The 2000 to 2009 MODIS dataset is composed of 214 NDVI files at a resolution of 250m and corresponding to an image taken every 16 days. The NDVI images were acquired online, cut for the Lao PDR, and then processed.

Several processing steps were required to render the MODIS image data suitable for land use change analysis. Interference from aerosols, water, and clouds had to be removed individually. Further, the NDVI scenes were filtered to eliminate any poor quality data (extreme high and low values). The resultant cleaned spectrum (line 1) was produced from the raw spectrum (line 2) by removing the noise (line 3) through application of a Fourier interpolation algorithm (Figure 4.1).

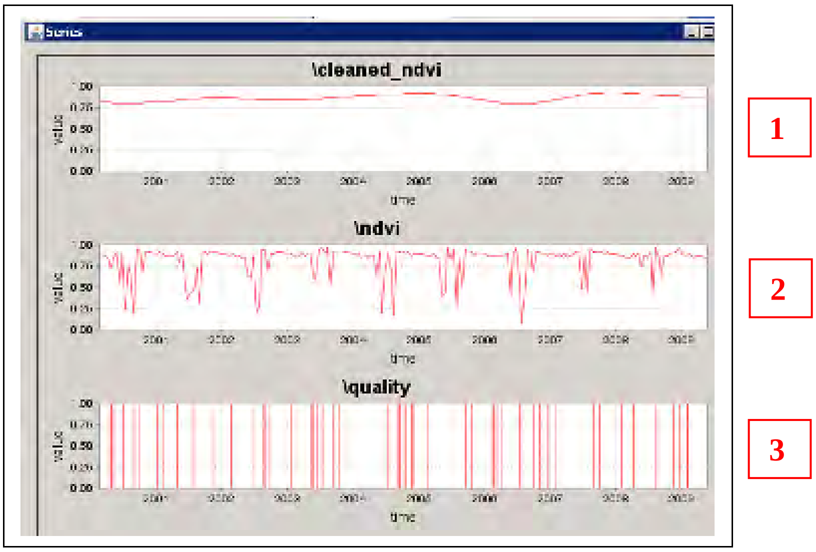
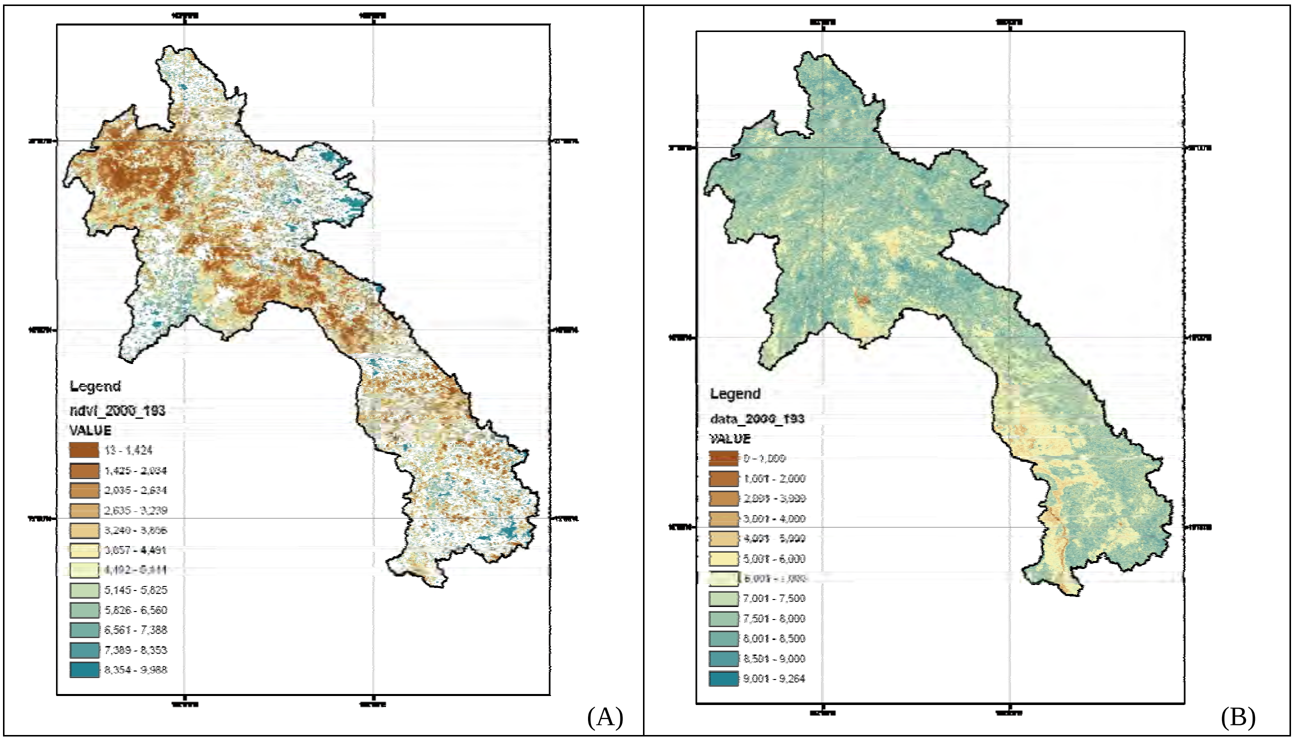


Figure 4.1 Screening of temporal profiles to restore historical multi-year MODIS-NDVI scenes

The quality of the filtering process can be evaluated by comparing the final restored results with the original MODIS NDVI for a summer day in 2000, in which major cloud cover affected the image quality (Figure 4.2).



(A) (B)

Figure 4.2 Comparison of the original (A) and restored (B) MODIS NDVI for the Lao PDR on July 11 2000

After the NDVI data were prepared for analysis, the two most suitable points in time had to be chosen for comparison and then the change in NDVI determined between these two points. March was considered a most suitable time for a number of reasons. Firstly, noise from clouds is less problematic at this time, during the dry season. Secondly, in March, before the growing season starts, vegetation is most likely to be in a similar condition across years, whereas a little later in the year and the data could be more affected by the timing of the early or pre-wet season rains, rather than true changes in land use. Thus, using March data meant that real changes due to deforestation, differences in cropping patterns, or other changes in land use were most accurately analysed and mapped. The availability of MODIS images from March 2000 and March 2009 meant that the full extent of available data could be used.

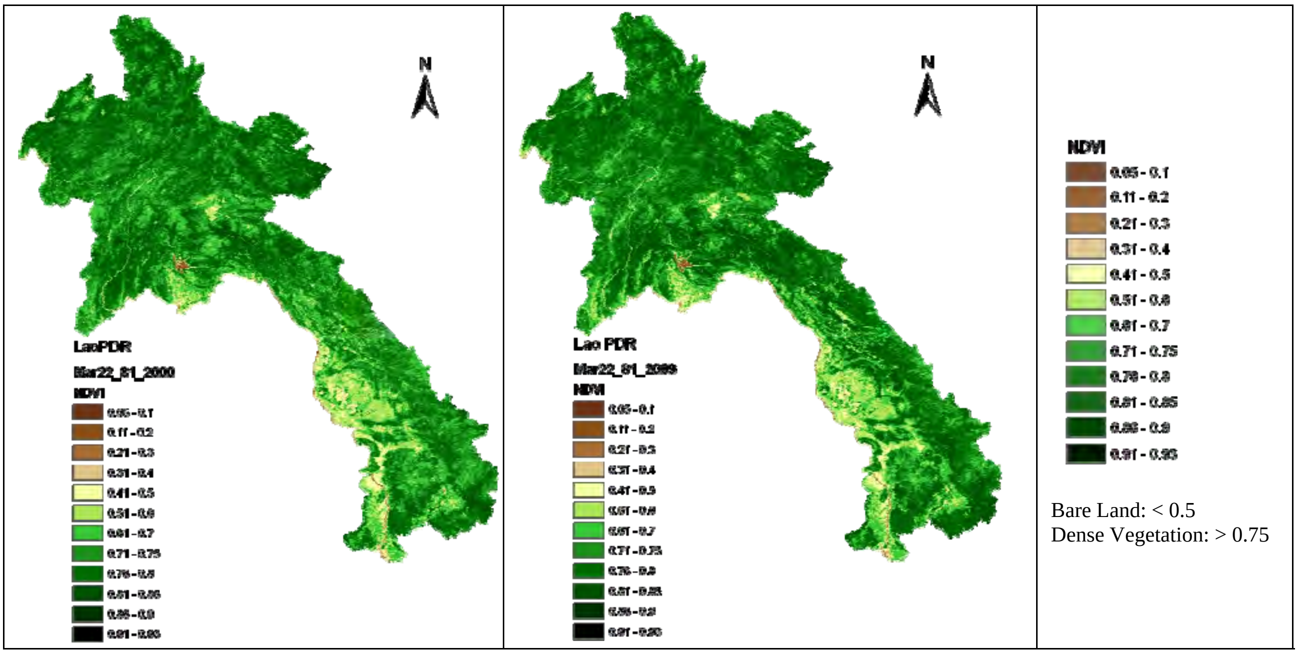
A map of land use change was produced through several steps. The first step was for all the NDVI ranges to be defined and mapped for 22 March in 2000 and 2009. An algorithm was applied to these two maps in order to obtain a representation of vegetation change over the 9 year period. The resulting map characterises the spectrum of changes in plant cover from highly negative to highly positive changes. The change is represented on a unit-less scale, with the magnitude of change separated into 12 categories. So far land use change analysis in the Lao PDR has been carried out with satellite and ground data for 1982, 1992 and 2002, where reasonably precise land use categories were defined optically and through ground truthing (DOF, 2002). Land use and land uses change analysis for the period from 2000 until 2009, as well as the approach of examining land use change in terms of NDVI, thus constitute new developments for the Lao PDR.

Land use change can also be examined through statistical data on changes in agricultural activities, roads, mining, hydropower and the like. These data can be analysed in conjunction with the analysis of satellite data, such that the changes in land use that occurred can be related reasonably directly with possible drivers of land use change. In the following section, evidence of changes in vegetation from the NDVI analysis is presented together with evidence from national and provincial cropping and forestry data as a means of identifying land use changes. In the subsequent section, some underlying drivers of land use change beyond agriculture are examined, such as infrastructure development and economic growth.

4.2 Changes in Land Use Patterns

Evidence from Satellite Imagery

From the multi-temporal NDVI images for the period from 2000 to 2009 the images for March 2000 and March 2009 were selected and analysed to indicate vegetation cover and density (Figure 4.3). Subsequently a map of Land Use Change was created, which depicts the patterns of change in vegetation across the Lao PDR by the change of NDVI from 2000 to 2009. Red depicts a decrease in NDVI, white depicts no changes, and green depicts an increase in NDVI.



Bare Land: < 0.5
Dense Vegetation: > 0.75

Figure 4.3 NDVI Maps for March 2000 and 2009, Lao PDR

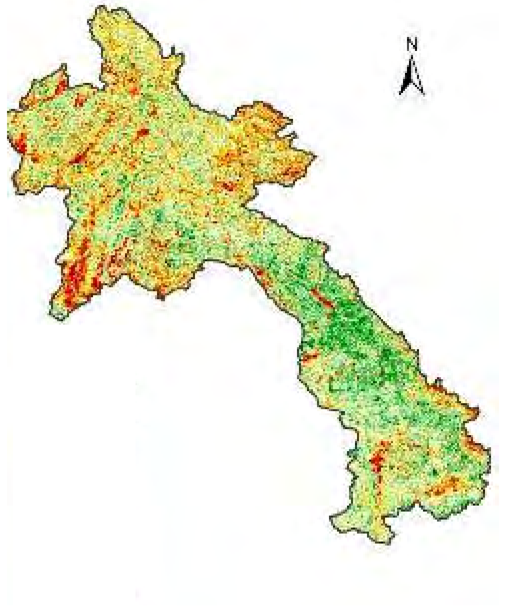
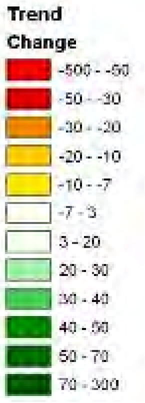
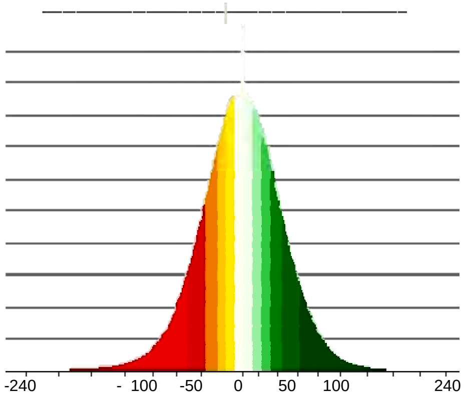
Land Use Change Map	Scale	Distribution of Pixels
	 Decrease in Vegetation: -500 to -7 Increase in Vegetation: 20 to 300	 Main decrease: -150 to -7 Main increase: 20 to 120 Mean: -2.32

Figure 4. 4 Change in Vegetation Cover 2000 – 2009, Lao PDR

The comparison of NDVI vegetation maps reveals that there is a large range in the values of NDVI across the country in both 2000 and 2009 (Figure 4.3). The images exhibit a general pattern of forested areas, cropping areas, and more urbanized areas. The map of Land Use Change (Figure 4.4) highlights where the changes in these various land uses have occurred and to what extent, with the intensity of the red and green directly related to the degree of negative and positive change, respectively. The distribution of pixels indicates the amount of negative and positive vegetation change, and the negative mean indicates that decreases in NDVI outweighed increases, thus suggesting a net loss in biomass.

Changes that occurred within the 4th and 6th ranks (0.61 – 0.8) of the 12 category NDVI scale (Figure 4.3) are indicative of very variable change patterns and appear to indicate shifting-cultivation systems. In addition to the variability of NDVI in these categories, resulting from the variability inherent in these rotational systems, there has been substantial net vegetation increase in this broad land use category, which is most likely due to an overall reduction in the area of slash and burn agriculture. This is most evident in parts of central and northern Lao PDR. As the slashing and burning of fallows declines, because of resettlement or land allocation, for example, some of the fallows are gradually transformed into more dense forest vegetation, whereas in other areas, more permanent forms of agriculture are practiced on land used formerly for shifting cultivation, and these systems are in turn responsible for a clear decline in the pattern of NDVI. If the more permanent or sedentary systems are based on annual cropping, then the March NDVI values are not likely to increase over time, as March will remain a time of low biomass, however, if shifting agriculture is replaced by permanent agriculture or agroforestry, based on the establishment of more permanent tree crops, then the NDVI would be expected to increase over time.

The red colour areas on the map of change in vegetation refer to “stressed” agro-ecosystems, where there were marked declines in NDVI. These can be seen clearly in some parts of southern and northern Lao PDR, with clear examples in Luang Prabang, Huaphanh, and, most particularly, in Sayabouri. In many of these regions the red areas may indicate the pressure of deforestation, which appears in NDVI categories above the 6th rank (<0.6). These more marked changes in vegetation cover can occur primarily from logging, or associated with hydropower ventures, mining developments, and infrastructure projects, with some of the transport infrastructure developments contributing to further declines in vegetation due to the provision of better access for logging and other activities.

The following maps (Figures 4.5 – 4.8) cover the four target provinces of the study and allow closer examination of where changes in land use occurred.

In Attapeu, most of the lower-lying, rather densely populated section of the province, as well as corridors along new roads, experienced a major decline in vegetation cover between 2000 and 2009 (Figure 4.5). As dipterocarp and other forests were cleared for annual and perennial cropping and for timber extraction, the NDVI became less intense. Areas at higher elevations experienced an increase in NDVI, however, most likely due to the low accessibility and to effective resettlement of villages from these areas to more accessible areas.

For Luang Namtha, a similar picture emerges, with the major land use change, showing a decline in NDVI, having occurred along with major infrastructure developments and around the most important population centres, such as Luang Namtha town and Muang Sing (Figure 4.6). The sweeping expansion of rubber plantations, for which large tracts of land were cleared, has contributed to low NDVI values in 2009 and the corresponding red areas on the ‘Change Map’. Assuming that rubber cultivation is successful, the NDVI of much of this area will increase as the rubber trees mature. As seen in Attapeu, the more remote regions feature a mosaic of values, with green areas, and thus positive changes in NDVI, dominating over negative changes in NDVI.

