Improving land change simulation capacity to reduce conflict from competing land demands – Inception report

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Institute for Environmental Studies,
VU University Amsterdam
De Boelelaan 1085,
1081 HV Amsterdam, The Netherlands
T: + 31 20 5989555
E: Info@ivm.vu.nl

Contact for this project:
Jasper van Vliet
T + 31 205983052
E: Jasper.van.vliet@vu.nl

ACRONYMS

ADB	–	Asian Development Bank
CEP	–	Core Environment Program
DSS	–	Decisions Support System
FAO	–	Food and Agricultural Organization of the United Nations
GHG	–	Greenhouse Gas Emissions
GIS	–	Geographical information System
GMS	–	Greater Mekong Subregion
IPCC	–	Intergovernmental Panel for Climate Change
IVM	–	Instituut voor Milieuvraagstukken / Institute for Environmental Studies
LUCS	–	Land Use Change Simulation
MEA	–	Millennium Ecosystem Assessment
NAC	–	National Academic Coordinator
NAI	–	National Academic institution
REDD	–	Reduction of Emissions from Deforestation and forest Degradation
RIKS	–	Research institute for Knowledge Systems

Note: In this report, “$” refers to US dollars.

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1. Introduction

1.1. Context of the study

The Greater Mekong Subregion (GMS), which started as an Economic Cooperation Program in 1992, has facilitated regional investment and consequently regional economic development and poverty reduction. As it was acknowledged that economic development poses pressures on the regions natural resources, the GMS also acknowledged its responsibility for sustainable land management. In 2005, this acknowledgement culminated into the Core Environment Program (CEP) Phase 1 (2005-2012), an Asian Development Bank (ADB) administered program that has aimed for a sustainable economic growth combined with a sound environmental management.

The second phase of the CEP (2012-2016) includes four thematic components, including component 1: Environmental Monitoring, Planning and Safeguards (ADB 2012B). This component strives amongst others to develop strategies, plans, and investments in the GMS economic corridors and conservation at strategic planning and design stages. To that effect it initiates and advances the use of tools such as ecosystem assessments and valuation, strategic environmental assessments, and spatial analysis to assess the implications of multi-sector development on natural resources and ecosystem services. The program also aims to safeguard capacity building in this area through training and operational application, as well as to enhance the countries monitoring processes, protocols and guidelines (ADB 2012B).

The integration of geographic analysis in land use planning processes was already encouraged in CEP Phase 1 and implemented by training national government agencies. However, the capacity of the governments of the GMS countries to apply land use change modeling in their processes for planning sustainable natural resources management was constrained by data availability, the time and effort required to fully understand land use modeling concepts and tools, and the limitations of these governments to maintain and foster this land use modeling capacity without external support. Despite these constraints, the importance of an operational land use change modeling capacity was widely acknowledged and as such a key priority in the CEP Phase 2 (ADB 2012B).

This document is the inception report of the Land Use Change Simulation and Training project, which aims to build capacity for land use change simulation in academic institutes in the GMS. Such academic capacity can ensure a steady provision of modelers that can maintain a capacity of land use change simulation modelers in the respective governments in the GMS.

1.2. Report structure and overview

This report is structured as follows:

Chapter 2 discusses ongoing land use changes in the GMS, as well as the challenges for natural resource management.

Chapter 3 provides a detailed overview of the project, its aim and scope, the contents of the work packages.

Chapter 4 presents the organization aspects of the project, including the institutions and people involved, and a detailed workplan.

Chapter 5 provides a plan for monitoring the project and subsequent reporting.

2. Background

2.1. Land use changes in the Greater Mekong Subregion

The Greater Mekong Subregion (GMS), comprising Cambodia, Myanmar, Lao PDR, Vietnam, Thailand, and the Yunnan and guangxi provinces in China, represents a globally important ecosystem with a valuable biological diversity. Moreover, it contains the headwaters of a number of important river systems, including the Mekong river itself. The land system of the region feeds over 60 million inhabitants and contains considerable forest stocks, containing important biodiversity and carbon storage. However, the land systems in the GMS have faced increasing pressures over the past decades, mostly from external influences. These pressures, which include large scale rubber plantations, illegal logging, increased demand for food production, and infrastructural developments, threaten the precious forest stocks and consequently they threaten the complete ecosystem and its biodiversity

2.1.1. Forest and biodiversity

The forests in the GMS are important providers of timber and non-timber products, but they also supply a wide range of other ecosystem services such as provision of food, pollination, soil stabilization, space for recreation, carbon sequestration, flood protection, provision of clean water, medicines, and places sacred to the world's various faiths (MEA 2005; Ten Brink 2011). While the GMS is rich in natural resource endowment, it has been experiencing rapid decline in forest area and biodiversity: since 1990, about 13 million hectares of forest have been lost – an area greater than half the size of Lao PDR. The largest losses have been in Myanmar (over 8 million hectares), while in Cambodia 2.9 million hectares have been lost. The rate of forest cover loss amounts to 310,000-435,000 ha/yr in Myanmar, and 310,000-435,000 ha/yr in Cambodia (FAO 2010). At present 45% of the GMS is forested. However, the primary forest represents only 13% of total forested area and the majority of the remaining forests are secondary forest with often low canopy cover (ADB, 2012). These forests are highly degraded and have lost part of their functions in providing biodiversity, hydrological and nutrient cycling, carbon sequestration, crop pollination, and pest regulation (FAO 2011).

Between 1997 and 2007, industrial wood production increased 270% in Thailand, 120 % in Myanmar, and 120% in Vietnam. This includes increased wood production from planted forests, the area of which has increased from 4.1 million ha in 1990 to 8.8 million ha in 2010, primarily originating from investments in Vietnam and Thailand. Hence, in terms of maintaining their forest cover, the countries in the GMS are facing a major challenge in achieving the Millennium Development Goals (EOC/ADB 2011). This development emphasizes the need for increased regional cooperation and land use planning in achieving sustainable development in the region, especially sustainable resource management. This need for sustainable land management is highlighted even more by the important role of forests in climate change mitigation through reducing emission from deforestation and forest degradation (REDD+).

2.1.2. Infrastructural development

Important infrastructural development projects have started and are planned in the GMS countries. The Asian Highway network of about 141,204-kilometer crosses 32 countries and even connects the region to Europe. This highway network is expected to boost the regional economies because it facilitates trade and tourism through its linkage of Asian seaports, airports and major tourist destinations. A large share of these major infrastructure development projects have been completed or are currently being implemented, such as the highway from Phnom Penh to Ho Chi

Minh City and the East-West Economic Corridor that will eventually extend from the Andaman Sea to Da Nang in Vietnam (ADB 2013). Thailand has built an extensive road network including cross-border bridges between Laos and Thailand, and is planning to continue investing in large scale infrastructure development projects (Bollard 2013).

Travel and tourism is by now a major economic sector worldwide, and the GMS is one of the most attractive destinations. While Thailand has been a major tourist attraction for longer time, these developments are more recent in other GMS countries as Cambodia, Vietnam and Lao PDR have seen an increase in tourists and Myanmar has opened for westerners visitors only relatively recently. Consequently, increasing numbers of tourists visit the GMS, and while these visitors add to the economic development of the region, they also require infrastructural developments, including hotels, transportation and recreation faculties. These developments may provide threats to the natural resources in the region, while at the same time these natural resources provide a main attraction to tourists and associated economic development.

Increased accessibility from these infrastructural developments has created many opportunities for economic development such as tourism, urbanization, and real estate developments (Luang Prabang, Vientiane, Phnom Penh, Mukdahan, etc). However, these economic improvements as a result of these highway expansions have come at large environmental costs, including increased logging, encroachment of tree plantations and killing of wild animals. These consequences emphasize that careful planning and ex-ante impact studies for new infrastructure projects are essential to mitigate undesired impacts on the ecosystem and the local communities.

2.1.3. Agriculture and food production

The fertile soils of the lower Mekong basin are important for the regional food security, with paddy rice being the single most important crop for the millions of people living in the region. Moreover, rice production is valuable as export product: Vietnam and Thailand are among the leading producers and exporters of rice in the world. Next to paddy rice parts of the regional population is still dependent on upland rice cultivation and also, vegetables, cash crops (such as cassava and sugarcane) and fruits (such as banana, pineapples, and papaya) are cultivated in the region for both domestic consumption as well as foreign trade.

Agriculture is changing rapidly in the GMS, both to match the increasing local demands and for export to other countries. As a consequence, the land system is intensifying by increased inputs such as fertilizer and pesticides, as well as other crop varieties that have a higher yield. Very notable is the shift from swidden cultivation systems to more intensive input-dependent permanent cropping systems as well as the emergency of larger agro-companies managing large tracts of land, which is a major shift from the household level farming systems that dominate the region. In addition, biomass production has entered the scene and is now taking a considerable land area. On the one hand these agricultural land system changes offer opportunities for economic growth, but on the other hand this change threatens the food security of local communities as well as the forests and other land in which these developments take place. Moreover, as these agricultural changes happen increasingly more rapidly, and as these developments are hardly governed by land management policies, there is a major challenge for policy development and sustainable management of agricultural land systems in anticipation of further development along this pathway.

2.1.4. Foreign land acquisition and large scale plantations

Next to the agricultural developments described above, large scale land acquisition for plantations (especially rubber) form a special thread for the GMS countries. Already, this is an ongoing development in especially Laos and Cambodia. Land acquisition was intensified globally due to high price of food and anticipated food crisis after 2007-2008. Gulf States, China, South Korea, Japan, Singapore and Malaysia are the major countries seeking for land to grow rice, but they also look for land for the production of bio-fuels, sugar, timber, and carbon credits. For example, Thailand has been a target for foreign investment with the aim of securing raw materials and food supplies, as it contains a large amount of fertile plain land with sufficient water supply. However, land acquisition also takes place by companies in the different Mekong countries. As a consequence, many important natural resources are now managed by foreign real estate businesses.

Rubber plantations play an important role in this land acquisition process, driven by high foreign demand international companies destroy the original forests and replace it by rubber plantations. In Cambodia and Laos, governments have already handed out respectively 2.6 and 1.1 million hectares in land concessions (Global Witness 2013). The Cambodian Government has pursued a policy of granting large-scale land, forestry and other types of concessions to private companies. The consequences are difficult to oversee at the moment but need a careful assessment as it may pose a serious threat to local communities living in these areas, constraining the access to land resources.

As many of the infrastructural developments as well as the allocation of large scale plantations conflict with the protection and development of protected areas in the region a careful ex-ante assessment of the different developments, their alternative implementations and their impacts on land systems and environmental indicators need to be made. Such assessment can help the region to develop and enforce land use policies that help a sustainable development of land management in the context of these development challenges and global land acquisition, to preserve the precious ecosystems in the GMS.

2.2. Challenges for sustainable natural resource management in the GMS

The ongoing land system changes in the GMS, as outlined above, make clear that land use planning and land management policies are instrumental in the mitigation of further undesired land use changes and their effects. However, since policies have to be effective in a complex setting, which involves competing claims and multiple stakeholders, assessing their impact ex-ante is challenging and requires sophisticated tools to support the process.

Land use models are used to simulate possible spatial developments and ex-ante assessment of related policies in terms of land use change and their impacts, such as greenhouse gas (GHG) emission, potential biodiversity, or water availability. Figure 1 present the subsequent phases of the policy planning process and indicates the role that land use models have in these processes: they facilitate understanding of the processes and identify in an early stage the land management challenges for different development scenarios. In addition, they can be used to support decisions by simulating possible future land use configurations under alternative policies or infrastructural plans under changing environmental boundary conditions. Moreover, the ADB project on “Development of a GMS forest cover and land use map to improve subregional planning and monitoring”, which is will run in parallel to this project is elementary in the evaluation phase, and as such complimentary to this project.

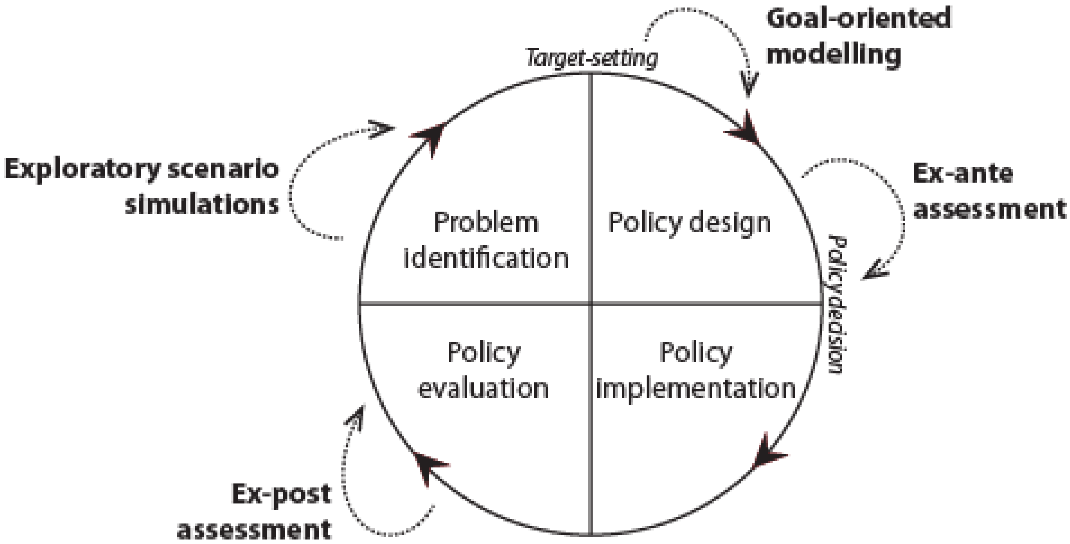

Figure 1: the planning process as cyclical activity.

Scenarios are a common technique in land use modeling for planning support (Rotmans et al. 2000). They are a means to sketch what could happen given certain changes in natural, social, or economic conditions. Land use models are used to assess the consequences of these assumed changed conditions on the studied land use system. Because scenarios are typically internally consistent, they are especially suitable to be used by policy makers from different policy domains. The generated merits and trade-offs of intended policy options can be compared and illustrated spatially, over time and over different indicators. Scenario approaches have been successfully applied in many studies at global (IPCC 2000), regional (Rounsevell et al. 2006), and national (Trisurat et al. 2011) scales, where the amount of detail in spatial and thematic representation typically depends on the scope of the study (Van Delden et al. 2011). Ongoing developments in the GMS, such as the major infrastructural project, land grabbing for rubber plantations or intensification of agricultural land systems are very appropriate issues to investigate using land use modeling, due to their spatial extent, the involvement of multiple stakeholders, and the time span over which changes are likely to take place.

Overall, scenarios will provide an outlook on the development and conservation challenges in the region. At the same time, policy options and other plans can be evaluated under different scenarios conditions to test the robustness of policies and infrastructure development impacts under alternating development directions, ensuring that decisions are based on assessments that incorporate some of the uncertainty in future (economic) development and are, therefore, more robust to changes outside the influence of the policy makers.

Ongoing land system changes in the GMS, as outlined above, make clear that land use planning and land management policies are instrumental in the mitigation of further undesired land use changes and their effects. However, since policies function in a complex setting, which involves competing claims and multiple stakeholders, assessing their impact is difficult.

3. Review and selection of models to explore future land use changes

3.1. Approaches towards land use change modelling

Models have played a major role in land system science in undertaking structured analysis of complex interactions within the land system. Where real-life experiments are not possible, models provide artificial experiments to explore system behaviour, i.e. as a computational laboratory (Matthews, Gilbert et al. 2007). In addition, models enable ex-ante assessments of policies and provide input to the planning process (Bennett, Carpenter et al. 2003; Helming, Diehl et al. 2011). Future land use will be strongly determined by policy changes such as reforms in agricultural policy, trade liberalisation and nature conservation, but also by fundamental changes in energy policy and new measures that relate to climate change adaptation and mitigation (Beringer et al., 2011; Lotze-Campen et al., 2014; Popp et al., 2010; Rounsevell and Reay, 2009). Yet, modelling efforts have focused on specific aspects of the land system with much ex-ante analysis based on the agricultural sector using models of the agricultural economy (Rounsevell et al., 2003; van Delden et al., 2010). Other models have targeted urbanisation processes (Aljoufie et al., 2013; van Vliet et al., 2009). At the case study level, models of human decision making (e.g. agent-based models) have been developed, but these are seldom applied in a policy and planning context (Matthews et al., 2007; Parker et al., 2003; Verburg, 2006) with limited exceptions (Gaube et al., 2009).

In the following, the different types of land use models are reviewed, discussing the individual model types from top-down (multi-)sectoral approaches to bottom-up, agent-based approaches.