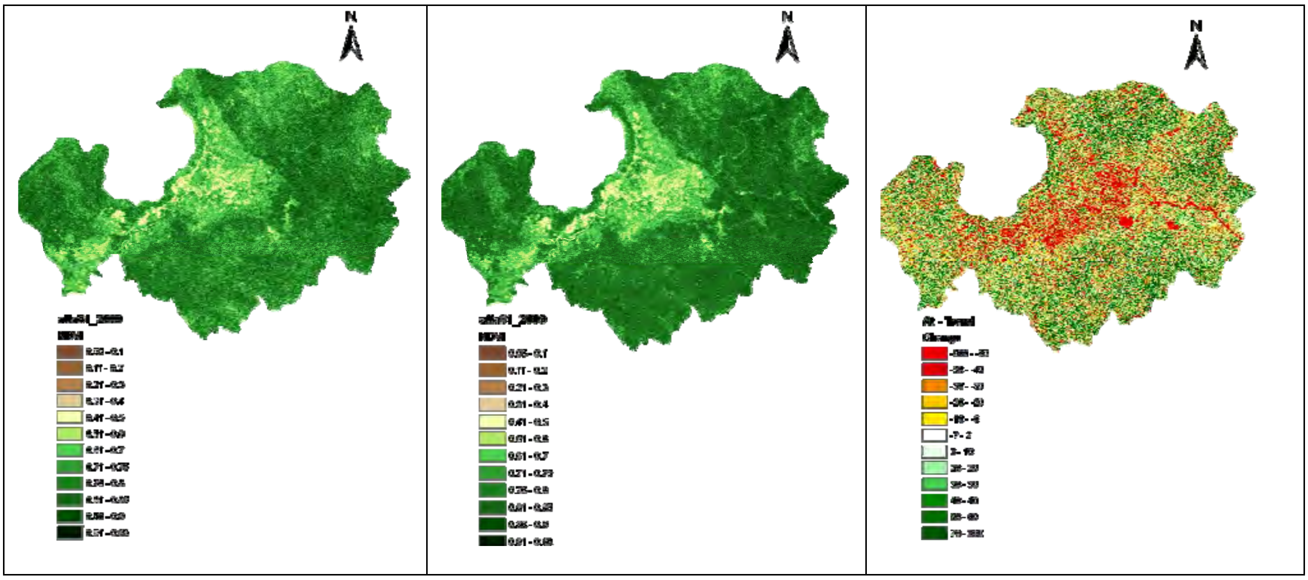


Figure 4.5 NDVI Maps of Attapeu Province for 2000 and 2009 and a map of vegetation change

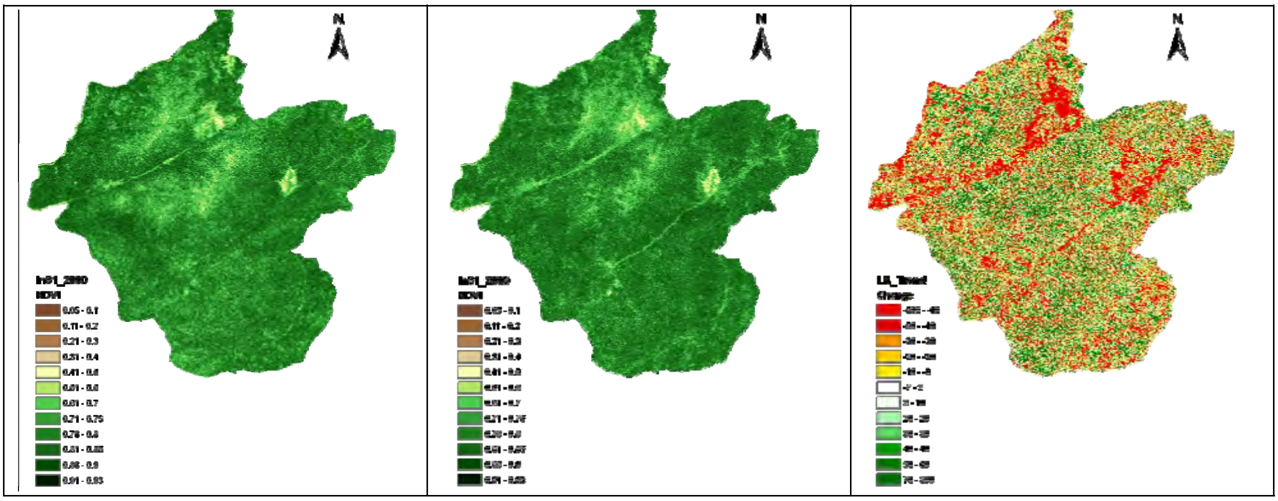


Figure 4.6: NDVI maps of Luang Namtha for 2000 and 2009 and a map of vegetation change

For Luang Prabang, one fairly large area that experienced a major reduction in NDVI stands out, while the rest of the province is characterized by a mosaic of NDVI increase and decrease (Figure 4.7). The large area showing loss of vegetation in the upper west of the province can be attributed to the expansion of cash crops (rubber, maize, job’s tear) in Nambak District, whereas maturing teak plantings most likely account for some of the more contiguous gains in vegetation in the lower portion of the province, especially to the east, south, and southeast of Luang Prabang town.

Sayabouri constitutes an extreme example of land use change (Figure 4.8). For the entire country the net vegetation loss (increases in vegetation cover minus the decreases in vegetation cover) was in the range of 2 – 3%, whereas for Sayabouri the net loss amounted to over 14% of the land area (Table 4.1). Some negative and positive changes in vegetation cover occurred in northern and central Sayabouri, along access roads and in a mosaic around villages, while the southern part of the province is characterized by some very large areas with severe reduction of NDVI values. The expansion of maize cultivation in Paklai and Kenethao districts, logging road construction and associated timber cutting, and the upgrading of main access roads appear to have been the main drivers of this reduction in vegetation cover. The most southerly district, Boten, experienced much less net decline in NDVI, but this is most likely as the expansion of maize production occurred here before 2000.

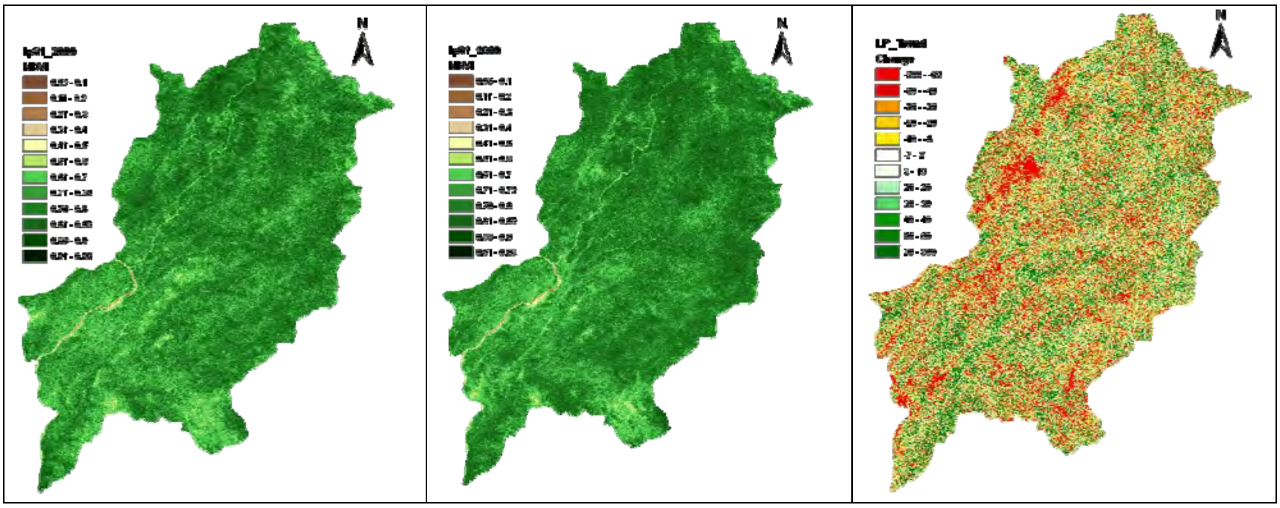


Figure 4.7: NDVI maps of Luang Prabang for 2000 and 2009 and a map of vegetation change

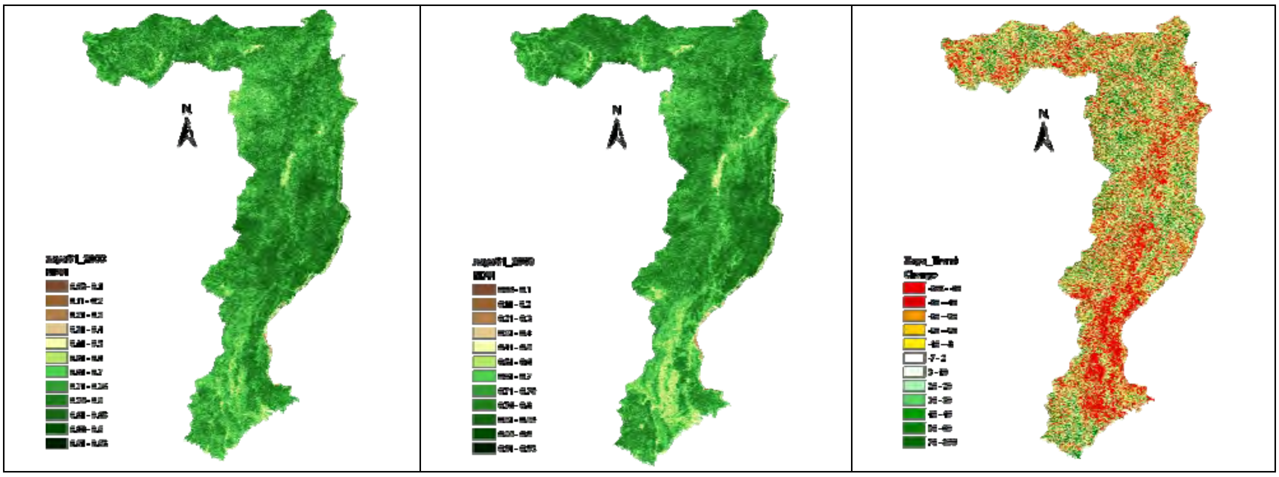


Figure 4.8 NDVI Maps 2000, 2009 and Map of Vegetation Change, Sayabouri

Table 4.1 Change in NDVI

	Vegetation cover for the Lao PDR and for Sayabouri Province	
	Whole country (ha)	Sayabouri Province (ha)
Decrease in NDVI/Vegetation	5,211,631	490,138
No change	18,527,038	1,206,606
Increase in NDVI/ Vegetation	4,545,869	211,744
Absolute difference	-2.35%	-14.59%

Comparison of the change in NDVI with recent satellite images from Google Earth highlight the accuracy of the NDVI analysis at the same time as identifying some of the direct drivers of change (Figures 4.9 to 4.12). These four examples illustrate some of the more significant changes in vegetation cover. They include examples from agriculture, hydropower development, urban development, and mining, and all demonstrate excellent congruence between changes in NDVI and clear examples of land use change.

The change values presented in these maps are related to severe vegetation losses above -100 up to -500 on the scale of change. In Sayabouri (Figure 4.9) the change values between -100 and -200 indicates that lower density vegetation (in this case maize and weeds) has replaced more dense forest vegetation. This indicates a loss of perennial vegetation (forest) and also may be related to a general decline in annual vegetation cover as increased land degradation occurs in these annual cropping systems. Logging and clearing in Khammouane Province for the Nam Theun 2

Hydropower dam, reservoir, power plant, and resettlement villages (Figure 4.10) and clearing for construction of the new stadium near Vientiane (Figure 4.11) indicate very high loss of NDVI on the maps, which match very closely the images from Google Earth. Finally, there is a clear match between the Google Earth image of mining in Savannakhet and the change in NDVI measurements (Figure 4.12), where red and black on the map indicate major loss of vegetation and complete loss of vegetation, respectively.

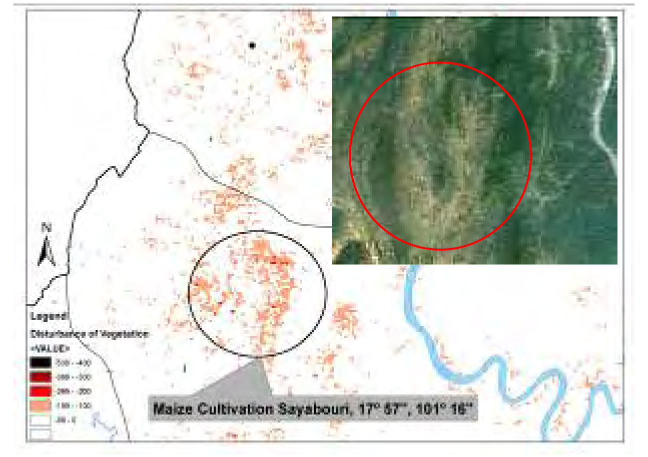


Figure 4.9 Expansion of maize cultivation, Sayabouri Province

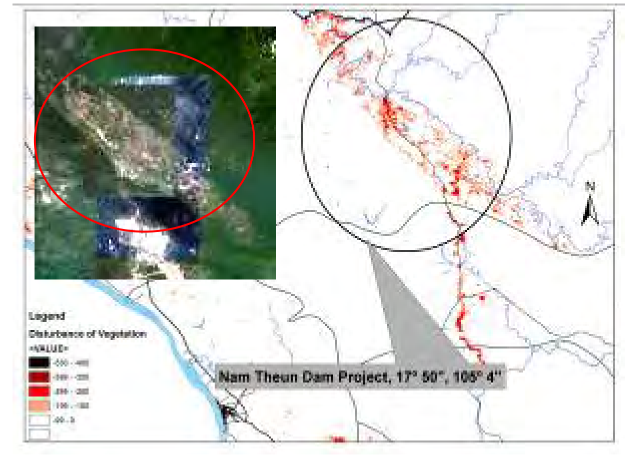


Figure 4.10 Expansion of hydropower, Khammouane Province

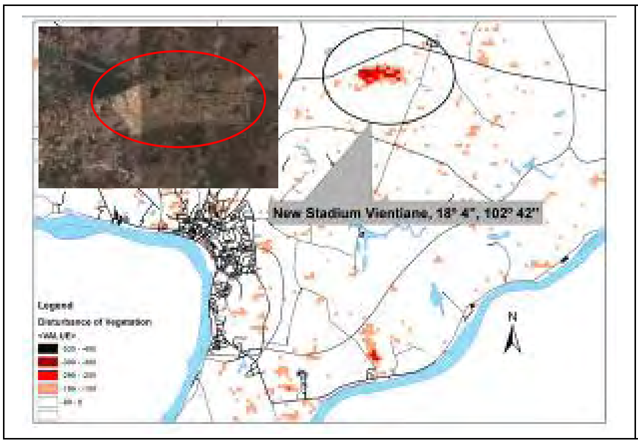


Figure 4.11 Urban area construction, Vientiane

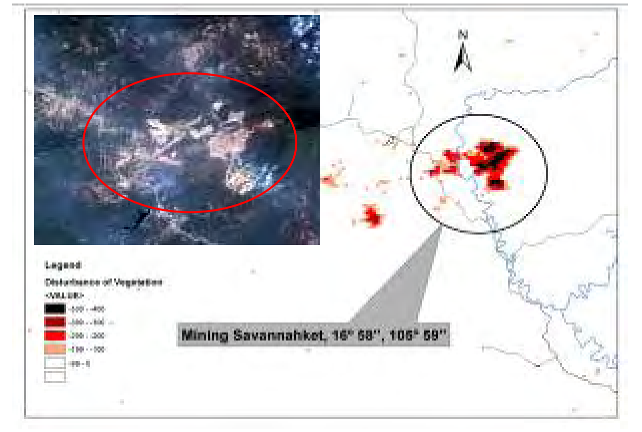


Figure 4.12 Mining in Savannakhet Province

Source: MODIS NDVI 2000 and 2009; Google Earth

The spatial analysis of land use change through measurement of long-term changes in NDVI means that change in vegetation cover can be related to other spatially related data. The analyses of NDVI indicate that there were no or very minor net changes in vegetation across large areas of the country for the period from 2000 to 2009, while much smaller areas appear to have lost vegetation and an even smaller area appeared to have increased vegetation cover (Figure 4.4 and Table 4.1). The areas where these changes occurred can be assessed further to see if the distribution of change was associated with differences in such parameters as altitude, slope, accessibility, and population density.