3.1.1. Integrated assessment models

We start with the representatives of large scale macro-economic or integrated assessment models (Heistermann et al., 2006) that commonly capture the macro-level context of local decision making (Table 1). Macro-economic models are designed to describe the operation of a country or region. This type of modelling is usually part of an integrated assessment model that combines models of e.g. the macro economy, the energy system and the climate system. Integrated assessment models are often used in environmental sciences and environmental policy analysis as environmental problems are not bound to a single academic discipline. These type of models integrate knowledge from two or more scientific domains into a single framework. Accounting for the global context is important, as local and regional demands can be met in spatially unconnected regions through international trade (Lofdahl, 1998; Lotze-Campen et al., 2010). While these models have proven capable of addressing land change (van Meijl et al., 2006; Verburg et al., 2008) the inherent characteristics and detailed processes of the land system are largely ignored by a high level of simplification.

Table 1: Examples of models under 'Integrated assessment models'

Model	Model characteristics		Holder
IMAGE	Ecological-Environmental	Global	PBL
NEMESIS	Economy	Global/National	
MIRAGE	Agriculture	Multi country	IFPRI, INRA

3.1.2. Economic models

Economic models (see Table 2 for examples) (e.g. Hertel, 1997; Kuhn, 2003) can address the links between demand, supply and trade via endogenous price mechanisms. However, they account only to a limited extent for physical resource constraints, they do not commonly reflect the impact of demand on actual land-use change processes, and they rarely represent human behaviour not reflected through price mechanisms. Land is usually implemented as a constraint in the production of land-intensive commodities, and economic competition of different types of production within one sector is represented endogenously. The simulation of management types as well as the competition for land (and water) between different sectors is supported by the structure of such models, but only at a spatially aggregated level.

Table 2: Examples of models under 'Economic models'

Model	Model characteristics		Holder
GTAP	Economy	Global	Purdue University
LEITAP	Economy	Global/EU/National	LEI-WUR
IMAGE	Ecological-Environmental	Global	
NEMESIS	Economy	Global/National	
MIRAGE	Agriculture	Multi country	IFPRI, INRA
MAGNET	Economy, Agriculture	112 world regions	LEI-WUR
CAPRI	Agriculture	NUTS2 to grid	Bonn
ESIM	Agriculture	EU/national	

A range of different strategies exist to project future land-use patterns from regional to global scales.

3.1.3. Geographic approaches

Geographic approaches (van Delden and Hurkens, 2011; Verburg and Overmars, 2009), concentrate on the supply side and compute land-use patterns based on spatially explicit data on land suitability and on external assumptions about agricultural demand (Table 3). These approaches are strong in capturing the spatial determination of land use and its constraints based on land resources. However, they lack the potential to treat the interplay between supply, demand and trade endogenously. Furthermore, these models are mostly based on remote sensing data of land cover and therefore ignore changes in land management (Verburg et al., 2011). Changes in land management have more far-reaching consequences for the environment and human well-being than land cover change alone (Ellis and Ramankutty, 2008).

Table 3: Examples of models under 'Geographic approaches'

Model / database	Type	Region / Resolution	Holder	Application
GLOBIOM	PEE (Dynamic recursive) integrating the	28 world regions	IIASA	Land allocation and deforestation projections. Biofuel

	agricultural, bioenergy and forestry sectors			policies, climate change policies.
Dyna-CLUE	Land change model (Partial equilibrium)	Regional,	IVM, VU Amsterdam	Land use conversion, environmental impacts and ecosystem services impacts
CLU-Mondo	Dynamic land change model	Global, 5 arcminutes resolution	IVM, VU Amsterdam	Land use conversion, land use intensity
LandShift	Land Simulation to Harmonise and Integrate Freshwater Availability and the Terrestrial Environment; Modelling of large-scale land-use systems	Global and regional; Global 5 arcminutes and 1 km^2 resolution for regional	Kassel Universität, Germany	Spatial multi-scale hierarchy; simulates interactions of socio-economic drivers and biophysical environment determining land use changes.
Land Use Scanner	Land use model based on current land use	Regional, 500 x 500m grid	PBL – Environmental Assessment Agency, Bilthoven	Predicts future land use change based on demands for land
METRONAMICA	Dynamic land-use model, coupled with spatial indicators	National or Regional, 1km^2 at the local level	RIKS, Maastricht	Forecasting tool to simulate and assess integrated effects of planning measures on urban and regional development

3.1.4. Integrated approaches

Integrated approaches accounting for both socio-economic and environmental processes across different scales (not only at macro level, as in the large-scale integrated assessment approaches), pursue different strategies. Some employ land allocation schemes, which use demand or price information from economic models to update land-use patterns in detailed environmental models (Rounsevell et al., 2006). Others improve the representation of resource constraints in detailed economic models (Darwin, 1999; Rosengrant et al., 2002). The dynamic coupling of economic, integrated assessment and land use models has been used to address the trade-off between the spatial expansion of agricultural production and intensification at various spatial scales (Eickhout et al., 2007; Verburg et al., 2008).

3.1.5. Agent Based Modelling (ABM)

ABM provides a framework for simulating complex decision making (Brown et al., 2005; Matthews et al., 2007; Murray-Rust et al., 2014; Parker et al., 2003). ABM originated in the computer sciences in the 1970s through artificial intelligence research (Hare and Deadman, 2004), but has recently gained popularity in the social sciences and is increasingly applied to land system change

(Evans and Kelley, 2004; Valbuena et al., 2010, 2009). Early agent-based models (Hägerstrand, 1967; Schelling, 1971) were explicitly devised to have the simplest possible rules necessary to produce the desired behaviour. ABM has undergone an evolution towards increasingly complex and empirically grounded models, used to produce results of increasing specificity. Only a very limited number of ABMs have attempted to do this for land system research and the development of these approaches further as part of a broader integrated modelling strategy would promote the progress in land system science enormously (Murray-Rust et al., 2011). Up-scaling of ABM applications to larger geographic regions would make model outputs relevant at the scales of analysis at which land management and policy plans are developed. Upscaling of ABM and integration with macro-level models has not previously been attempted.

3.2. Selecting a generic land use model for the GMS

In this project, we will use the CLUMondo model, implemented within the GEONAMICA software environment. This section will first discuss the requirements for a generic land use model for the GMS that lead to the selection of CLUMondo, and subsequently describe both models in more detail.

3.2.1. Requirements for a generic land use model in the GMS

As indicated in the review presented above, a wide range of land use modelling approaches exists. Selecting the appropriate approach, and subsequently selecting the appropriate model, depend on the requirements. The modelling approach is especially depending on the type of questions that the model is expected to support, while practical constraints like data availability, or technical requirements are also important.

The selected land use model is expected to support land use planning and policy making at a national or regional (subnational) scale. Of the selected approaches, Integrated assessment models and economic models typically use a country as the smallest unit in a global or large scale assessment, while subnational changes are not represented. Moreover, these models represent the economy as it is included in official reports, while swidden and other land systems that are very important for land use assessment in the GMS are not included.

Geographic approaches, integrated approaches and ABM on the other hand do target the appropriate scale for policy making. Of these three approaches, integrated approaches and ABM are very difficult to calibrate which hampers the application in policy cases by non-experts. In the case of integrated approaches this is mainly due to large data demands, while ABM mostly suffer from unavailable data at the level of an agent. Moreover, both are complex models to the point that a significant investment is required before they can be applied meaningfully.

Consequently, of the model types described in the previous section, the geographic approaches stand out as the most appropriate type of land use model, as they are relatively easy to use, have relatively little data requirements, and because quite a few of these models are generic, in the sense that they can be applied to multiple different areas.

Geographic land use models are generally driven by an exogenous demand for specific land use types. For example, scenarios are defined as an area for cropland, forested land and urban land per year for the simulated period, and these areas are subsequently allocated by the model. These demands are usually derived from the main economic sectors, i.e. agriculture for cropland demand, population increase for urbanization, and timber production for managed forests. This direct relation between economic sectors and land use demands ignores the fact that land uses often provide other ecosystem services as well, such as carbon sequestration or biodiversity preservation. Hence land uses are often multifunctional.

The CLUMondo model, the newest version of the widely used CLUE model, is based on the land systems approach, in which land systems are typical combinations of land uses, which can provide a combination of Ecosystem services, including food production, accommodating people, but also carbon sequestration. As the CLUMondo model is developed and maintained by the lead contractor, we can also guarantee that it is available free of charge. In order to facilitate its usage by as many universities and institutions as possible, it will be implemented in the GEONAMIC software framework, which is specifically designed for developing spatial decision support systems.

3.2.2. The CLUMondo land use model

The Conversion of Land Use and its Effects (CLUE) model is a dynamic, spatially explicit, land use and land cover change model (Verburg et al., 2002). It is one of the most frequently used land use models globally. The CLUE model is a flexible, generic land use modeling framework which allows scale and context specific specification for regional applications. Different version of this model have been applied to many different regions worldwide, among which multiple applications in the GMS: Thailand (Trisurat et al., 2010), Vietnam (Castella et al., 2007), and the Mekong catchment (Fox et al., 2012). In addition, It has been applied in several other areas in Southeast Asia: Philipines (Verburg et al., 2006), China (Zhang et al. 2005) and Taiwan (Lin et al., 2009). Many of these applications are developed by users without involvement of the contractor, which indicates the suitability of the CLUE modeling framework for capacity building and application for policy support without interference of the model developers.

The CLUE model was developed to simulate land use changes using relations between land use and its driving factors based on empirical analysis, neighborhood analysis or scenario specific decision rules in combination with dynamic modeling of competition between land use types. The CLUE-s and Dyna-CLUE model versions have been developed by Peter Verburg, the team leader of this project, in the period 2000-2005. In this project, we will apply the CLUMondo model, which combines the strengths of the CLUE-s/Dyna-CLUE models, with the latest advances in land change modelling. CLUMONDO advances from earlier versions of CLUE in that it builds on the land systems approach (van Asselen and Verburg, 2013) instead of representing land cover types only. Land systems essentially represent a combination of land uses that typically exist on a location and the combination of functions they provide. This approach is very relevant to the GMS region due to the existence of many mosaic land cover types that can be represented more adequately using the land systems approach than in the traditional land cover based approach. Especially swidden agricultural systems, which still form an important land use in the region, as well as forest degradation can be properly represented as result of the advances made in this modeling framework.

In many land use models, land change is driven by changes by regional demands (top-down), and at the same time influenced by local factors that either constrain or promote the conversion of land and account for land-use history, leading to path dependence of land change trajectories. Demands in these cases are defined as land areas, which are for example derived from coarse-scale global or regional economic models, such as the GTAP model (Van Meijl et al, 2006; Hertel, 2011). Some models use a hierarchical approach of allocating these areas, assuming a dominance of urban expansion while having (semi) natural areas as the remaining land change type (Pontius et al., 2004). Others allocate land cover areas in a synchronous manner assuming competition between the different land cover types for locations (Verburg and Overmars, 2009). However, in all models, demand for land cover types is one-to-one allocated to changes in the spatial distribution of these land cover types.

The CLUMONDO model, in contrast, simulates changes in land systems that are capable of providing various ecosystem goods and services at the same time. Land systems have characteristics such as crop production, livestock density, biomass and biodiversity. Therefore, the same production of ecosystem goods and services can be fulfilled by multiple combinations of land systems and the areas occupied by the different land systems are not straightforwardly determined by the regionally aggregated areas of land cover types. Consequently, the CLUMONDO approach allows to directly respond to demands for ecosystem goods and services rather than only to areas per land cover type. Since the uses of the land in large parts of the GMS are essentially multifunctional, this approach is especially appropriate for application in this region.

The structure of the CLUMONDO model is visualized in Figure 2. The model allocates at time (t) for each grid cell the land system (LS) with the highest transition potential. The transition potential is the sum of the local suitability, the conversion resistance and the competitive advantage of a land system. The local suitability of a land system is determined based on a logistic regression of available biophysical and socio-economic datasets. Logistic regressions are frequently used as input to spatial land change allocation models (Letourneau et al., 2012; Serneels and Lambin, 2001). The resistance factor is a measure for the costs of conversion of one land system into another. For example, land systems with high capital investment (e.g. urban settlements) are not easily converted to other systems, and hence, have relatively high conversion costs. Therefore, in case such a land system is present at that location a high resistance factor is added to the transition potential to illustrate the low conversion elasticity. Land systems like extensively managed cropland or grassland are easily converted (with low costs) to other systems, and, therefore, have low values of the resistance factor. The values of the resistance factor are determined based on expert knowledge and can be calibrated for a specific model run. The relative competitive advantage is a factor that is included to ensure that demands and supply are meet in the system. It is determined in an iterative procedure in which the goods or services provided by the allocated land systems are compared to the aggregated quantities at the level of world regions as derived from an external global economic model.

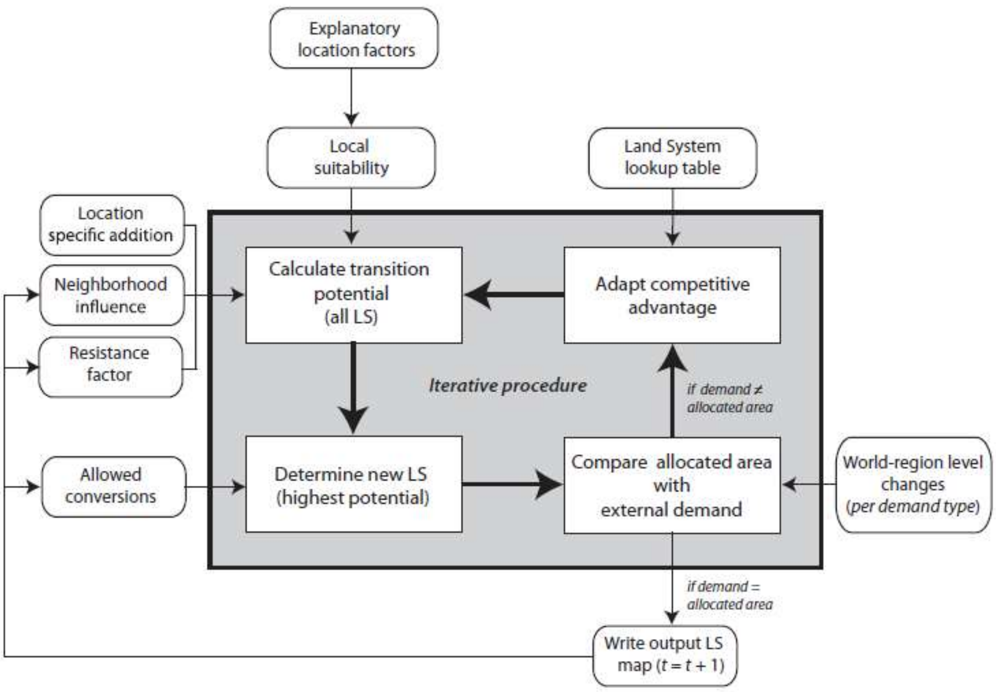

Figure 2: Model structure of the CLUMONDO model.

CLUMONDO is essentially a generic land use model, in the sense that it is not restricted in its application, but that it can be applied to any case study area, and that the number and definition of land system types, as well as the spatial resolution and extent of the case study application are flexible. This is particularly advantageous for the capacity building around which this project is built, since academics in the individual GMS countries or regions can build different applications using different model definitions if desired (see Table 4).

Table 4: CLUMONDO specifications

Model characteristics	Model properties
Spatial resolution	Flexible, between 50 meter and 5000 meter.
Thematic resolution	Flexible, land use types/land system to be determined in cooperation with the relevant stakeholders and national academic staff and flexible to the specific application requirements
Geographic extent	Flexible, countries in the GMS can be included as separate applications as well as all countries combined. (Sub-) regional applications are possible
Regional divisions	Demands for ecosystem goods or services are given per country or country region. Land system change is simulated at the pixel level can be aggregated into subnational regions
Temporal resolution	Yearly time steps
Time horizon	Flexible, mostly up to 40 years after the starting year
Allocation principle	Yearly dynamic allocation based on econometric estimation of suitability and process knowledge (e.g. growth processes); neighborhood processes included for urban growth.
Reliability	Validation of Dyna-CLUE model core on multiple cases available (Castella et al., 2007; Pontius et al., 2008); validation for Vietnam based on SPOT imagery available.