The percentage of land in the six altitude categories up to 1500m are reasonably similar, although with the largest proportion of land (22%) in the 1000-1500m category (Figure 4.13a). The amount of land above 1500m is much smaller (<4%). In these same altitude categories, there was a lower loss of vegetation (decrease in NDVI) at altitudes from 0 to 200m and proportionally greater loss of vegetation between 200 and 600m and no difference at higher altitudes. This distribution is most likely related directly to the location of a larger proportion of villages.

While 27% of the land in the country is reasonably flat, with a slope of 5º or less, much of the country has significant slope; with 11% of the country between 5º and 10º, 32% between 10º and 20º, and a further 30% is steeper than 20º (Figure 4.13b). The risk of soil erosion varies with many factors, but primarily with the amount and intensity of rainfall, the soil type, the farming system and consequent soil surface management, and the slope. Critical slopes for soil erosion can be as low as 3º with very erosive soils and 15º or more for soils with reasonably low erosivity. A disproportionate amount of land in the slope category from 10º to 15º and even more so from 5º to 10º showed a decline in vegetation, while proportionally less land above 20º showed a decline in NDVI. While this suggests less clearing of vegetation (for agriculture or forestry) on the steepest lands, which is good, the amount of loss of vegetation in the 5º to 15º range is a potential concern for erosion and subsequent soil resource degradation.

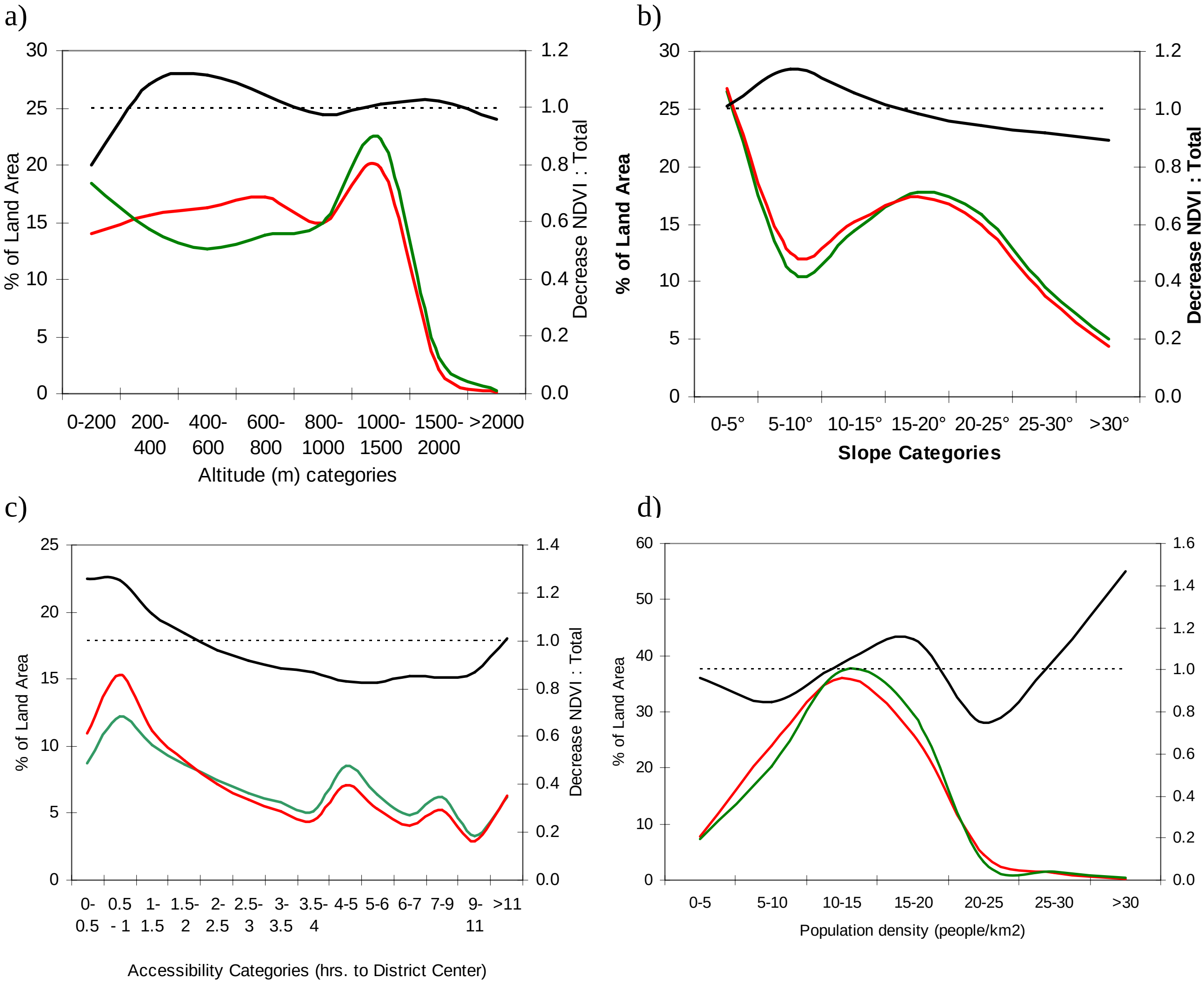


Figure 4.13 Relationship between change in vegetation and (a) altitude (mamsl), (b) slope, (c) accessibility to the District center (hrs) by the best transport option and (d) population density (no. per km^2)

Green line: % of Total land for each category; Red line: % of land that had a decrease in NDVI for each category; Black line: ratio of Land with decreased NDVI:Total Land for each category

Using an algorithm to estimate accessibility expressed as the travel time to the District center it was estimated that about 30% of the land is accessible within 1.5 hours of the District center (Figure 4.13c). Not surprisingly, a disproportionate amount of the loss of vegetation occurred in this more accessible zone, although there was significant reduction in NDVI at great distance from the

District centers, and presumably forestry plays a greater role at distance. The relationship between vegetation loss and population density is more complicated (Figure 4.13d). The disproportionately high loss with high population densities would have most likely been related to the small areas of urban and peri-urban development, whereas the higher losses at middle order population densities would have most likely been related to agricultural expansion. Any losses through forestry in areas of lower population densities appears to have been balanced by similar gains in these areas through forest growth and protection areas.

The analyses reported in the preceding sections provide a reasonably clear picture of where land use changes, in terms of vegetation changes, have occurred over the past 10 years. By combining NDVI analyses with common knowledge of the regions and recent satellite images, conclusions were drawn of specific causes of land use change, which indicated that the NDVI analysis technique worked well. In the following sections, the NDVI analysis of land use change will be complemented by assessments of statistical evidence of land use patterns for the country and the four target provinces.

Evidence from Agricultural and Forestry Statistics

In addition to direct analysis of satellite data, land use changes can be by explored through the agricultural statistics available for the Lao PDR. For this purpose, data was collected from the FAOSTAT database, from the Ministry of Agriculture and Forestry (MAF), and from the Provincial Agriculture and Forestry Offices (PAFO) in the four target provinces. As seen above, land use change can be driven directly by non-agricultural development, such as hydropower, mining and roads, but also by major changes in the area of agriculture and forestry.

For the country as a whole, land use statistics indicate that the area of forest declined considerably, by 3.3% (546,000 ha), from 2000 to 2009 (Figure 4.14). This decline in forest area was matched by an increase of area in the categories 'Other Land' (Figure 4.15) and 'Total Agricultural Land' (Figure 4.16), amounting to 253,000 and 293,000 ha, respectively (Table 4.2). The category 'Other Land' comprises such land types as 'Other Wooded Land' (shrubs, savannah, unstocked forest), 'Grassland', 'Urban Areas' and 'Barren Land', although they are not listed separately in FAOSTAT. On the other hand, 'Total Agricultural Land' is reported in the subcategories 'Pastures and Meadows', 'Arable Land', and 'Permanent Crops'. As there is no change in the permanent crops category, and yet we know that the planting of rubber expanded quite dramatically during this period, it is clear that not all agricultural land use statistics are captured by FAOSTAT.

The FAO statistics, which are derived from statistics compiled by MAF, indicate the increase in area under cultivation in major agricultural land categories for the whole country. The source statistics from MAF and the different PAFOs allow for more detailed assessment of changes in land use, for individual crops and at the scale of the province or even district.

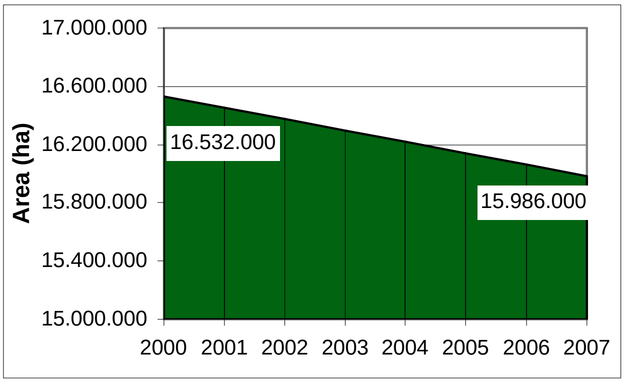


Figure 4.14 Change in Forest Land in the period 2000 to 2007

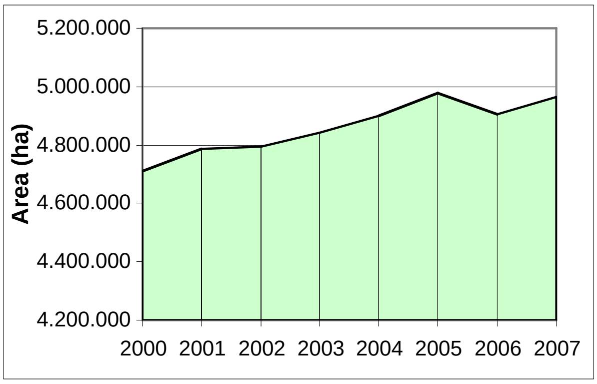


Figure 4.15 Change in "Other Land" in the period 2000 to 2007

Table 4.2 Change in Land Use Categories (ha) in the Lao PDR from 2000 to 2007

	2000	2007	Change
Arable Land	877,000	1,170,000	293,000
Permanent Crops	81,000	81,000	0
Pastures and Meadows	878,000	878,000	0
Total Agricultural Land	1,836,000	2,129,000	293,000
Other Lands	4,712,000	4,965,000	253,000

Source: FAOSTAT

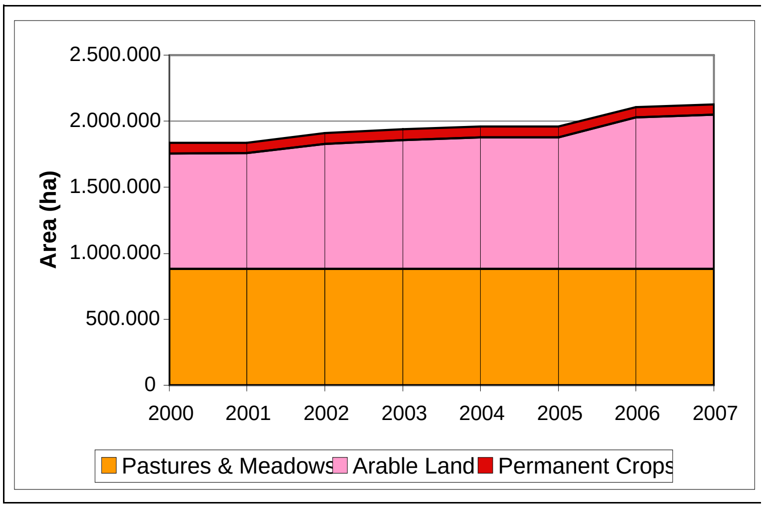


Figure 4.16 Change in Agricultural Land in the period from 2000 to 2007 Source: FAOSTAT

During the period from 2000 to 2007 there was an increase of more than 350,000 ha in total for the cultivation of maize, lowland rice, coffee, and cassava, as well as an increase of about 20,000 ha for sugar cane, peanut, soybean, and irrigated rice (Table 4.3, Figure 4.17). At the same time, there was a large decline in the areas of upland rice and vegetables, totalling more than 60,000 ha. These changes of (275,991 ha excluding coffee and 304,380 ha including coffee) explain nearly all of the increase by 293,000 ha seen in the 'Arable Land' utilized for the whole country (Figure 4.16, Table 4.2). This increase represented a 33% increase in the area of land cropped.

Table 4.3 Change in area harvested (ha) of selected crops in the Lao PDR from 2000 to 2007

	2000	2007	Change
Lowland Rice	475,470	619,950	144,480
Upland Rice	152,100	111,523	-40,577
Irrigated Rice	91,800	94,072	2,272
Maize	49,000	206,770	157,770
Vegetables	104,700	81,305	-23,395
Cassava	1,500	18,335	16,835
Peanuts	12,800	19,377	6,577
Sugarcane	8,400	17,055	8,655
Soybean	6,400	9,690	3,290
Coffee	29,406	57,875	28,469
Total	931,576	1,235,952	304,380

Source: Lao Ministry of Agriculture and Forestry

Just like the FAOSTAT agricultural statistics, the published MAF statistics do not include rubber, although planting of rubber has expanded in many parts of the Lao PDR during this time. Not only was there no data on planting of rubber, the data on some other crops, such as job's tears and paper mulberry, is limited to only a few years. This may be because these crops have been planted only recently, as cropping systems diversify, however, we know that this is not the case for job's tears, which has been grown for many years. In the case of paper mulberry, the lack of data may be that this crop has been regarded more as an opportunistic species that is encouraged to establish during the fallow period, or collected from uncultivated land, rather than being an actively planted crop species, although specific planting of the crop is increasing. The relatively limited period over which the planting area of these two crops (and perhaps others, such as rubber) has been recorded may simply reflect when they started to be considered as important crops, not as a true reflection of when they were first planted (Figure 4.18).

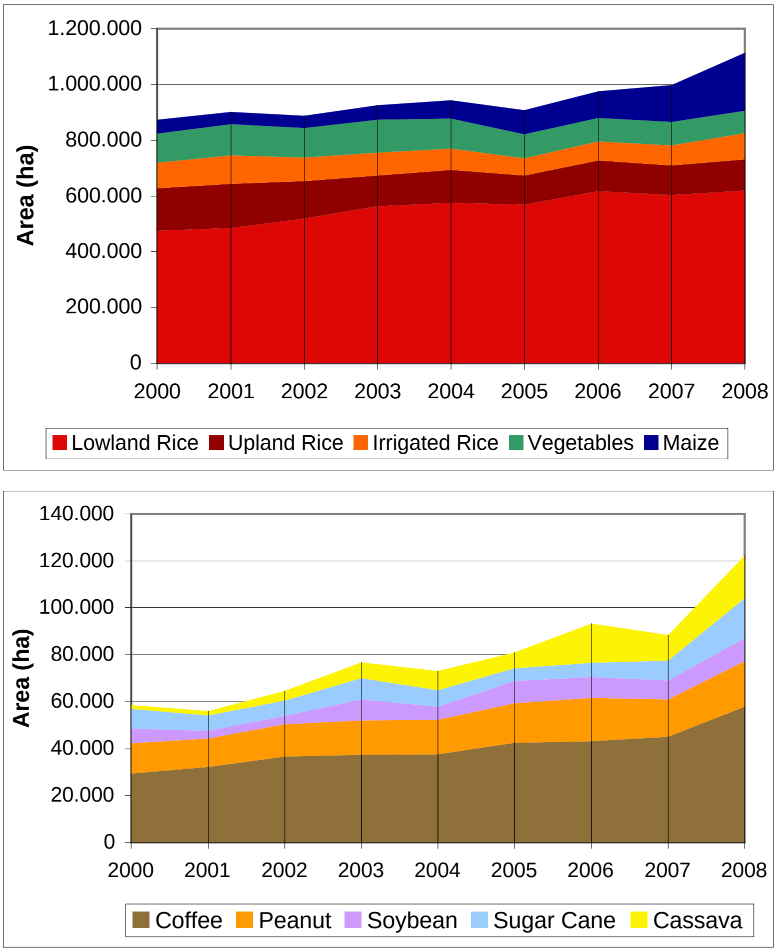


Figure 4.17 Area harvested of selected crops in the Lao PDR
Source: Ministry of Agriculture and Forestry (MAF), Lao PDR, 2009

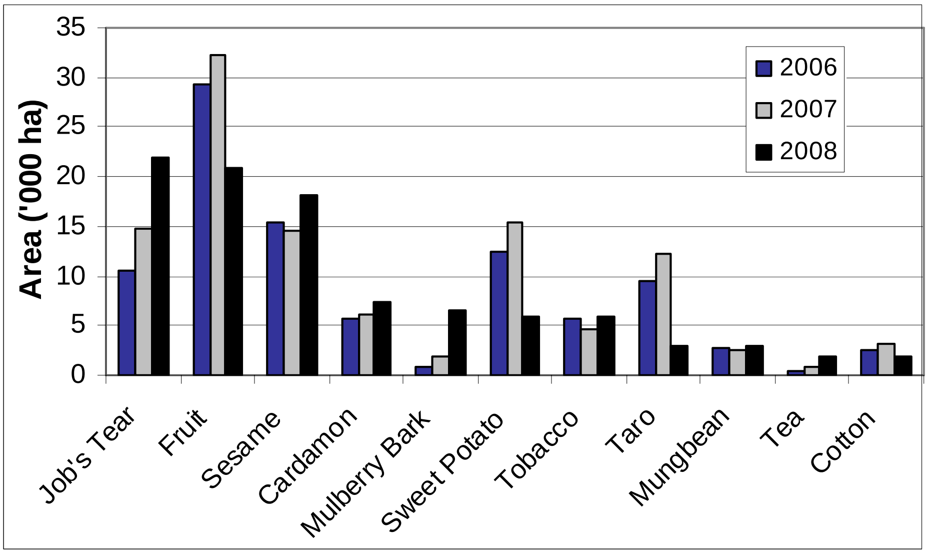


Figure 4.18 Area harvested of selected crops in the Lao PDR
Source: Ministry of Agriculture and Forestry (MAF), Lao PDR, 2009

Analysis of provincial data

Data from **Attapeu** Province indicates that from 2000 to 2008 there was an increase in lowland rice cultivation and a reduction in upland rice cultivation (Table 4.4, Figure 4.19), as was seen for the whole country. The areas planted to other crops were very variable, particularly for crops such as cassava, sugar cane, and tobacco. The area planted to coffee increased slightly. The total area of land cropped in Attapeu, at least for the crops recorded, increased during this period from 19,600ha to 22,000 ha, an increase of 12%, compared to the national increase of 33%. According to the data, the overall area under agricultural production is comparatively low in Attapeu Province, which can most likely be attributed to the low population density, poorer accessibility, and poor soils. Corridor development that has followed the improvement of road links to Vietnam suggests that accessibility, either direct access, access to markets, or both, has been an issue in driving recent land use change (Figure 4.5).