3.2.3. The Geonamica framework

The CLUMONDO model will be implemented in the Geonamica software framework, which is developed specifically to build user friendly decision support systems based on spatial modeling. Geonamica is an object-oriented application framework developed to build decision support systems based on spatial modeling. It has been developed over the past 20 years and has been used to generate integrated spatial decision support systems, such as the Environment Explorer (Engelen et al., 2003), MedAction (van Delden et al., 2007), and LUMOCAP (van Delden et al., 2010). Geonamica offers set components for the storage of spatial data, time series and cross-sectional data. It provides a modeling framework based on the Discrete Event System Specification (DEVS) formalism and includes a model controller that manages the models, makes sure they interact properly and tells each model when to perform certain, predefined actions. To create a user interface, Geonamica includes a skeleton structure and a rich class library of user interface components, such as map display and editing tools, list and table views and two-dimensional graph editing components (see Figure 3 for an example).

The strength of Geonamica lies in the fact that the application framework provides a generic structure for the models that allows them to be integrated more easily, while enabling complex dynamic models to be executed efficiently. The environment is set up in such a way as to enable users to run simulations interactively, by allowing them to intervene in the system and observe the results of their actions directly in a comprehensive manner or save the results to persistent storage for more elaborate analysis or presentational purposes. Spatial decision support systems built in Geonamica are by design extensible and flexible: components like model blocks, complete models or user interfaces can be added, removed or replaced to allow for maximum flexibility not only during development, but also in later stages of the lifecycle of the system when changing circumstances or new knowledge necessitates modifications to the system. Geonamica is especially suited for building systems that are explicitly spatial, as its roots lie land use modeling.

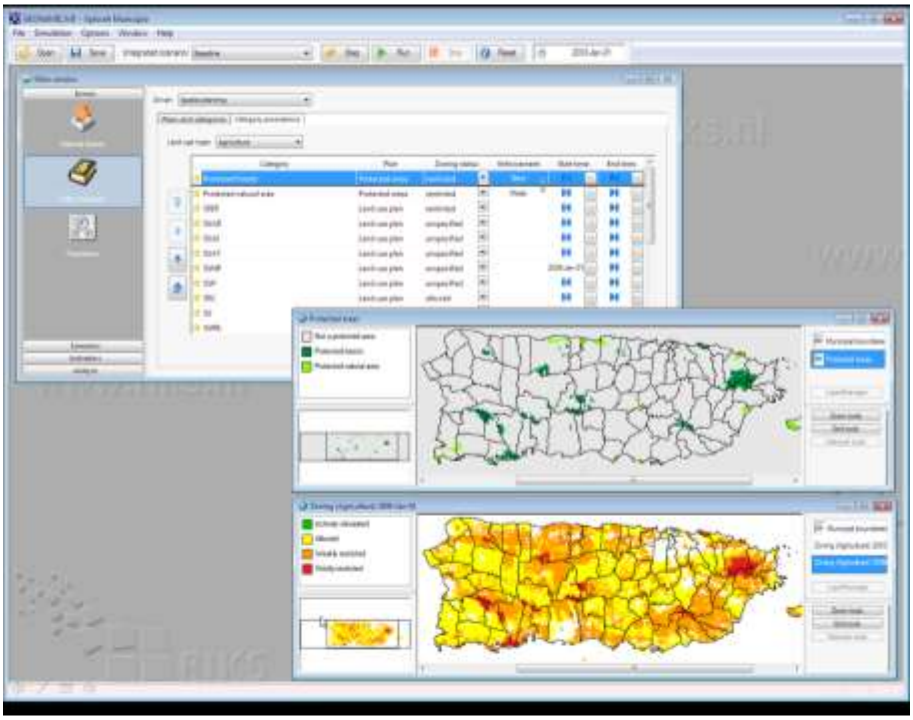

Figure 3: User interface of Xplorah, a spatial decisions support system for Puerto Rico.

4. Project overview

4.1. Aim of the project

The main aim of this project is to enhance the capacity of national academic institutes to support the relevant governments and institutions in the GMS in making well-informed land use policies and infrastructural decisions, as well as making assessments of the impacts of land changes and related policies. To achieve this objective, using the CLUMondo model as described in section 3.2, we have identified a number of well-defined tasks, that are elaborated below.

4.2. Co-design

This project builds on a co-design and co-production approach for building land use change simulation (LUCS) modeling capacity in the countries of the GMS. This approach involves a continuous interaction between the national and international experts of the project team, and the relevant stakeholders in national academic and government institutions. This co-design approach will ensure that all stakeholders, in itself, have a sense of ownership of the project results, which encourages them to contribute, and to continue using project results during and after the project.

This co-design approach will be applied in 1) the design of the user-interface, 2) the development of the training program for selected national academic staff members, 3) the development of an academic curriculum for LUCS modeling and 4) to the projects in which the LUCS model will be applied to support policy making in the countries of the GMS. Applying a co-design approach requires an ongoing interaction with the relevant stakeholders, and thus requires iteration during the project. It is for that reason that we have invited planners and policy makers already to the kick-off meeting, and that we will invite them again to the LUCS model network meeting. In both cases their participation will ensure that the training and academic curriculum we develop is relevant for actual policy support, and that we can take advantage of their experience in building a LUCS model network around best practice examples.

As this project on LUCS modeling capacity building will be complimented by a parallel project on the development of a GMS forest cover and land use map to improve planning and monitoring, we will also collaborate with the contractors of that project from the very start of their project. This ensures that the new land use and forest cover maps and the LUCS model can be used together. To further facilitate collaboration with project partners, representatives from the land cover mapping project, stakeholders from the policy and planning practice as well as the executing agency, we will conduct regular conference calls to discuss project progress as to provide feedback to all involved stakeholders also outside the formal project meetings.

This report already incorporates the results of the feedback provided during the kick-off meeting. In addition, we asked all stakeholders to provide one suggestion for each task, that will make it a success. These suggestions are included at the end of each task description below.

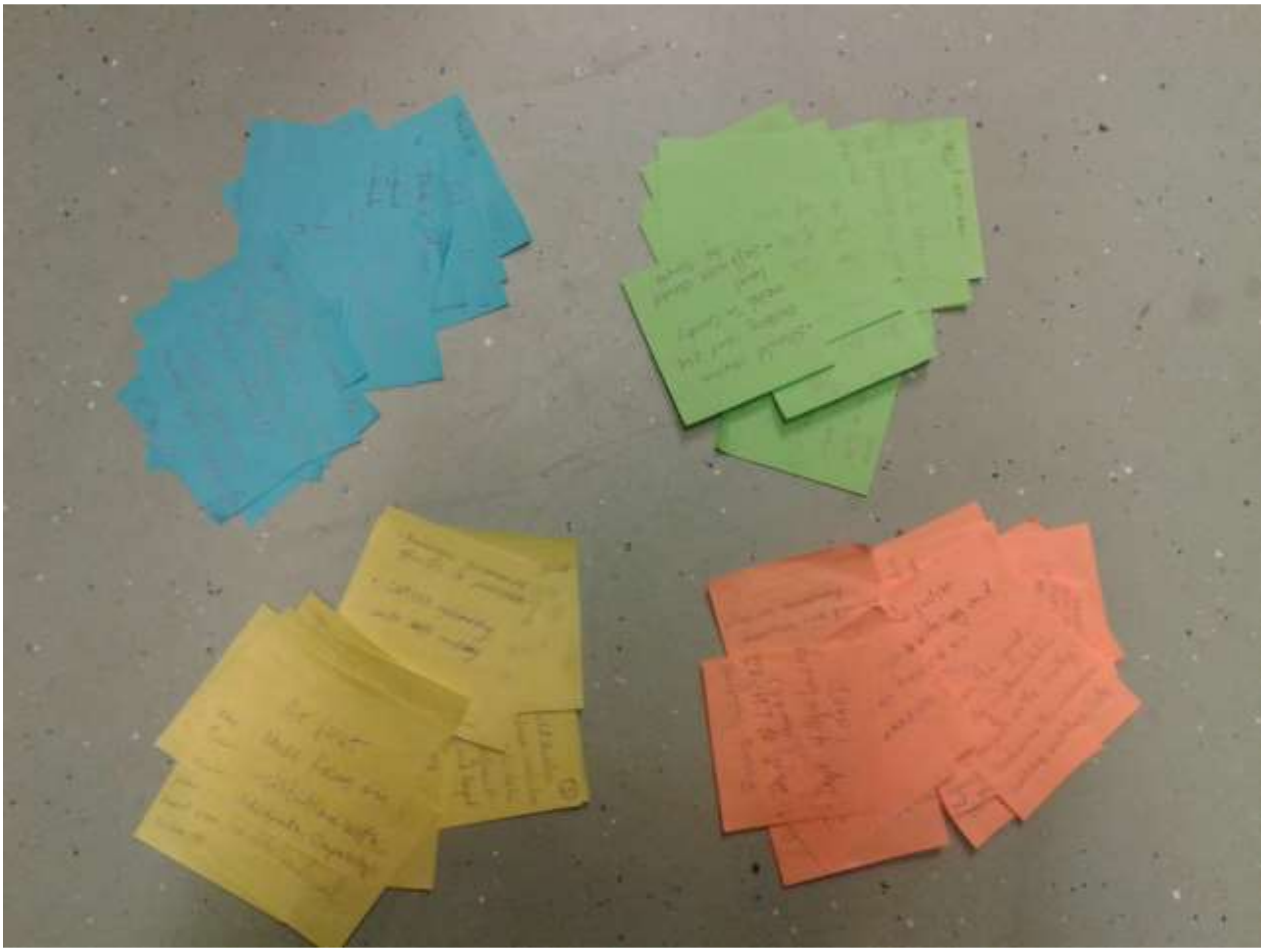

Figure 4: sticky notes with stakeholder suggestions to make this project a success.

Finally, we also aim to collaborate with other capacity building initiatives in the region from the kick-off meeting onwards, to increase exposure and learn by example. Specifically, we will collaborate with the LEAF program and the START network, as well as others when they are identified.

4.3. Overview of tasks, results and deliverables

The main objective of this project is to enhance the capacity for LUCS in national academic institutes to support relevant governments and institutes in the GMS. To that effect, the work is divided in four main tasks: 1) LUCS development and documentation, 2) training of national academic institutions, 3) the development of an academic curriculum to maintain LUCS capacity in the longer term, and 4) to foster policy-science interactions and operationalize LUCS modeling capacity. In addition, there is an overarching task in management and organization of this project.

The next sections describe the contents of each task in more detail, and provide insight in the implementation of the methodology, the proposed meetings and deliverables. The relation between tasks is indicated in Figure 5, below.

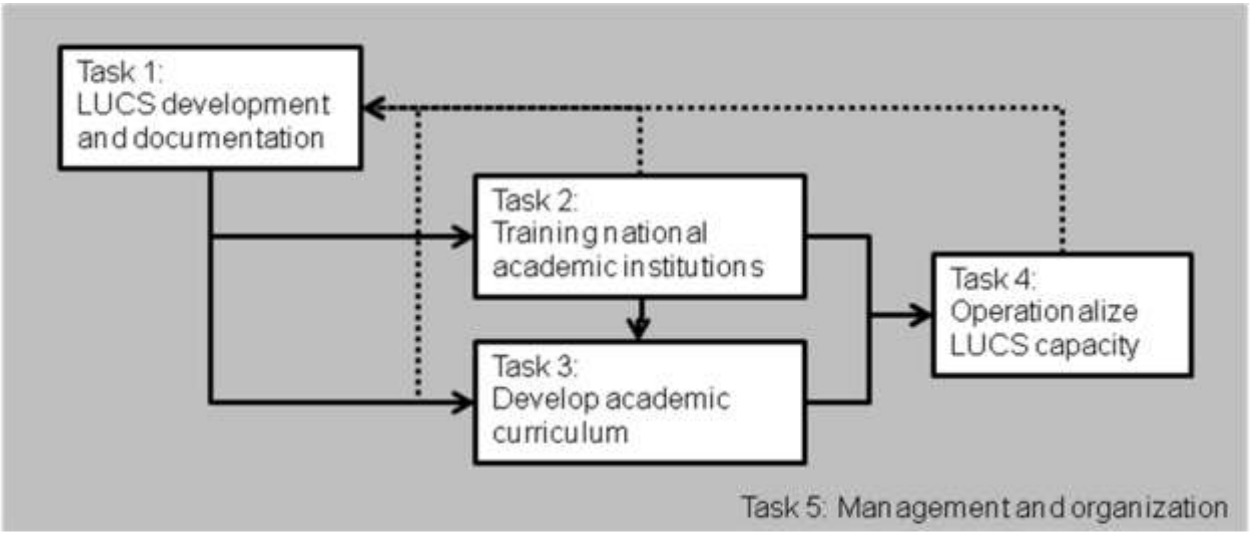

Figure 5: relation between tasks in this project; dashed lines indicate feedback within the project, to facilitate co-design

4.4. Task 1: LUCS development and documentation

The objective of task 1 is to enhance an easy-to-use and license free LUCS model. This LUCS model will build on the CLUMONDO model, the newest version of the family of CLUE models that are the most frequently applied land change models, both in academia and for supporting decision making. The CLUMONDO model as well as the ecosystem services module is described in detail in the methodology section above.

4.4.1. Task 1.1: Review of present LUCS models and functionality

The suitability of LUCS models for planning support is depending on usability, usefulness and credibility of a model. The usability of a LUCS model refers to the model as a software package: can users work with the system independently after some basic training? The usefulness of a LUCS model relates to the model functionality: is the model able to support relevant national spatial planning, and does it provide the right type of answers? Credibility is based on the ways in which the models realistically present land use changes and can be measured by validation. Section 3 provides a review of the different land use model types and argues that CLUMondo is a very suitable candidate land use model. The results of this review are used as a starting point in the further development of the selected LUCS model software for the GMS.

4.4.2. Task 1.2: Development of an ecosystem service demand module

Many land use models use an external (area) demand for specific land use types, which is subsequently allocated on the map. Often large scale economic models are used to generate such demands to account for international trade. In other cases simple trend extrapolations are used. This is a rather simplistic approach, as it does not acknowledge that in fact there is not a straightforward demand for land use areas, but rather that demand for ecosystem goods and services, for example food production, soil protection or biodiversity conservation, are creating a pressure for land system changes. Many land systems, and especially many of those in the GMS region, are multifunctional in that they provide several services. At the same time, multiple, competing, claims for ecosystem goods and services are exerting a pressure on land resources.

This project will apply the ecosystem services demand module that has been included in CLUMONDO. This module makes the model more flexible in its range of possible applications and reflects the state-of-the-art in land change modeling. While the model will still be able to run in 'traditional mode' it is no longer required to specify demands for land-use types in area units. Instead developments in the demands for multiple ecosystem goods and services can be used to steer the model, allowing the incorporation of assessments and scenarios of tourism development, carbon sequestration (REDD+) and others. Consequently, land systems can be represented in their full multi-functionality, while on the other hand, ecosystem goods and services can be provided by more than one land system. At the same time, output of the model is not only provided in land use areas, but also in terms of the changing ecosystem service provisioning, allowing to evaluate policy options and infrastructural plans based on their ecosystem service tradeoffs. While the ecosystem services module is already implemented, it is only being tested for application with different ecosystem services demands at this moment (specifically, carbon sequestration and biodiversity). Other ecosystem services are possible, and could be part of the PhD projects proposed in Task 4.

4.4.3. Task 1.3: Development of Graphical User Interface

The usability of a LUCS model for policy support is critically dependent on the user friendliness of the software within which it is presented. This is even more the case for LUCS models that are intended for widespread use and in academic training. The CLUMondo model is being implemented in the GEONAMICA software framework, to equip the model with a Graphical User Interface (GUI) for easy editing of input data and parameters and model control. Moreover, this implementation facilitates model output for further processing. Mock-ups of the GUI design and user requirement were presented to stakeholders in the inception workshop, and were seen as user friendly, and an improvement over many existing land use models.

4.4.4. Task 1.4: Implementation of all model functions and graphical user interface in license free software

Next to the usability and user friendliness, model uptake depends critically on the availability of the LUCS software. To maximize this availability, the GMS model as implemented in the GEONAMICA framework will be made available without any license costs. Moreover, the model functional code will be made available as open source code under the creative commons license. Moreover, the pre- and post-processing of model input and output can also be conducted in freely available and open source software, and will be described as such in the manual.

The implementation will include the use of free-ware statistical software and GIS software such as R and Q-GIS. A relative high level of flexibility in linking to such external software will be maintained to ensure that users can apply their preferred or institutional software as well as easily make use of new developments in software and software availability. Hard coupling of software is avoided to make sure that new versions of software remain compatible with the user interface. Users will have the choice of using simple GIS facilities within the land use model user interface or using more specialized software for advanced analysis or visualization. This flexibility will ensure attractiveness of the software and user-interface for both starting and advanced users with different software capabilities.