Table 4.4 Change in area harvested (ha) of selected crops in Attapeu Province from 2000 to 2008

	2000	2008	Change
Lowland Rice	12,390	18,289	5,899
Upland Rice	4,465	1,350	-3,115
Irrigated Rice	450	672	222
Maize	449	680	231
Vegetables	887	450	-437
Cassava	245	55	-190
Sugarcane	183	0	-183
Tobacco	310	260	-50
Coffee	230	265	35
Total	19,609	22,021	2,412

Source: Lao Ministry of Agriculture and Forestry

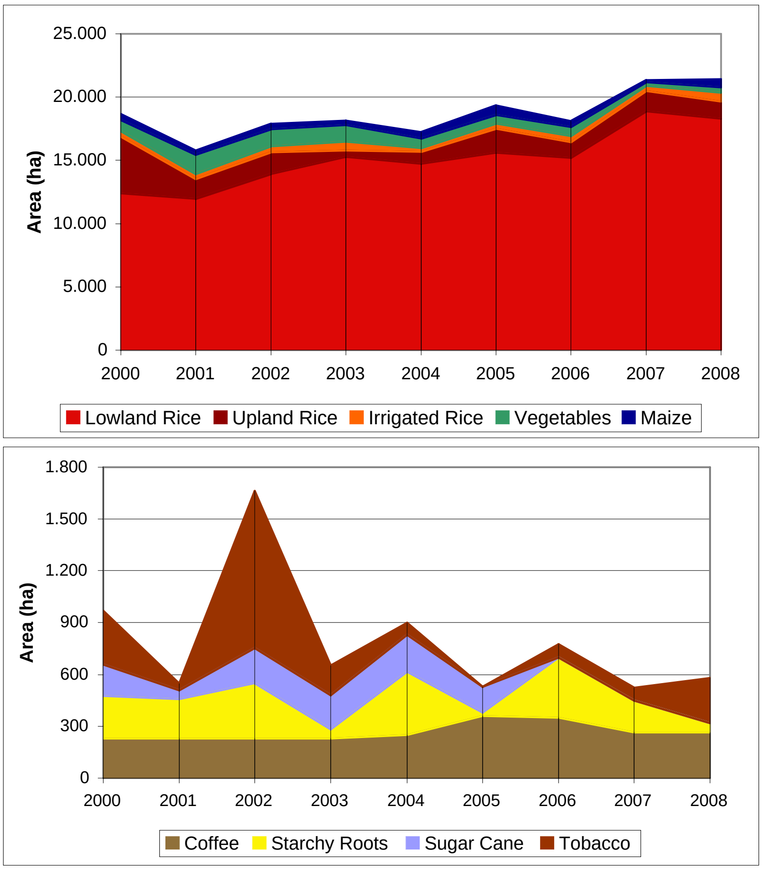


Figure 4.19 Area Harvested of Selected Crops, Attapeu. Source: MAF, Lao PDR, 2009

Agricultural land use in **Luang Namtha** has undergone drastic changes during this period and particularly from 2004 to 2008 (Table 4.5). Although the total area of rice cultivation declined by about 5%, there was a major shift as the area cultivated to upland rice was halved, the area of lowland rice increased by 50% and the much smaller area of irrigated rice went up by a factor of 5 (Figure 4.20). For non-rice crops, the area of maize increased by a factor of 10, of cassava by more than three times, sugarcane more than doubled, and the small area of fruit trees increased even more, as cropping for cash and animal feed increased. The areas cultivated to vegetables, cotton, and soybean declined. The most dramatic change, however, was the area of rubber planted, with more than 22,000 ha planted during this period (Figure 4.21). This is not only a large area of agricultural land, it entails a major shift to perennial cropping and under a wide range of land ownership deals, including concessions, contract farming, and smallholder rubber. Assessment of the areas planted at the district level indicate that sugarcane and fruit dominates in Sing District, maize in Namtha and Viangphoukha, and cassava in Long District (Figure 4.22).

Table 4.5 Change in area harvested (ha) of selected crops in Luang Namtha from 2000 to 2008

	2000	2008	Change
Lowland Rice	7,850	11,221	3,371
Upland Rice	10,576	5,141	-5,435
Irrigated Rice	740	1,882	1,142
Maize	367	3,750	3,383
Vegetables	3,143	1,145	-1,998
Cassava	636	2,270	1,634
Sugarcane	777	1,920	1,143
Soybean	234	30	-204
Cotton	245	105	-140
Fruit Trees	20	343	323
Total	24,588	27,807	3,219

Source: Lao Ministry of Agriculture and Forestry

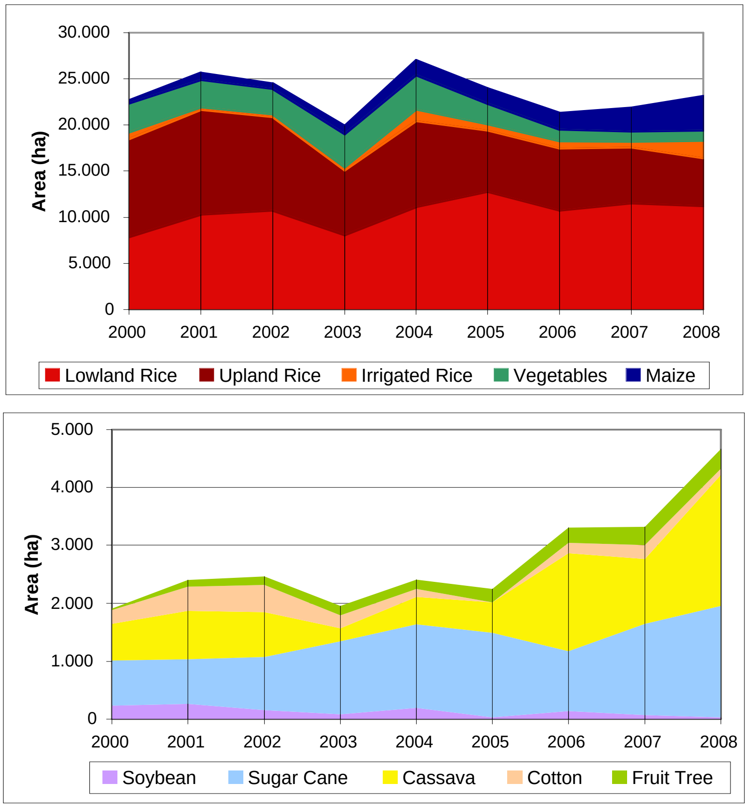


Figure 4.20 Area Harvested of Selected Crops, Luang Namtha Source: MAF, Lao PDR, 2009

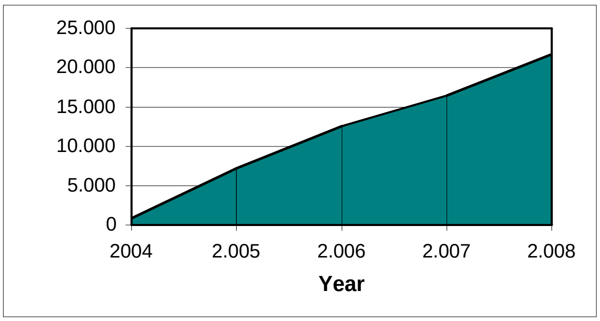


Figure 4.21 Area of Rubber Plantation, Luang Namtha.

Source: Luang Namtha PAFO

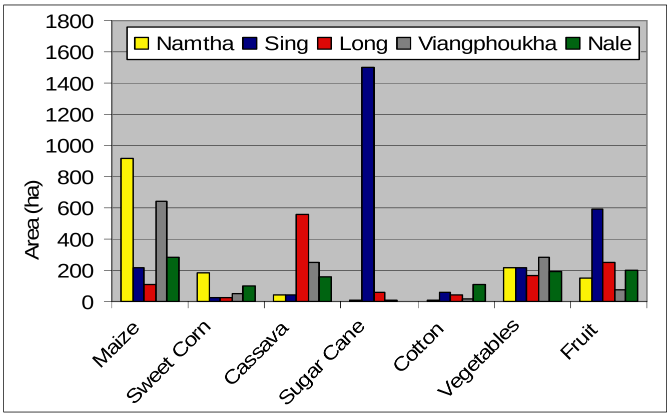


Figure 4.22 2007 Areas of Crops by District, Luang Namtha

Luang Prabang is a larger and more populous province, with a much larger area of cropping. As with other provinces, the area of upland rice has declined massively in this period, to less than 50% of the area in 2000 (Table 4.6, Figure 4.23). At the same time, the area of lowland and irrigated rice has increased, although not to the same extent as the decline in upland rice, so the net area of rice production has decreased, although with more productive systems prevailing. There has been a huge increase in the area grown to maize, as well as large increases in the areas of job's tears, sesame, paper mulberry, fruit, soybean, and cassava, and, unlike much of the country, in vegetables. The total area of arable cropping reported for Luang Prabang in 2008 is about 11% of that for the whole country (Figure 4.17) and the area of arable cropping in Luang Prabang has approximately doubled since 2000, compared to a national increase of 33%

The PAFO staff identified some of the large contiguous areas where NDVI declined (Figure 4.7) as areas in which there had been large areas of rubber planted, for instance in Nambak District, although no official data was available. Another tree crop that has been planted widely in Luang Prabang is teak (Figure 4.24), with a doubling in the area planted over the period from 2000 to 2008, and with substantial areas planted before 2000. At least some of the teak was planted on land formerly used for shifting cultivation, and the impact can be seen in the increase in vegetation (NDVI) in parts of the province, which also matches part of the decline in upland rice cultivation.

Table 4.6 Change in area harvested (ha) of selected crops in Luang Prabang from 2000 to 2008

	2000	2008	Change '00-'08
Lowland Rice	9,770	12,578	2,808
Upland Rice	32,109	15,779	-16,330
Irrigated Rice	1,800	2,176	376
Maize	4,726	34,700	29,974
Vegetables	8,540	11,375	2,835
Cassava	1,500	18,335	16,835
Peanuts	780	2,330	1,550
Soybean	185	2,790	2,605
Subtotal	59,410	100,063	40,653
	2005	2008	Change '05-'08
Job's Tears	5,750	15,680	9,930
Sesame	6,915	12,225	5,310
Paper Mulberry	0	5,525	5,525
Fruit Trees	1,740	2,195	455
Subtotal	14,4050	35,6250	21,220
Total for 2008		135,688	

Source: Lao Ministry of Agriculture and Forestry

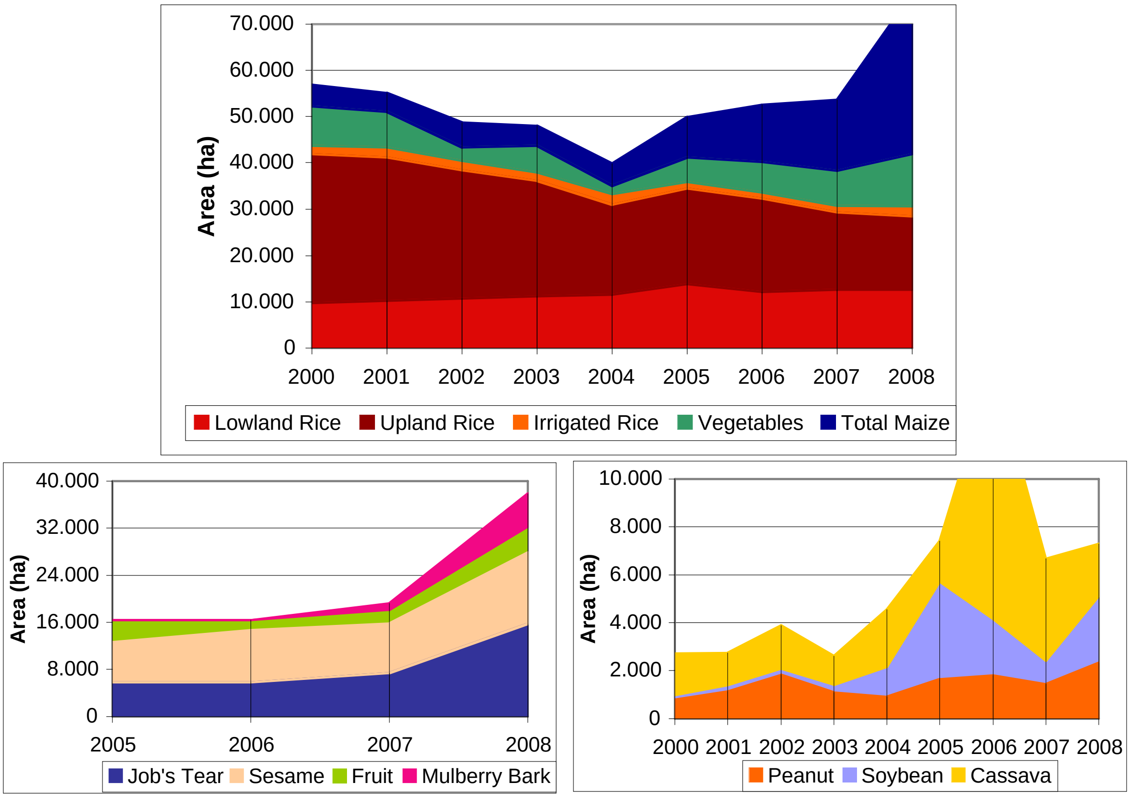


Figure 4. 23: Area Harvested of Selected Crops, Luang Prabang (LP)

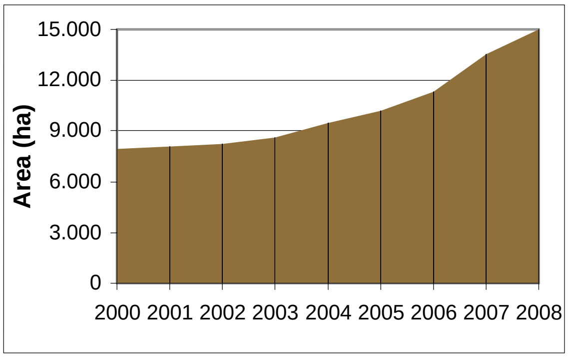


Figure 4.24 Area of Teak Plantation, LP Source: PAFO, LP, 2009

The large decreases in vegetation cover observed for **Sayabouri** Province between 2000 and 2009, particularly in the southern districts (Figure 4.8), is explained by the agricultural statistics of cropping land (Table 4.7, Figure 4.25). The total area of rice cultivation increased, although upland rice cultivation decreased slightly, and the area of vegetables declined, but the biggest change was a ten-fold increase in the area cultivated to maize, which drove an almost doubling of the total area under arable agriculture in the province. The overall area of maize production in 2008 was 58,270 ha, which corresponds to 51% of all arable land accounted for in the MAF data for Sayabouri Province. The other large proportional changes, although much smaller in total area, were an increase in the area of job’s tears and a decrease in the area of peanuts.