4.4.5. Task 1.5: Model documentation

Accompanying the LUCS modeling software we will develop a model documentation and self-teaching manual that explains the basic concepts, technical aspects and application of the

CLUMONDO model. This manual will be developed in close collaboration with national academic coordinator (NAC) and tested in the identified national academic institutions, to allow for feedback and questions. The manual will be used in Task 2 to develop the self-teaching manual in the six languages of the GMS.

The manual development will take stock of experiences in many applications of the current CLUE-s software and accompanying manual that has been used by many for self-study and in teaching and for which, based on monitoring of the questions arising from using the manual, a good knowledge base exists on the strengths and weaknesses of different forms of explaining and teaching the software.

4.4.6. Task 1.6 Fix software bugs

Software systems can contain small errors in their first version, as well as inconveniences in its design. In addition, additional requirements or improvements may emerge in the co-design process adopted in this project. As a consequence resources are reserved for fixing bugs in the LUCS model software as developed and implemented in this project.

4.4.7. Output and deliverables

Task 1 will yield the following deliverables:

Deliverable 1A (Month 6): A review of LUCS models and functionality (Month 6). This review is included as chapter 3 in this report.

Deliverable 1A (month 6): Implementation of a module which allows to steer land use change by the demand for ecosystem services. This module is currently available in the CLUMondo model.

Deliverable 1B (month 14): License free LUCS model software available for use in GMS, including ecosystem services demand module and graphical user interface. This LUCS model software will be made available through a dedicated website at the contracting institution as well as through an appropriate open source repository and ADB.

Deliverable 1C (month 14): Full documentation of the LUCS model and software available from a website. This documentation contains the technical documentation of the Land use change model and manual for usage of the user interface (implemented in the format of a help function in the user-interface).

4.4.8. Stakeholder suggestions to make task 1 a success

The following list of is a summary of the suggestions provided by stakeholders in the kick-off meeting.

Suggestions for the LUCS model:

- Should provide information for country strategy development
- Develop more function for environmental protection use such as spatial pollution change.
- Don’t require to many databases, but be flexible and allow the user to design the model themselves to fix with their own demand and specific case.
- Technical expertise and stakeholders who have interest should be invited to this task for their precious contribution.
- Good support for natural governmental stakeholders

- Top-down and bottom-up: more feedback from government units in the module design
- Good model structure;
- Take into consideration the natural features of the GMS.

The suggestions related to the selection and development of the model indicate the purpose of the LUCS model (national strategy development), as well as the practical aspects (data requirements, flexibility). These aspects have been incorporated in the selection of the CLUMondo model, as set out in section 3.2.

Suggestions for the LUCS model implementation:

- The software could be open source so that each country can justify to make it more suitable for actual application
- Design with more graphics, to be easy to understand by the participants.
- Consider the data availability, try to make the module using the most of the easily available data.
- The LUCS software should be user friendly and free for non-profit and education purposes.
- Easy, clear for use in daily work.

Suggestions regarding the model implementation mainly relate to the user friendliness. Existing land use model applications built within the GEONAMICA framework have been evaluated as user friendly and the mock-ups shown during the kick-off meeting were generally appreciated for the graphical part. The model functional code will be made available.

Suggestions for the documentation:

- precise and easy language; Use simplified words in the document
- Detail the steps for operating the system and more connection with other general systems.
- Give a glossary in the first page
- Develop a user friendly style

From these suggestions it is clear that the documentation should be clear and easy to understand. To ensure this, we will ask for the feedback of the NACs initially, and other stakeholders subsequently.

4.5. Task 2: Training and capacity building

The aim of task 2 is to develop land-use modeling capacity in identified national academic institutions in the countries of the GMS.

4.5.1. Task 2.1: Identification of 7 national academic institutions

In each country (or province in China) we have identified one National Academic Institution (NAI), where at least three academic staff will be selected to receive training in the concepts, background and application of the LUCS model, particularly to support land-use planning and policy making. National academic institutions were selected in close collaboration with the NACs based on their relevant expertise (GIS, land use planning), ability to implement a LUCS modeling course, their willingness to participate in the capacity building program with at least three staff members, and their location. Selected institutes are presented in page 32. Identified staff members will take the role of knowledge brokers: a bridge between academic expertise and planning practice.

4.5.2. Task 2.2: Develop train-the-trainer program

Successful application of LUCS modeling for land use planning and policy support requires more than only pushing the right button: it requires a thorough understanding of the land system, its drivers and their representation. It requires experts that are able to invest sufficient time to internalize the necessary expertise and knowledge. Due to the dynamics within policy institutions it is difficult to maintain such capacity. Therefore, this project builds on the train-the-trainer principle to generate LUCS modeling capacity in National Academic Institutions that can support policy institutions with this knowledge and assessments and ensure perennity of this knowledge by teaching students. The train-the-trainer program will be developed using a combination of self-study and face-to-face interaction over a prolonged period of time. Such an approach allows trainers to revisit aspects of the LUCS model and application over time, and provide feedback to the LUCS modeling expert and LUCS capacity builder. Moreover, such a continuous engagement increases the attachment of identified staff with this project.

4.5.3. Task 2.3: Training of national academic staff in all GMS countries in LUCS modeling

The train-the-trainer program consists of three components: First, participants will use the self-teaching manual to get familiar with the basics of the CLUMONDO model; then, each NAI will be visited for a one-week intensive course to really get to know the details of the model and its application for land use planning. Finally, in the last year of the project, trainers are invited for a centrally organized LUCS model network meeting. This network meeting will focus specifically on good-practice examples for land use planning and on to foster science-policy collaboration. The train-the-trainer program will build on IVMs extensive experience with LUCS teaching and course development, specifically related to the CLUE model. These courses have frequently resulted in successful uptake by national institutes without further need for involvement of the model development team.

4.5.4. Task 2.4: Translation of the LUCS self-teaching manual in 6 GMS languages

The self-teaching manual developed in Task 1.5 will be translated by National Academic Coordinators in the six languages of the GMS. This translation will take place during and after the intensive training courses in the respective national academic institutes. At this point also the NACs are fully familiar with the LUCS modeling software, which will ensure a high quality of the translated manual and it will allow to build on the GMS applications that are developed within this project. The translations of the self-teaching manual will be created within the document template that is also used for the English version to ensure reuse of figures and a well-organized and consistent layout.

4.5.5. Output and deliverables

At the end of the project, each of the countries in the GMS will have at least three academic staff members that are familiar with the CLUMONDO model and its application for land use planning and policy support. These scientists, together with the national policy institutes NACs, the GMS-EOC and the international staff in this project will function as a network of experts that share ideas knowledge, insights and best-practice examples.

Deliverable 2A (Month 6) Listing of 7 national academic institutes and 7 national academic coordinators provided to the ADB. This list has been presented during the kick-off meeting and the outcomes of this are included in section 5 of this inception report.

Deliverable 2B (Month 14) Document describing the program for training academics in national academic institutions provided to ADB.

Deliverable 2D (Month 18) Academics from national academic institutes in 7 GMS countries are trained in the independent application of the LUCS model.

Deliverable 2C (Month 20) Manual for the application of the CLUMONDO model available in English and 6 GMS languages available from the website.

4.5.6. Stakeholder suggestions to make task 2 a success

At the end of the kick-off meeting, stakeholders were asked to provide suggestions for making task 2 a success. The main points addressed were:

Regarding the National Academic institutes:

- NAI should ensure a balancing of applications between government agencies and universities.
- Have engineers from different groups participating.
- Commitment of teachers after the training of trainer to roll out the training awareness raising.
- Appropriate staff and institutions have been selected.
- Please include pertinent resources for persons, and more importantly, trainees from relevant institutions which directly or indirectly manage land.
- At first more focus on institutions with adequate capacity.

We have selected NAIs and staff members that include a significant number of engineers or staff members with a technical background, which will facilitate the technical uptake of the model. Some resources have been reserved for the training as well.

Regarding the train the trainer program and implementation:

- Trainer should develop different academic curricula and supply availability data for practicing at different study levels and target groups.
- Organize LUCS events during staff school holidays.
- Training materials to be translated into at least lower Mekong countries languages.
- Encourage government officials to participate, as well as CEP implementers.
- Governmental sectors need to get involved from the very first stage (train-the-trainer program).
- Is a formal workshop possible? Suitable for little bit more training with hard copy materials.
- A gender balance for participants.
- Linking with more stakeholders, to make decisions on inputs and outputs.
- Provide certificates for trainees after finishing the trainings.
- Hold seminars and conferences is crucial.
- Open environment.
- Proper networking.
- Training national academic staff requires a place, some time and people, hence funds are required to solve these problems.
- Provide explicit guidelines on how to work with the material.