The importance of maize in the province is evident not only in the area cultivated to maize, but also the yield per ha, which has double in the same period as the area has increased more than 10-fold (Figure 4.26). During the same period the yield of upland rice has remained fairly constant and the yields of lowland and irrigated rice have increased only modestly.

As the increase of maize is not compensated by an equivalent reduction in other arable crops, this indicates that new crop land was cleared, as was suggested by the change in NDVI (Figure 4.8). Forests in the province, particularly in the south, are under massive pressure through on-going logging activities. Valuable timber continues to be extracted reducing the area of the remaining natural forests, which include one of the larger areas of natural teak in the country. The Nam Phoun National Biodiversity Conservation Area has been established in the west of the province and the NDVI analysis does indicate that over the period from 2000 to 2009 there was a quite substantial area in the south of the NBCA that showed a marked decline in vegetation through some significant land use change.

Table 4.7 Change in area harvested (ha) of selected crops in Sayabouri from 2000 to 2008

	2000	2008	Change '00-'08
Lowland Rice	21,530	27,370	5,840
Upland Rice	14,125	13,450	-675
Irrigated Rice	1,950	2,238	288
Maize	5,586	58,270	52,684
Vegetables	6,758	1,295	-5,463
Cassava	420	540	120
Peanuts	2,439	1,434	-1,005
Tobacco	132	185	53
Cotton	853	85	-768
Subtotal	53,793	104,867	51,074
	2005	2008	Change '05-'08
Job's Tears	1,670	3,940	2,270
Sesame	1,515	1,470	-45
Paper Mulberry	0	1,055	1,055
Fruit Trees	1,325	335	-990
Subtotal	4,510	6,800	2,290
Total for 2008		111,667	

Source: Lao Ministry of Agriculture and Forestry

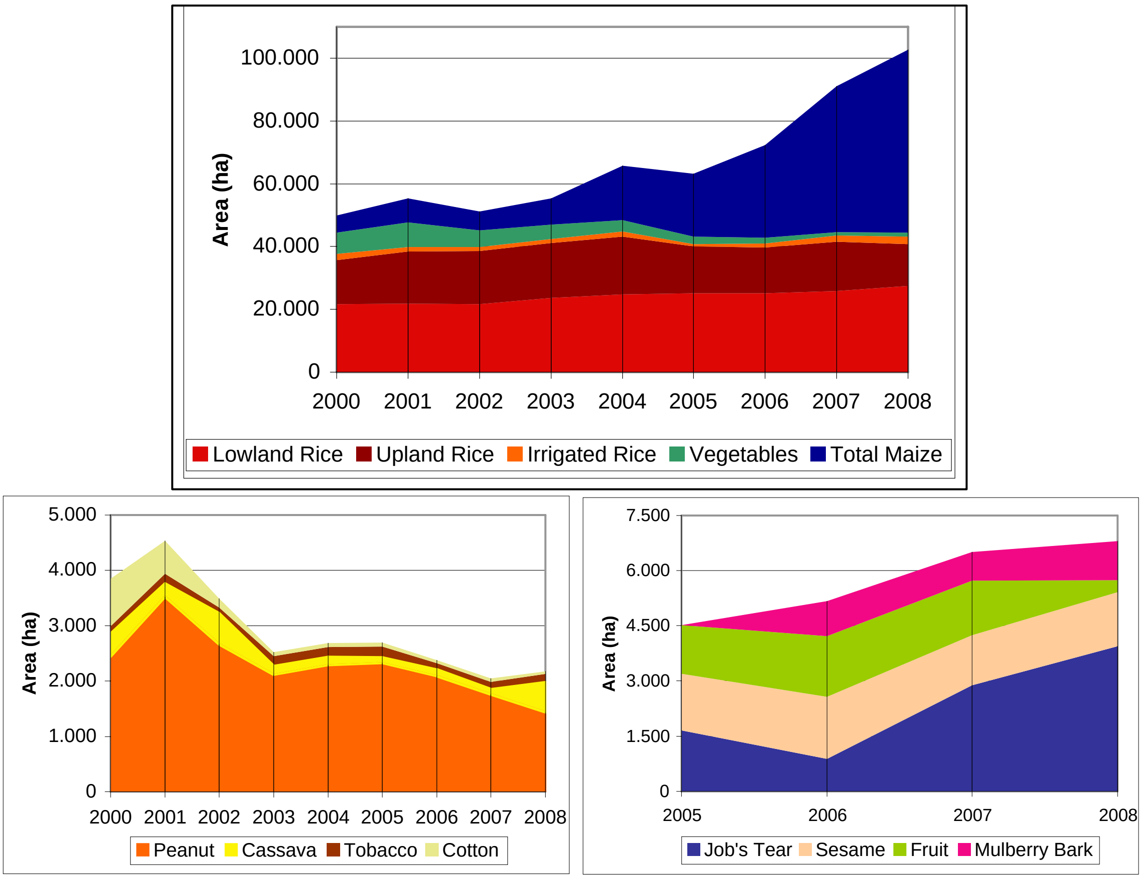


Figure 4.25 Area Harvested of Selected Crops, Sayabouri (SB)

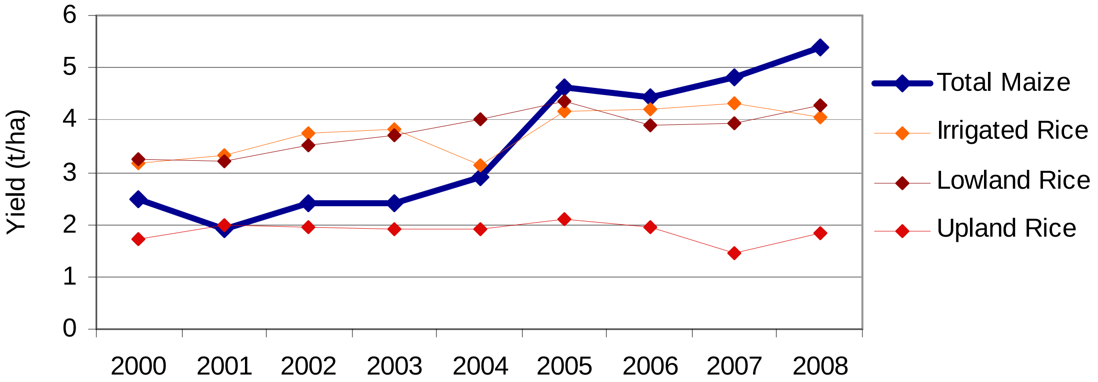


Figure 4.26 Yield of maize and rice in Sayabouri

Other drivers of land use change

In addition to the land use changes driven by agricultural expansion, other factors drive land use change, both directly and indirectly. The development of roads is a case in point. The development of economic corridors and associated transport developments across the Greater Mekong Subregion (GMS) causes significant direct land use change, associated with the construction of the road and the associated infrastructure (Figure 4.27). In addition, these roads provide both direct access for development of agriculture and forestry and greatly improved market access, which is a further stimulus for agricultural and forestry development and thus land use change. The change in NDVI indicates the importance of roads and access, as can be seen by comparing the improved road network (Figure 4.27) with the maps of change in NDVI (Figure 4.4), and especially for Attapeu (Figure 4.5), Luang Namtha (Figure 4.6), and Sayabouri (Figure 4.8).

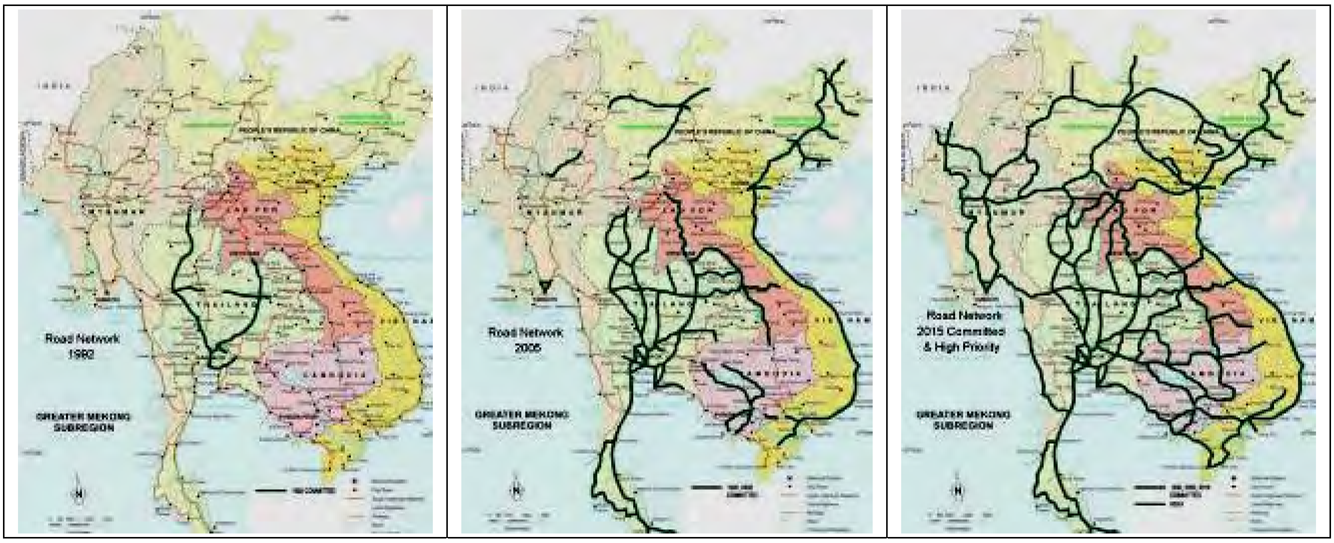


Figure 4.27 Infrastructure Development in the Greater Mekong Subregion, 1992, 2005, 2015 Source: ADB

The impact of hydropower development was seen clearly in relation to the Nam Theun II construction (Figures 4.3 and 4.10). The impact on land use was primarily through the establishment of the reservoir, but with additional land use impacts through the infrastructure for construction and maintenance of the facility, the construction of the dam and associated power generators, the impact on down stream communities, and the longer-term impact on economic development, both locally and across the country. The Department of Energy Promotion and Development within the Ministry of Energy and Mines lists the countries power projects (Table 4.8), which to May 2010 includes 11 operational plants with an output of 1.8GW, another 3.2GW to come from eight plants under construction (including one lignite powered station), all due for completion by 2015, and a further 17.8GW in 70 prospective projects. Of the prospective projects, about one-third are being planned and the other two-thirds are undergoing feasibility assessment. If all of these projects are completed, the energy generation capacity of the country would increase by a factor of more than ten from the current level. While the impacts on land use are not likely to be directly in proportion to the power produced, especially as the prospective projects include dams on the mainstream of the Mekong, rather than the creation of large reservoirs, the impacts on land use can be expected to be large.

Table 4.8 Power Generation: Now and in the future

Status	Number	Power (GW)
In Operation	11	1.8
Under construction [1]	8	3.2
Planning stage	20	6.0
Feasibility Stage	50	11.8

[1] Including a 1.8GW lignite-powered generator Source: EPD, 2010

Mining is another sector that has direct impacts on land use (as was seen with the specific example in Savannakhet in Figure 4.12), with impacts on land use at the mining site, for related infrastructure, such as roads and processing, and through local and broader economic development. The power of the energy and mining sectors as drivers of land use change is indicated by the number and value of approved Foreign Direct Investment (FDI) projects. Of the USD 5.5 billion approved for FDI from 2000 to 2006 (Tong, 2009), 60% was for electricity generation and 9% for mining, which compares to 10.6% for agriculture and the remaining 19% for the other seven sectors, which are, in decreasing order, industry and handicrafts, trading, construction, services, hotels and restaurants, telecommunications, and the wood industry.

4.3 Underlying Drivers of Land Use Change

The previous section outlined large changes in land use that were driven by expansion of the land used for agriculture, but with clear reference to the impacts of forestry, road construction, hydropower construction, and mining. These all have very direct, and some times rather large indirect, affects on land use change. This section will explore some of the underlying causes for land-use change, which are the real power behind the direct drivers mentioned above. These underlying drivers comprise a complex system of interrelations and dependencies between different factors at various levels of society, economy, and policy. Here they are grouped in demographic trends, economic development, and institutional framework.

4.3.1 Demographic trends

South East Asia has experienced rapid population growth in recent decades. In the GMS (Cambodia, Lao PDR, Myanmar, Thailand, Vietnam and Yunnan Province of China) the current population of about 320 million is double that of about three decades ago. As for future growth in population, the current population in the Lao PDR of about 6 million is expected to exceed 10 million by 2050, and for the whole of SE Asia a total population of over 700 million people is projected for 2050 (Figure 4.28). Such population increases are a direct driver of land use change related to the direct increase in demand for agricultural products, for energy, for minerals, and for transport.

4.3.2 Economic Development and Rising Demand

In addition to population growth, another major underlying cause for land-use change is the steady high rate of economic growth in Lao PDR and in the whole region of South East and East Asia (Figure 4.29). In the last ten years the growth rate of the Lao PDR has remained at 5% or higher (ADB, 2008), as in many of the more populous neighbours. This has resulted in a further steady increase in the demand for agricultural and non-agricultural resources.

There is a strong relationship between these two underlying drivers, population size and economic growth, and the amount of agricultural land in use in the Lao PDR (Figure 4.30), which is much stronger than would be see in a country in which the agricultural sector is much smaller, in terms of both size and percentage of the population involved.

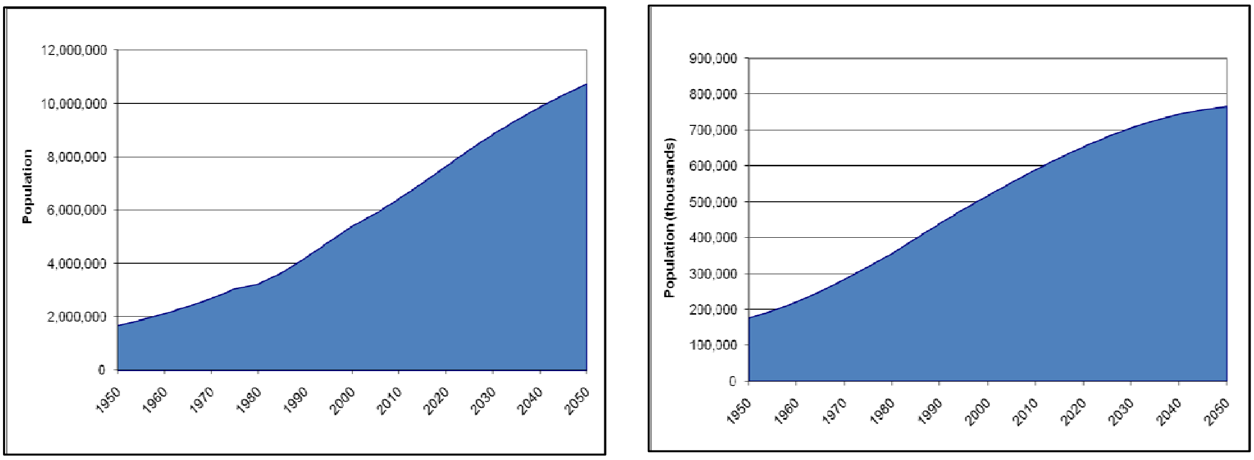


Figure 4.28 Population Growth in (a) Lao PDR and (b) SE Asia (1950-2050)
Source: Population Division of the Department of Economic and Social Affairs, UN Secretariat, 2008

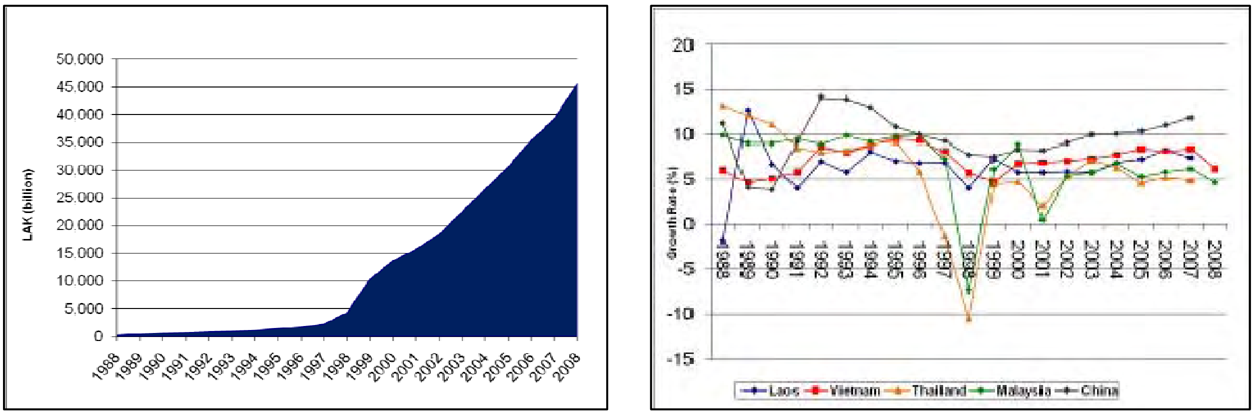


Figure 4.29 (a) Economic Growth of the Lao economy and (b) annual economic growth rates of the Lao PDR and neighbours
Source: Asian Development Bank (ADB), Statistical Database System, 2009 – Online Query

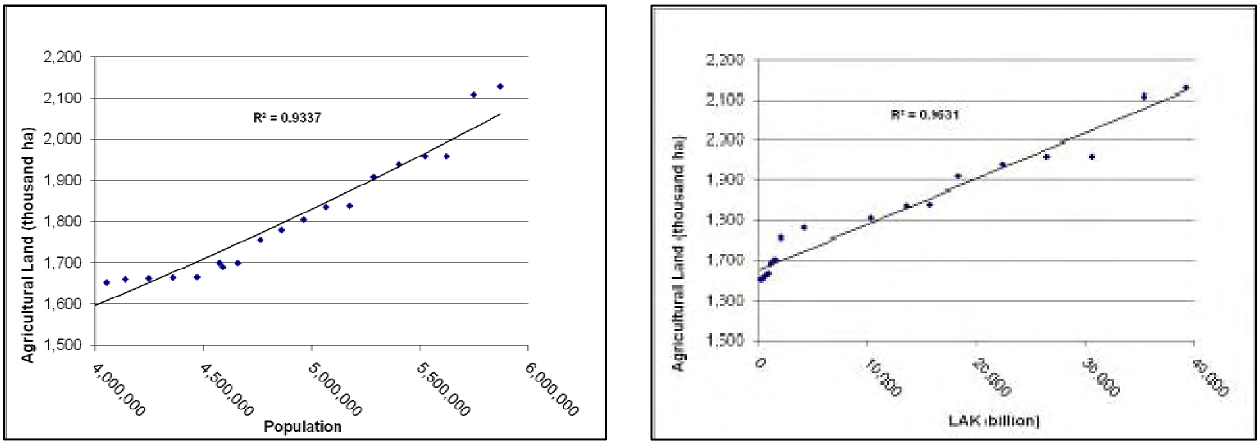


Figure 4.30 Relationship between the area under agriculture in the in Lao PDR and (a) population and (b) GDP (Source: Data taken from MAF, Lao PDR (2009); UN (2009); and ADB (2008))

As economic growth increases the income of people, they change their lifestyle accordingly. Higher incomes and expectations influence consumption patterns directly. This results in changes in diets and so changes in the demand for agricultural products, particularly more meat, fruits, and vegetables. Even if such changes in the diet of the Lao have not happened yet to any great extent, the economic development in China, Thailand, and Vietnam have had these affects and so change the demand for agricultural products in the region and thus from the Lao PDR.

Foreign Direct Investment

A major underlying driver of land-use change in the Lao PDR is Foreign Direct Investment (FDI). Between 1989 and 2008, 54% of all capital invested in Lao PDR was in the energy and hydropower sector, followed by 18% for mining.

The situation in Luang Namtha provides a powerful example of the change in FDI. Since the province started the authorization of state land leases and concessions in 1999 there has been a steady rise in the number of projects approved, with the greatest number being in the agricultural sector (Figure 4.31). The main investments in Luang Namtha are represented by rubber concessions (large and small-scale) and contract farming, with the principle driver being the rising demand for rubber for the rapidly growing car industry in China.

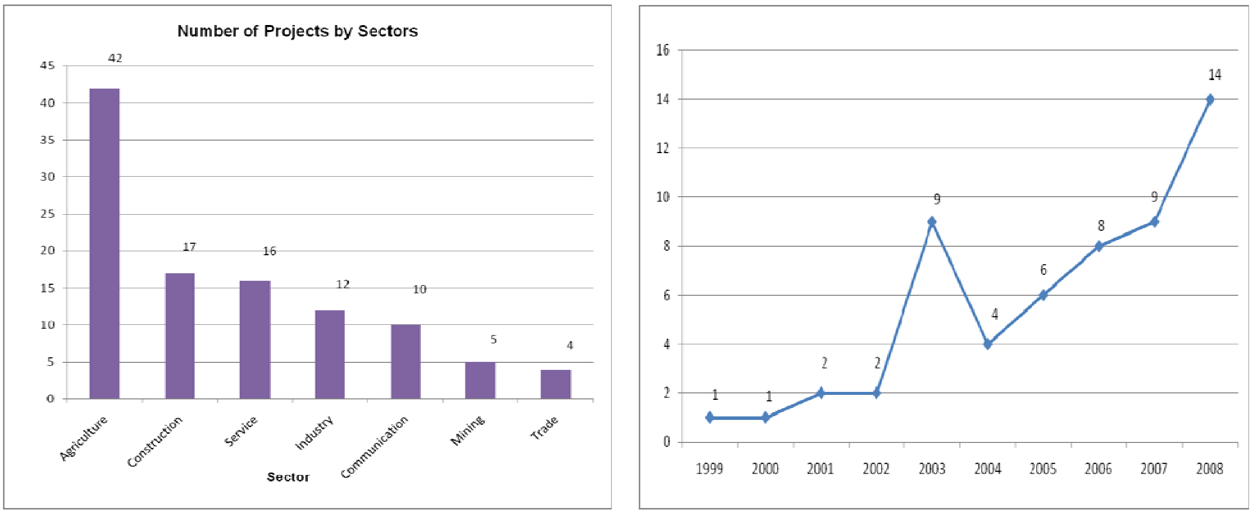


Figure 4.31 Number of projects by sector and number approved (Luang Namtha)
Source: GTZ (2009)

Demand for energy

Land-use change is indirectly driven by the rising demand for energy. In the Lao PDR the greatest potential for energy generation lies in hydropower, which is used domestically although primarily it is exported to neighbouring countries. The development of the electricity sector can be seen through the number of projects and the energy exports (Figure 4.32). The rising demand for biofuel is also leading to an increasing production of, or at least interest in, energy crops such as maize, cassava, oil palm, and jatropha, with the first three having significant non-energy industrial uses as well.

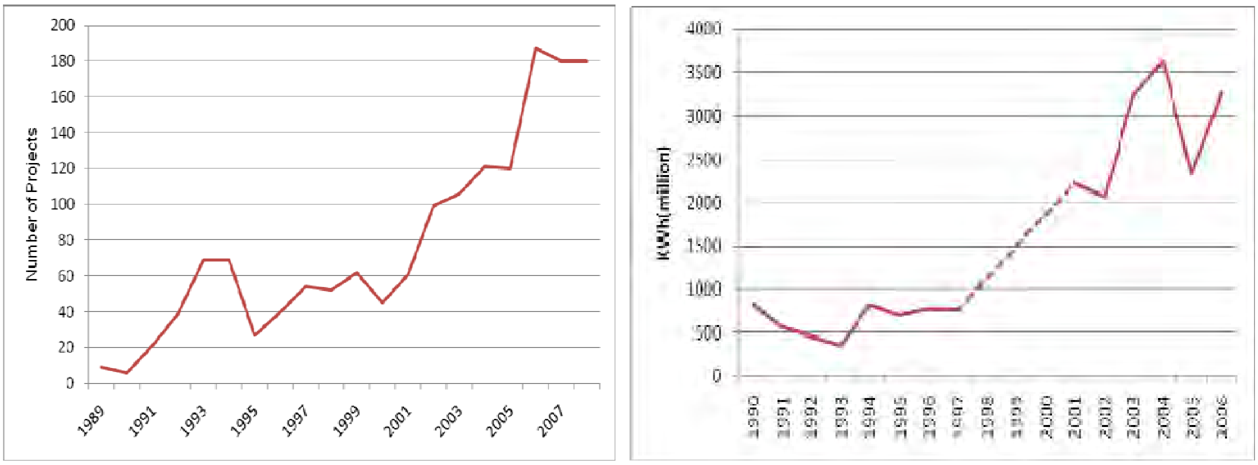


Figure 4.32 FDI and energy exports in Lao PDR (Source: ADB, 2008; Phouphet, 2009)

4.3.3 Institutional and policy framework

Another important driver of land-use change is represented by the institutional framework conditions, such as government policies, legal conditions, or economic incentives. Such preconditions influence the intensity and direction of direct land-use change drivers.

Land tenure and the security of land tenure in rural areas are examples. While the country is undergoing a shift to the issuance of land tenure security and compliance with land tenure laws, the task of establishing land tenure is incomplete and the necessary enforcement of land tenure is not always clear. In many cases local and foreign investors are able to gain access to large areas of land either because land tenure does not exist fully or because the short-term gain of cash to a poor landowner is far more appealing than the benefits of longer-term land ownership and stewardship and the associated production. As smallholders have become more engaged in the market economy so they value their land more highly and thus are less likely to sell or at least expect a higher price.

Other government policies can result in direct land-use change. For example, the strategy of the government on shifting cultivation has probably accelerated the move from slash and burn agriculture to more stable or sedentary systems. Similarly, some of the active resettlement programmes have moved people and as a consequence they have ended up with a very different resource base, which in turn has resulted in changes in farming systems and consequent land use change. Beginning in the 1980s the government started to relocate communities in the northern Lao PDR from upland areas to the lowland. In the 1990s new legislation on conservation imposed restrictions on shifting cultivation. The agriculture systems moved from subsistence to commercial farming at the same time as increasing investment from China brought new economic opportunities for farmers, who started to increase their focus on cash crops (Fox *et al.*, 2009), which can be seen in the documented land use change.

4.3.4 Climate Change

A final consideration as a driver of land use change is climate change. With an understanding of the degree of climate change that has occurred so far (section 2) combined with an appreciation of the very large land use changes that have occurred and the main drivers of these changes (section 4), it can be concluded that climate change has had no major affect on agricultural production or land use change to date. The trends in climate change already observed, for higher temperatures and a delayed wet season, do not appear to have had much if any affect on agriculture or on changing land use, largely because of the already highly variable nature of the current climate, and because of the strength of other drivers of land use change. In addition, with an appreciation of the predicted changes in climate to 2050, and an expectation that the main drivers of land use change in recent years will remain and, in many cases (population, economic growth and expectations, market engagement, FDI, etc.) will intensify, it would appear that climate change will not be a major driver of land use change in the future, at least in the near future. Possible changes in land use that may be caused by climate change or that may help cope with climate change, even if the changes did not result directly from climate change, will be discussed in following sections.

5 Resilience of smallholder farming systems in the Lao PDR

5.1 Background

The analysis of past and future climate change (section 2), the analysis of the current and future crop bioclimatic suitability (section 3), and the analysis of land use change by various means (section 4) constitute the major analyses of this study, but they were complimented by field visits to the four selected target provinces. There were several purposes for the fieldwork. Firstly, there was a desire to gauge the awareness of and understanding of climate change by the provincial and district officials and by villagers. Secondly, there was a need and desire to learn more about land use change on the ground and see if the analyses undertaken, to assess land use change and the drivers of land use change, assess the climate and climate change, and assess the crop suitability, appeared sensible to provincial and district officials, and, where possible, to farmers. Thirdly, there was a desire to learn more about the current agricultural systems, the resource availability, and the resilience of the rural population and their current farming systems and ascertain the potential for change and improvement.

In all four target provinces, Attapeu, Luang Namtha, Luang Prabang, and Sayabouri, a presentation of preliminary findings was made to the PAFO, and in most cases with some District Agriculture and Forestry Office (DAFO) people in attendance. This allowed for feedback on the findings and the provision of additional data. In particular, there were some very useful discussions on land use change measurements, including affirmation of the major changes, the major drivers, and the current and future crop suitability assessments.

In three of the provinces (all but Luang Prabang), two villages in each of two Districts were selected, with the help of DAFO and PAFO staff, and short visits were made to each of these twelve villages. The DAFO and PAFO were asked, where possible, to nominate villages that would present a range in terms of resource availability, agricultural systems, ethnicity, and access to markets, to ensure reasonable diversity for assessing the possible impacts of climate change. The aim of these visits was to gain an understanding of the current farming systems, the risks inherent in these systems, and the interest in, and potential for change. This information was gained through focussed village meetings with anything from just the headman (*nai ban*) and one or two people, through to an assembly of a large proportion of the village population. In most cases, although most of the comments were made by a reasonably small number of people, they did include males and females, and young and old.

In some cases the land use change assessments from satellite images were checked, either with the villagers or by observations. In all cases the perceptions of the villagers to climate change were assessed, in terms of what, if anything, has changed and if they were aware of the issue of climate change.

In all cases there was a great deal of interest in the results presented during the presentations, which were followed by some excellent discussions. The village discussions helped to assess the resilience of their farming systems and resulted in some interesting discussions about diversification and the sustainability of their current farming systems.

5.2 Evidence from the field

5.2.1 Climate Change

There was interest and awareness about the issue of climate change, although little appreciation of likely changes – which is hardly surprising. Amongst villagers there was a reasonably strong impression that temperatures were increasing, particularly, but not only, in the south of the country, in Attapeu,. In several cases villagers identified the time from when they remember hotter temperatures and these coincided with the analyses that suggested temperatures started to increase from about 1993. In terms of temperature change, some said simply that it was hotter, others that the hottest days tended to be hotter, and several commented that they notice that the cooling affect of rain seems to disappear more quickly once the rain stops, so the cooler times in the wet season were perhaps hotter. As far as rainfall is concerned, the main issue was variability, not trends for a distinct change in the rainfall patterns. There was, however, a perception by some that there was a slight shift on the rainfall patterns, with the wet season starting and ending later.

The PAFO and DAFO appeared to be less convinced that the changes in the climate were significant, although many villagers were quite firm in their belief that temperatures were hotter, or at least the extreme temperatures were hotter. The PAFO comments on the amount and distribution of rainfall matched well with their data (and the data presented in Chapter 2), which reflect great variability, not distinct trends. Some PAFO did mention a possible delay in the start and end of the wet season, but the variability of rainfall remained the main issue.

5.2.2 Land Use Change and crop suitability

Many of the PAFO and DAFO staff were very interested by the satellite imagery presented as the change map of NDVI. In most cases they agreed with the evidence of vegetation loss and they were able to provide good explanations of many of the changes for which a clear explanation had not been available immediately. This occurred in all provinces, but a particular example was the large area of vegetation loss in Nambak, Luang Prabang, for which the PAFO in Luang Prabang were able to identify rubber and other concessions as at least part of the cause. In some cases additional data were provided to assist in interpretation of land use change, such as the data on the area of rubber planted in Luang Namtha, although mostly they provided very valuable informed comment, rather than data to back up the observations.

In presenting the data on crop suitability (section 3), we were keen to see if the parameters selected appeared appropriate, and if improvements could be suggested as we expected some degree of disagreement with our initial suitability assessments. In the main, however, there was general agreement with the Ecocrop results. Surprisingly, this was the case with the assessment of suitability for rubber, which indicated that, at least in some instances especially in the north, rubber was not particularly well suited to the conditions where it was being planted. At the time of the field visits, the analysis for low temperature-acclimatized rubber had not been completed, but despite this, at least in Luang Prabang, the PAFO staff were reasonably comfortable with the indication that rubber is not particularly well adapted to the conditions in the province. These analyses also fit with the information that the more successful rubber farmers in the north are those who had direct access to information from relatives in southern China, who in turn were able to assist by sharing acclimatized planting material and in deciding the best locations for planting rubber. This advice on location within the microclimate of their villages probably had as much to do with coping with cooler temperatures and avoiding frost damage as anything else.

5.3 Resilience of smallholder farming systems in the Lao PDR

The resource base and the farming systems covered across the limited number of villages visited was quite large, varying between provinces, between villages within provinces, and, to a lesser extent, between households in the same village. The village visited in Paklai of Sayabouri province was by far the wealthiest, and yet even there the resilience of the farming systems was not very high and was a concern to the farmers.

Before proceeding, it may be necessary to state what is understood by **resilience**. The resilience of a system has been defined as the capacity of a system to absorb disturbance, undergo change and still retain essentially the same function, structure, identity, and feedbacks. While resilience is related to sustainability, the resilience is more a characteristic of the system, while the sustainability is more about the consequences. Sustainability has many definitions, depending on the focus of the sustainability. In the Bruntdland Report (WCED, 1987), sustainable development was defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

In every target province there were villages that had been resettled in the last two decades, mainly from upland areas to lowland areas. This has resulted in a wide range of consequences. In many cases farmers have had to deal with less fertile land or with smaller production areas, and thus significant pressure on their farming systems. On the other hand, there are tangible benefits in terms of access to health care, education, and markets.

An important starting point in the discussions in the villages was the rice security of the households and the village and how this has changed in recent years. If shortfalls of rice occurred, which was the case in every village, and sometimes to the extent of more than 70% of households, the villagers were asked to explain their approaches to overcoming these shortfalls. In most cases the additional rice was purchased with cash from the sale of livestock, other crops, and NTFPs.

The overall impression was that their farming systems were extremely vulnerable to the current variability in climate, particularly rainfall. This is hardly surprising, and in fact is the case in so many farming systems around the world, especially in the tropics and subtropics. To a degree, analysis would suggest that their systems do include a degree of risk management in the sense that different parts of their systems perform reasonably under different seasonal conditions, but at such a low level that their whole farming system cannot be regarded as risk averse. Many farmers described production problems, particularly rice production problems, in different parts of their farm in all years. In the bad years, only a small area of their paddy fields received enough water to yield a crop, and yet in the good rainfall years they reported losing large areas through flooding.

The **rice** cultivation systems in most villages are rather risky, with very little built in capacity to cope with the worst variations experienced in rainfall and water availability. In many cases it seems that much could be done to improve the availability of water and the ability of coping with limited water and even reducing flooding risks. The strategies that may be useful would include better management of the hardpan to reduced infiltration; better use of water delivery channels (in many cases there were dry paddies and yet clearly a lot of surface water was simply running by); improved levelling of paddy fields; use of storage ponds for water, which can also be used to supply water to vegetables and animals; in some cases the potential for using groundwater from tube wells should be investigated; and finally, as a last option, some irrigation schemes could be established or improved, although many of these could be very simple irrigation schemes established by individual farmers or groups of farmers, although not necessarily major infrastructure projects. All of the above could help manage water better and so achieve better establishment, reduce the impact of intra seasonal dry periods, and extend the water supply at the end of the season to ensure good grain fill.

In some cases, where villages were established recently or have expanded their paddy fields it is likely that there has simply not been sufficient time to establish level paddy fields with good hardpans and with good water delivery systems. In these and other cases, a shortage of labour, of cash to cover some expenses (or at least offset the labour required), and a lack of knowledge may have been as important. Well targeted research and extension could have significant impact in improving rice cultivation.

There is potential to develop new rice varieties that use less water, or use water more efficiently, through so-called aerobic rice cultivation. In addition, with the identification of a submergence tolerance gene, it should be possible to develop rice varieties that can tolerate extended periods of inundation. Even before such varieties are available, it should be possible to use the current range of rice varieties. Currently, farmers rely on a limited number of rice varieties and these cannot be selected particularly well to suit the intra-farm variation or, perhaps more critically, be able to cope with the differences between wet seasons. Farmers should be assisted to select the best varieties for different parts of the farm and even to decide which varieties to plant and where, although normally this can be done only once there is an indication about how the wet season is likely to develop. Many people wonder why short season varieties are not used more, especially as they are likely to perform much better if there is a delay in the start of the wet season or if the wet season ends early. The problem is that they waste a lot of potential yield <u>if</u> the season is good, so farmers quite understandably take a gamble and frequently opt for their more traditional longer season varieties, partly as they know them better, but also in the hope that the season will turn out well. If appropriate seed supplies were available, either stored by the farmer or from input suppliers, then it could be possible for farmers to make informed decisions for different parts of the farm and perhaps even for different parts of the farm once there is an indication of how the season is likely to develop. While this may be an expensive strategy, in terms of seed storage, seed availability, and seedling production, the risks would be greatly reduced if some of the measures to improve the availability and delivery of water were combined with improved varieties and improved capacity to choose varieties.

The land and labour use efficiency of paddy rice, as opposed to upland rice, has become increasingly obvious to farmers, especially those in the uplands where fallow systems have reduced such that soil fertility is lower and weed pressure is significantly higher. In many of these areas, wherever possible, upland rice farmers have become paddy rice farmers, with significant development of lowland rice in the uplands, which has also helped move towards the cessation of slash and burn agriculture. The returns on shifting from upland rice to paddy rice, especially the returns to labour, plus the reductions in risk, are very clear, and yet there is much that can be done to improve these systems. Improvements can be in terms of water delivery to these paddy fields, more efficient use of the water once in the paddies, and improved farming systems, with pre- and post rice crops that can help with weed management and soil fertility improvement, as well as for provision of animal feed. There should be potential for selecting and breeding rice varieties that are better adapted to these lowlands in the uplands, based on pest resistance and the possible inclusion of Japonica/Javanica rice genes in these varieties.

Once the stability of the rice production systems has been improved, be they traditional rainfed lowland rice systems or the expanding lowland rice paddy fields in the uplands, then there should be much greater potential for improved agronomy through the use of appropriate soil fertility improvement and pest and disease control.

In addition to improving rice production systems, there is a great deal of potential to improve other parts of the farming system, which in turn would take a lot of pressure off rice production.

Livestock are recognized as an important component of household livelihoods. In many cases, it was the sale of livestock that was used to overcome rice shortages. Despite the importance of livestock, it is clear that there is a great deal that could be done to improve their livestock systems. In most cases the villagers can be considered as keepers of livestock, not producers of livestock. The turn-off of animals appears to be very low, and it is almost certain that diseases reduce production, or worse still, lead to death of animals, and that fertility rates are low, in terms of time to maturity, number of live births, and survival of the off-spring. Improved feeding systems, based on village production of crop residues and high quality feeds, will address all of these problems. Once farmers have shifted from being keepers of livestock to being producers of livestock then they will be better placed to manage livestock diseases, begin to improve other aspects of management, such as housing and breed management, and then become truly engaged with markets, so they sell animals when they can make the greatest profit, rather than just as a necessity.

A final but important benefit of improved livestock production is the increased availability of manure, which can contribute to greatly improved crop production, with subsequent additional benefits to village livestock systems through more crop residues and the capacity to improve animal feed production.

Most villagers appeared very interested in methods for improving their animal production, management, and marketing systems. This is an obvious area for increased and improved extension activities and the development of ways in which smallholder farmers can be encouraged and assisted to improve their livestock systems.

The production of **non-rice crops**, both annual and perennial, was important to many farmers, if for no other reason than these crops were a source of income to make up for rice shortfalls.

The case of **maize** production in Sayabouri is an interesting case. The area planted to maize and the yield of maize have increased dramatically in Sayabouri in recent years. Despite this, it is clear that many of the maize production systems do not have a high degree of sustainability. The preferred method of cultivation of maize is in fields, often with quite steep slopes, that are ploughed by large tractors that back up the hill and then plough straight down. This is leading to substantial soil erosion and thus reducing the sustainability of these systems very quickly. As was discussed earlier, farmers recognized the soil loss and recognize at least some of the implications in terms of causing sedimentation in the rivers and streams, which in turn had caused flooding, even in a year that did not have particularly high or heavy rainfall. The value of the soil that is lost is not always appreciated, which is why soil conservation techniques are not easily adopted, but perhaps reducing erosion to reduce sedimentation and thus flooding is a more tangible reason for action, at least until the soil fertility benefits of reducing soil erosion become evident.

A range of **no-till conservation agriculture systems** have been demonstrated and shown to work, but, as admitted by the farmers and the extension officer, the adoption is not good. While it would be good to move towards no-till or minimum tillage system, the first achievement has to be that farmers adopt improved management systems, even if they do not immediately adopt the best management systems.

Contour ploughing, sometimes with the use of hedgerows or simply uncultivated strips, has been practiced on these soils in limited instances and shown to work well. While initially the ploughing can be difficult, within a short time small terraces are formed, which make cultivation easier and further reduce erosion. Once these systems have been established, then the move to no-till or minimum till can continue.

Whether through maize, other annual crops, or perennial crops, the introduction of diversity in the farming systems adds a great deal in terms of both biological resilience (with improved capacity to cope with variations in climate, pests and diseases, etc.), and economic resilience (with the benefit of being able to cope with variations in the market price of products or the costs of inputs). Most villagers appears to value diversification, although it is clear that much more can be done to develop and manage production in more diverse farming systems and even more can be done to achieve better market linkages so that economic resilience becomes a cornerstone of their farming systems.

The case of **perennial crops** is interesting. The right perennials can provide a steady source of income once established, but they do take time to establish and there is always the risk of massive changes in the market situation as other suppliers, with lower costs, enter the market.

One incidence of a perennial that we saw was the establishment of Jatropha in Hongsa district of Sayabouri. Jatropha should be well adapted to the area (Figure 3.21), although the yields the farmers had been told to expect by the buyer (who supplied the planting material) sounds very optimistic, as does the price they have been promised. If the yields and prices do not materialise, then there are other options that can be considered.

Non-timber forest products are another important source of both food and cash in many areas. While domestication, if appropriate, and better management of forests, are methods for increasing productivity, the largest gains as far as NTFPs are concerned is probably through improved marketing. One benefit of improved farming systems is that they can reduce the pressure on the forests, which can in turn not only increase the production of NTFPs, but can also lead to a range of environmental services including better management of resources such as water for village use, whether for household use or for agriculture.

The developments outlined above, in terms of changes to the current farming systems, would reduce the riskiness of these systems in the current biophysical and economic climates, and these more resilient and productive systems will contribute to improvements in livelihoods and so reductions in poverty. In addition, most of the improvements suggested in cropping and farming systems, should also be much better able to cope with any changes in climate that are likely to develop over the next decades. Thus, the response to possible, or even likely, climate change should be to improve the resilience of the current farming systems in the current climate. In terms of specific developments aimed at agriculture in a changed climate, the crop suitability assessment suggested several crops that are likely to become more suited to production, such as cassava and sugarcane. They need to be considered carefully within new and improved farming systems and in terms of their requirements for processing and marketing. At the same time, some crops are likely to become less well suited to the changed climate, such as maize and soybean. In these cases more tolerant varieties need to be accessed or bred, and more appropriate farming systems developed to reduce the negative impacts of the expected changes in climate.

6 Conclusions and Recommendations

6.1 Results and Conclusions

This study on climate change and land use change has involved four separate but related components: (i) to analyses the changes in climate over the last 100 years and the likely change in climate up to 2050; (ii) to assess the suitability of crops to the current climate and how suitability will be affected by climate change; (iii) to study the recent changes in land use and to identify the main drivers of land use change; and (iv) to assess the current farming systems and the changes that may be required to cope with climate change.

Analysis of past/current climate

The analysis of long-term climatic conditions in the Lao PDR shows very clearly that the climate is very variable, and most particularly the amount and distribution of rainfall includes huge year to year and within year variations. This variability introduces a great deal of risk and uncertainty into the agricultural systems, which is a major concern to marginalized smallholder farmers who have very little in the way of cash or non-cash reserves. Analysis of the Lao climate from 1900 to 2002, using a reconstruction of the climate based on the Climate Research Unit dataset, highlighted the variability, but also did show some significant trends in climate variables. During the 20th century, the minimum, mean, and maximum temperatures increased throughout the country, but particularly in the south and mainly in the last decade of the century. Minimum and mean temperatures rose by between 0.1 and 1.0°C, and maximum temperatures rose by between 0.5 and 4.5°C. Discussions with villagers, especially in Attapeu, indicated that they were aware of these changes and that the temperature increase started in the early 1990s. In one village in Attapeu, 1993 was mentioned specifically, which is exactly the time indicated by the analyses as the start of the period from when large increases in maximum temperature were observed, especially in the south of Laos.

There were significant trends in rainfall patterns over the century, but even these trends remained within the range of the highly variable rainfall patterns. The trends varied for different parts of the country. The main change was a reduction in the rainfall in May, by between 4 and 50mm, and an increase in the rainfall in October, by between 4 and 20mm, which produces a slight delay in the wet season. In some parts there was a slight increase in April rainfall. Total rainfall tended to increase by up to 115mm in the lower north and upper central part of the country, and decrease by up to 200mm in the upper north, lower central, and south of the country. A delay in the wet season may be an issue for photoperiod sensitive crops and varieties, including many rice varieties, in which flowering is triggered by shorter days, although if the delay is relatively small there may be a net benefit in those areas where a dry period during grain filling can reduce yields. A slight increase in April rain may increase the slight bimodality of the wet season and introduce greater risk of a "false start" to the wet season, in which the dry period after the opening rans is too long. These trends need to be seen in the context of the overall variation between years. As an example, in the period from 1953 to 2004 the average annual rainfall was nearly 1300mm, but the driest and wettest years in this period showed a threefold range in the total amount of rain received, from just over 500mm to more than 1800mm (Figure 2.13). It is little wonder that there is such an element of risk in Lao farming systems.

Projections of the future climate

Using the mean projections of seven Global Climate Models and based on the A1B IPCC emission scenario the changes in climate were predicted for 2020 and 2050. The A1B scenario was seen as a reasonably conservative scenario, with continued rapid economic growth, population peaking in the middle of the 21st century, a reduction in regional differences, and the adoption of efficient technologies, albeit with only a partial shift away from fossil fuels. It yields lower GHG emissions than some scenarios, which continue to rely on fossil fuel, but much more than scenarios that move more quickly away from fossil fuel and towards greater use of resource-efficient technologies. The continued growth of GHG emissions in the first decade of the 21st century suggests that perhaps the A1B scenario is less easy to achieve than first thought.

The analysis predicted that by 2050 the minimum and mean temperatures will increase by up to 2°C, compared to the mean value for 1982-2002, and the maximum temperature is predicted to increase by up to 5°C. It must be remembered that the mean temperatures for 1982-2002 were less than the temperatures at the very end of the 20th century as much of the increase in temperature during the 20th century occurred in the final decade. This means that the increases in temperatures from now until 2050 should be less than projected as some of the projected increase has occurred already.

The predictions for rainfall suggest that rainfall in May will decrease further and that rainfall in April and October will increase, which constitutes a continuation of the trend seen in the 20th century for a delay in the wet season, as well as increased risk of a false start to the wet season in April.

In addition to considering the mean values of temperature and rainfall, there is a need to consider the extreme events of extreme heat and cold and of floods and droughts. There is very limited capacity for prediction of extreme events in the Global Climate Models, largely because, by there very nature, they involve and require far greater temporal and spatial resolution than the annually or monthly means. Having said that, however, there is good evidence that the changes observed in mean values are driven, at least in part, by changes in the extreme values. In particular, where increases in temperatures have been observed the trend has been for changes in the extremes of night time temperatures - less cold nights and more hot nights - more so than the extremes of day time temperatures. For rainfall, even where there has been limited change in the overall amount of rainfall, the incidence of heavy and very heavy rainfall appears to have increased. While the incidence of storm events, such as tropical storms and hurricanes, is highly variable, and is frequently influenced by such regional factors as the El Nino-Southern Oscillation, there is evidence that the number and intensity of storm events has increased in the last three decades of the 20th century, and the expectation is that this trend is likely to continue and strengthen.

In summary, the climate in the Lao PDR has become and is likely to continue to become hotter and with a slightly delayed wet season. The variations in rainfall, even if the trends are for significant change in rainfall patterns, are within the order of the normal year to year variations, so the climate change induced variations in rainfall patterns are unlikely to be observed easily, at least for some time. As the annual variation in rainfall is so large it may be that the longer-term trends in climate are masked and so lead to some complacency. For this reason, it is important that the climate is monitored carefully so as to keep track of the many changes that may occur. The incidence of extreme events, such as hotter nights and days and heavy storms, is likely to increase.

Climate variability, and in particular the large yearly and monthly variations in rainfall, irrespective of climate change, will remain the dominant climatic issues as far as Lao agriculture is concerned, especially as most current farming systems are particularly susceptible to variations in rainfall patterns, whether they result in drought or in inundation.

Crop suitability: Current and projected

The bioclimatic suitability of 17 crops/trees was assessed against the current and predicted 2050 climate using the Ecocrop model based on temperature and rainfall limits to growth. While this approach is robust, the results need to be interpreted carefully. Firstly, the model parameters used in these analyses were for average varieties or accessions, and yet we know that varieties vary substantially in their tolerance of cold, heat, flood, and drought. Secondly, soil quality and the incidence of pests and diseases, which are not included in Ecocrop, have major impacts on crops and thus on crop suitability, and some of these effects can compound bioclimatic effects. For instance, a crop that is flood sensitive may grow well under heavy rainfall conditions on a light textured soil, while a drought-prone crop may grow quite well under relatively low rainfall conditions on a soil with a large capacity to store water. Thirdly, the management of the crop can have a large bearing on bioclimatic suitability. A well-mulched crop or a crop that has developed a good, deep root system as a result of fertilizer applications will be less likely to suffer from water shortage under the same rainfall situation than a crop that has been managed differently.

Analysis of crop suitability under the current climate matches current cropping patterns for most, but not all crops. Maize showed large differences in suitability in different parts of the country, but, although widely grown throughout the country, these differences in suitability were reflected in the relative importance of maize in different provinces, and especially the large amounts of maize grown in Sayabouri, Huaphanh, Luang Prabang, Xieng Khuang, and Oudomxay. In contrast, the expansion of rubber in the northern provinces does not reflect the assessed suitability, compared to the suitability in the south. This may partially reflect the more cold-tolerant clones being used in the north, but it is also probably indicative that rubber is being grown in less than ideal environments.

Across all crops, the change in bioclimatic suitability for the predicted 2050 climate was positive for seven crops: Indica-type paddy rice, Indica-type upland rice, cassava, sugarcane, banana, rubber; and teak; eight crops showed a decline in suitability: maize, soybean, common bean, chilli, sweet corn, Arabica coffee, Jatropha, and eucalyptus; three showed little change: Japonica-type paddy rice, Japonica-type upland rice, and peanuts; and one, Robusta coffee, showed areas of large increases in suitability and areas of decline in suitability.

Of the negative changes in suitability, the most critical is probably for maize, which has become an important cash crop for smallholders in recent years. There is scope for improving the current maize production systems, as for other crops, which should make them more resilient in the current climate and likely to make them more resilient as climate change develops further towards the predictions of 2050. In addition, being such an important crop worldwide, it is likely that there will be further developments in terms of improved varieties that can cope better with the bioclimatic environments expected in the future. The main challenges in this area are likely be the development of greater tolerance to higher temperatures and to drought. Similar changes in varieties of soybean may be important to maintain production for both human and animal feed.

Without a clearer understanding of exactly where the different crops are grown currently, how crop suitability changes in these areas, and how directly suitability is related to production, it is difficult to say how the overall productivity of cropping will change with climate change. The benefits to suitability and thus productivity for some important crops (rice, cassava, sugarcane) may well out-weigh any negative impacts of reduced crop suitability or other crops (maize and soybean), but further analysis would help to predict likely changes in agricultural production.

Land Use Changes

The analysis of land use and land use change indicated large changes in land use in recent times, with a specific focus for this study on the period from 2000 to 2009. The area of land used for agriculture in the Lao PDR increased significantly during this period, and this, at least in part, explains the reduction in vegetation cover seen across the Lao PDR through analysis of satellite images. Other causes for reductions in vegetation cover are forest logging, the development of hydropower schemes, mining, road construction, and urban development. All of these changes are being driven by population growth and economic development, both within the Lao PDR and in the neighbouring countries, with a specific driver, at least for some sectors, being the increasing levels of Foreign Direct Investments.

There is no evidence that the changes that have occurred in the climate of the Lao PDR, especially those in the last decade of the 20th century, have had a significant affect on land use change. Similarly, with the main drivers of land use change – population growth, economic development, and foreign direct investment – showing no sign of reducing in the next years, and in fact quite likely to increase, there is no evidence that the predicted changes in climate to 2050 will have major affects on land use change compared to the affects of these major drivers. This does not mean that both land use and climate should not be monitored carefully, nor that some adaptation strategies to cope with current climate variability and projected climate change should not be considered as relatively high priority, but it is unlikely that climate change will affect land use change significantly compared to other drivers of change.

6.2 Recommendations

Assessment and monitoring

The methods used for analysis of land use change, and specifically the use of MODIS NDVI from satellite images, proved to be both novel and very useful. This technique warrants further investigation and development as a tool for monitoring land use and land use change, whether as affected by climate change or not, as well as for use in more specific studies. For instance, much greater use could be made of the temporal information on NDVI, with data recorded every 16 days, which was hardly explored in this study. Such information would allow a much deeper understanding of the crop-fallow cycle and comparative recovery rates in different parts of the country under different climatic and management conditions. Analysing changes in NDVI with changes in climate (both temperature and rainfall) may allow for a better understanding of both the impact of the current climate, of the variability in that climate, and of the climate change that is occurring.

As new satellite image sources, with greater resolution, become available and affordable so these techniques will become even more useful. The current resolution means that each pixel is most likely to include a mosaic of land use types, but as resolution increases so the possibility for following individual land use types increases, thus allowing greater understanding of the dynamics of different farming and forest management systems and the comparative impacts of both climate and management. This form of analysis and monitoring could become an important tool in the work of the Climate Change Office of WREA and of MAF, or of their technical support partners, in monitoring forest cover, agricultural land expansion, NCBA integrity, and many other aspects of land use.

Easy access to high quality data on agriculture, forestry, population, expenditure, and economic development, as well as to comprehensive meteorological data, is essential for monitoring land use change and particularly with respect to climate change. The more readily these data are available and the better the quality of the data, the more likely that good studies and monitoring of development can and will be undertaken. The current systems of data access is not easy. Detailed data on crop and livestock production and on climate measurements have been collected at the District level for many years, but it does not seem possible to access this information readily, and only an incomplete set of information for the Provincial level is accessible in hardcopy. A reliable electronic database of these parameters is essential for the work of government and would greatly assist future studies on climate change, agricultural expansion, forestry and biodiversity, and many other topics.

Risk reduction

The current farming systems of many villagers in the Lao PDR have high levels of risk, with little resilience, and, in some cases, with limited sustainability and quite low productivity. Much of this risk is associated with the current climate and particularly with the very variable rainfall patterns. Any measures that can be taken to reduce the risks associated with the current variable climate are almost certainly going to help villagers cope with any changes in climate. There are a number of broad approaches to coping with the current variation in rainfall and these include (i) reduction in the losses of water, (ii) better management of the supply of water, and (iii) management of the demand for water, largely through greater water-use efficiency. Specifically, these approaches could include (i) mulching, cover crops, reduced tillage, and cropping systems management to reduce water loss; (ii) water capture, diversion, levelling, controlling across a mini-watersheds, and gravity and pumped irrigation to better manage the supply of water; and (iii) changes in the cropping and farming systems, including the crop varieties and species, to manage the demand for water and to use water more efficiently. Of course there are other aspects of the farming systems that need to be addressed, such as efficient nutrient application and cycling, appropriate pest and disease management, and appropriate market linkages, and each of these can have important direct and indirect affects on water use efficiency, but the main issue regarding land use and farming systems related to climate and climate change is the highly variable and often inadequate rainfall.

The specific selection and combination of these broad approaches will depend on the specific farming system and the resources of labour, capital and information available to the farmers. Some examples were provided in section 5, as well as in the following paragraph.

Improving productivity, sustainability, and diversity

There are a number of options for improving the sustainability of the current farming systems and these can be focussed on (i) increasing the availability of water and the efficiency with which it is used in lowland rice farming systems, (ii) increasing the sustainability of non-rice cropping systems, such as maize, which have significant risks due to unsustainable land management practices, especially related to soil erosion and degradation, (iii) improved livestock production and better linking of livestock producers to markets, (iv) more diversified cropping and farming systems, based on rice, other annual crops, perennial crops, and livestock, so as to achieve greater biological and economic efficiency and resilience, and (v) improved management, and perhaps specifically marketing, of non-timber forest products.

While there are a number of areas in which the research, development, and extension efforts in the Lao PDR could take a specific focus on preparing for changes in climate – and particular cases would be in the selection and breeding of maize and soybean varieties that are more tolerant of the predicted climates – however, greatest benefit is likely to result from focussing on achieving more sustainable farming systems for the current climate. The aim of research activities should be to develop improved, more resilient, and more sustainable farming systems for the current farming systems. The effectiveness of these research efforts are likely to be gradual, like climate change. This poses significant challenges in both research and extension, as providing strong evidence of the effectiveness of measures aimed at gradual but sustained improvement is much harder than proving a short-term impact of a change that may not have longer term sustainability. Unfortunately, it is the longer-term but most likely gradual improvements in farming systems that are required for sustained reductions in risk and improvements in the resilience of farming systems.

Mitigation strategies

Despite the relatively rapid economic growth rates seen in recent years and the high rate of population growth, the small population, relatively small land area, and current low emissions of greenhouse gases in the Lao PDR, mean that it is unlikely that any strategies to reduce emissions will have a significant affect on the global or even regional emissions and thus on climate change *per se*. This does not mean, however, that mitigation strategies should not be adopted, but it perhaps affects the drivers of adoption.

Firstly, some of the mitigation strategies, although having minimal global or regional impacts, may have very localized and positive microclimate effects on agricultural or forestry systems, particularly with respect to the availability of water in terms of increasing the water supply, through the impact of forests on rainfall, and reducing water loss, through wind boundary effects and lower temperatures reducing evaporation. Secondly, many GHG emission reduction strategies will lead to direct and indirect economic impacts as the costs of greenhouse gas emissions are factored into the cost of inputs and the prices of products. As realistic costs of GHG emissions are included in the costs of inputs, labour, transport, and the like, the adoption of GHG mitigation strategies will be driven by eco-efficiency being properly costed and so an economic driver for adoption takes over. Thirdly, it is important that all countries, whether large or small emitters of GHG, do participate in mitigation efforts so as to be good global citizens and be part of a global effort in addressing what is a truly global problem.

The Clean Development Mechanism that emerged from the Kyoto Protocol has been a method for funding some activities that reduce greenhouse gas emissions, however, CDM was not available for agriculture and only available in restricted cases for forestry. Future developments in carbon trading, and particularly in schemes such as Reducing Emissions from Deforestation and forest Degradation (REDD), may present opportunities for payments for emissions reductions and carbon capture. Awareness of, and involvement in, schemes such as REDD are recommended, although the measurement and validation steps in such schemes will remain critical steps that may limit the usefulness for agricultural systems, particularly for the mixed agricultural systems that are the mainstay of agriculture in the Lao PDR. While benefits through these schemes may flow quite easily to larger forestry and plantation agriculture schemes, there will always be a challenge in ensuring that benefits flow directly to smallholder farmers when their livelihood systems are considered. Again, this does not mean that mitigation strategies in forestry and agriculture should not be implemented, but that the drivers of adoption may need to be the increased resilience and sustainability of the farming systems. Rather than being encouraged through on-going direct payment for mitigation per unit of reduced emission or of carbon captured, adoption can be driven by the cost savings that accrue as the real costs of emissions are factored into the cost of production and product prices. As an example, the development of sustainable agricultural practices that reduce petro-chemical inputs, for transport, fertilizers, and the like, will result in smallholder farming systems that are more eco-efficient and these systems will become more economically competitive as oil prices rise, thus paying for themselves. Thus the value of a mitigation payment schemes may be to achieve initial adoption of improved practices, which then pay for themselves through increased eco-efficiency, rather than the value of one-off or on-going payments for mitigation services. A general approach to Payments for Environmental Services (PES), based on impacts on water quality, water quantity, biodiversity, and the like may be an alternative to direct GHG mitigation payment schemes. Such PES schemes could be targeted at dealing with the initial costs of adoption and any resistance to adoption of more eco-efficient systems that once established will pay for themselves. A further alternative would be to provide loans for adoption of improved practices that are paid back by the farmer through the cost savings that result from greater efficiency, rather than through direct carbon or GHG emissions payments, which involve complex and expensive measurement and validation processes.

In short, although climate change will almost certainly have some affect on the Lao agricultural and land use systems, it appears that none of the changes that may result will be as large as the huge changes in land use that are occurring, and are expected to continue to occur, as a result of population growth, economic development, and related development policies. In addition, all of the changes to agriculture and land use that are required to adapt to these changes in climate and that may contribute to mitigation efforts, are all changes that should be encouraged irrespective of climate change. In fact, the driver for more eco-efficient agricultural, forestry, and land use policies should be the need to cope much better with the current highly variable climate and the current high risk, low resilience, and barely sustainable farming systems that produce the inadequate livelihoods of a large number of children, women, and men who constitute the marginalized rural poor of the Lao PDR.

7 References

Appa Rao, S., Schiller, J.M., Bounphanousay, C., and Jackson, M.T. (2006) Diversity within the traditional rice varieties of Laos. In “Rice in Laos” Ed. J.M. Schiller, M.B. Chanphengxay, B. Linquist, and S. Appa Rao. International Rice Research Institute, Los Baños, Philippines. 457 pp

Box, G.E.P. and Jenkins, G.M. (1976). Time Series Analysis: Forecasting and Control (revised edition), Holden Day, San Francisco.

EPD (2010) Electric power plants in Laos, May 2010. Department of Energy Promotion and Development, Ministry of Energy and Mines. http://www.poweringprogress.org//download//Electric_Power_Plants_in_Laos_May_2010.pdf

Foley, S. (2009) Growing resilience: Adapting for Climate Change in Upland Laos. Norwegian Church Aid, Laos

Fox, J., Fujita, Y., Ngidang, D., Peluso, N., Potter, L., Sakuntaladewi, N., Sturgeon, J., Thomas, D., 2009: Policies, Political-Economy, and Swidden in Southeast Asia. Human Ecology, 37 (3): 305-322, Springer Netherlands

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., and Jarvis, A. (2005) Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.

Hijmans, R.J., Guarino, L., Jarvis, A., O’Brien, R., Mathur, P., Bussink, C., Cruz, M., Barrentes, I., and Rojas, E. (2005) Diva-GIS version 5.2.

IPCC (2000) Special Report on Emissions Scenarios, A Special Report of IPCC Working Group III, Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland

IPCC (2001) Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 398 pp

IPCC (2007) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 104 pp.

IWMI (2009) Scoping Study on Natural Resources and Climate Change in Southeast Asia with a Focus on Agriculture

Jiang, A. (1988) Climate and natural production of rubber (Hevea brasiliensis) in Xishuangbanna, southern part of Yunnan province, China. International Journal of Biometeorology 32:280-282

Mitchell, T.D. and Jones, R.G. (2005) An improved method of constructing a database of monthly climate observations and associated high-resolution grids, International Journal of Climatology vol 25, 693 - 712

MRC-GTZ (2008) “Climate Change Adaptation in the Lower Mekong Basin”, MRC-GTZ Watershed Management Project

New, M., Hulme, M. and Jones, P.D. (2000) Representing twentieth century space-time climate variability. Part 2: development of 1901–96 monthly grids of terrestrial surface climate. Journal of Climate 13, 2217-2238

Tong, P.S. 2009. Lao People’s Democratic Republic forestry outlook study. *In* Asia-Pacific Forestry Sector Outlook Study II Working Paper Series. No. APFSOS II/WP/2009/17, pp. 62, FAO.

Velleman, P.F. and Hoaglin, D.C. (1981) Applications, Basics, and Computing of Exploratory Data Analysis. Duxbury Press, Boston, MA

World Commission on Environment and Development (1987) Our Common Future: Brundtland Report, Oxford University Press, Oxford.

WREA (2009) National Adaptation Programme of Action to Climate Change (NAPA)

WREA (2010) Strategy of Climate Change of the Lao PDR

Published by
Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

– German Technical Cooperation –

Land Management and Registration Project (LMRP)
PO Box 9233
Vientiane, Lao PDR

T: +856 21 353605
F: +856 21 312408
E: gtz-laos@gtz.de
I: www.gtz.de/laos