Practical suggestions (regarding the school holidays, the open environment, etc), will certainly be acknowledged during the workshops. While the train-the-trainer workshop is primarily targeted at academic staff, we will organize one day per country in which government stakeholders are invited as well, both to build a network with the academic staff and to get further acquainted with the LUCS model.

4.6. Task 3: Development of an academic curriculum to maintain LUCS capacity

To continue the application of LUCS modeling it is important that a new generation of experts becomes aware of the existence, concepts and applications of land use modeling in general, and for land use planning and policy support specifically. This task will develop an academic curriculum that can be implemented in the selected national academic institutions, and potentially also in other academic institutions in the GMS.

4.6.1. Task 3.1: Design a student training course in LUCS modeling

A long lasting LUCS modelling capacity in the policy context requires embedding such approach in the curriculum of relevant universities in the GMS. To that effect we will develop a LUCS training course aimed for students in GMS based universities in general, and selected national academic institutions in particular. To facilitate a widespread uptake of this curriculum, it will be based completely on freely available software.

The training course will be developed in parallel with the LUCS model, so that both the training course and the model are available for implementation during the course of the project. National Academic Institutions were selected based on their availability to implement an academic curriculum in their education program, and all institutions agreed to implement it. As the input and expertise of selected national academic staff is essential, the student training course will only be developed and implemented after the train-the-trainer course (Task 2.3).

Course material will include presentations that can easily be used by trainers in different contexts, exercises (with and without the use of software) and a collection of literature that can be used as part of the background teaching materials. The course material will cover:

- an introduction to the processes of land use change and monitoring efforts/data
- an introduction to the drivers of land use change
- an introduction to the impacts of land use change
- an overview of the role of land use models in assessing land use change and informing policy
- a tutorial on the use of land use models and its application in decision support, largely based on the CLUMONDO software.

From the feedback in the inception workshop we learned that the background knowledge and skills will differ considerably from one university to another. Therefore, the training material will be offered as modules, ranging from the basics to more advanced material, and not as one standard package. NAIs can subsequently select those modules that are appropriate given the level of their students.

4.6.2. Task 3.2: Supervision of MSc and PhD students

To further encourage the uptake of LUCS modeling in the GMS countries, IVM staff will supervise at least two students in the region. Supervision will be arranged as a collaborative effort between the international and the national academic staff in this project, to make sure that it relates both to state of the art in LUCS modeling and that it is relevant for policy support in the respective GMS countries. In addition, selected MSc or PhD students are encouraged to further contribute in this project by participating in the LUCS model network meeting and presenting (preliminary) results to relevant stakeholders.

4.6.3. Task 3.3: Prepare a scientific paper

The results of the model development and application in the context of this project will be presented in a scientific paper that will be submitted to an international peer-reviewed journal. While some aspects of the model application are already sufficiently innovative for scientific publications, the scientific output of this project should preferably discuss the application of the land use model to assist land use planning in the GMS, as this is key to the project and as it can serve as a good practice example for other stakeholders. The peer-reviewed paper will be written by the international academic staff, in collaboration with selected national academic staff and national academic coordinators to facilitate knowledge sharing, to create involvement, and to ensure its relevance for the GMS.

4.6.4. Task 3.4: Conference presentation of a GMS LUCS application

Prior to writing a full paper, results of the application of the LUCS model in the GMS will be presented in a relevant international conference. Moreover, the international academic staff will encourage and support national academic staff and PhD students to present their work on LUCS modeling. The exact conference(s) or symposium(s) will be selected in consultation with the ADB staff and other relevant stakeholders to optimize (international) impact and dissemination of the experiences in the region.

4.6.5. Output and deliverables

Deliverable 3A (Month 20) Document describing the detailed outline of the student training course provided to ADB.

Deliverable 3B (Month 32) Student training course included in the curriculum of 3 institutions.

Deliverable 3C (Month 32) One scientific paper on the improved LUCS model and its GMS application submitted to an ISI rated peer-reviewed journal.

Deliverable 3D (Month 26) GMS model results are presented in an international conference or symposium.

4.6.6. Stakeholder suggestions to make task 3 a success

The following suggestions were provided by stakeholders at the end of the workshop to make task 3 a success:

Regarding the LUCS curriculum:

- Enough granularity for customization, but not a heap of disjoint pieces.
- First should put the LUCS as part of a GIS subject and then make a separate LUCS subject
- Learning outcomes should be clearly defined in the curriculum.
- Include the synergy/connection/comparison of the model / developed software with other commonly used models and tools.
- Consider the data available and whether they fit the curriculum or lecture/exercises
- General concept to cover mulit-sectoral needs.
- Include some theoretical background and a lot of workshops and examples

- Please consult with the former academics and researchers as well as with current implementors who have had sufficient expertise and experience for the development of academic curricula.
- Universal and simple.
- Fit with existing curricula.
- Simple, and more practical work and exercises.
- Allow refinement of the curriculum until the end of the project and incorporate lessons learned from implementation
- The curriculum should not be hard to accept. Thus we can let more students learn the model.
- Simplify words from the academic curriculum
- NACs need to consult with respective national translation council to keep their translation in line with national standards
- Simple language for curriculum since the students may not have a strong background.
- Good coordination and inclusion
- Knowledge on land resources
- Land use planning, and future socio-economic scenarios
- Make the curriculum simple and textbook alike, while the model for implementation can be more complex and academic.
- Voice from government units.

The modular structure of the academic curriculum that will be developed in this task is a direct result of the suggestions about flexibility provided here. In addition, we will ensure that the curriculum, just as the model documentation, is relatively easy to understand and uses easy language.

Other suggestions:

- Set up a forum and network for encouraging and facilitating research applying LUCS
- Provide funding for trainers have small application projects.

Setting up a network is part of this project, which will be implemented through the organization of different meetings, in which staff and students involved are encouraged to participate. Additional funds for application projects have not been included in this project, but such projects could be supported for example as part of the Student projects or LUCS implementation projects.

4.7. Task 4: Operationalize LUCS modeling to support land use planning

The goal of the LUCS model and related capacity building is to support land use planning and policy making in the GMS. This task aims at operationalizing the model for this goal.

4.7.1. Task 4.1: Design LUCS awareness raising strategy

In order to guarantee the usefulness of the project results we will apply a co-design strategy throughout the project, which at the same time serves to raise awareness. In this process, policy makers are involved from the design phase onwards and provide their inputs to the LUCS model, the train-the-trainer program and the academic curriculum. Specifically, this means that selected stakeholders from government agencies were invited for the kick-off meeting, and will be invited for parts of the training sessions and the LUCS model network meeting. Moreover, they will be involved in the application of CLUMondo for national planning processes.

Further awareness raising activities will be organized primarily in consultation with the NACs, which are the interface between the international academic staff and the stakeholders in the GMS. This awareness raising strategy eventually culminates in the LUCS model network meeting and a LUCS modeling brochure, in which good practice examples from this project will be presented.

4.7.2. Task 4.2: Provide input to 2 national planning processes

National planning entry points will be proposed by the NACs in consultation with the ADB staff, as they are most knowledgeable of governance structures in the GMS region and as they have the best contacts with local stakeholders. While the international academic staff will encourage and support all national academic institutes to provide input to this selected planning process by the application of the CLUMondo model, two processes will be selected to be supported jointly by the national academic staff and the LUCS model capacity building expert.

The input to these planning processes will, preferably, be provided as much as possible by the national academic staff, in order to establish a partnership between them and the relevant stakeholders. The roles of the LUCS modeling expert and LUCS capacity builder are, therefore, primarily to assist and supervise the national academic staff in implementing the model, and to ensure the quality of the assessments made.

4.7.3. Task 4.3: Organize awareness raising events in 6 GMS countries

Each of the NACs has the responsibility to organize one LUCS awareness raising event in their country as they are the main interface between science and policy in this project. Focus of these awareness raising events are national level planners and policy makers. The events will provide presentations and demonstrations of the added value of the LUCS model capacity based on the actual and ongoing projects in which LUCS modeling is being used in the GMS. In addition we will discussing the demands from the policy process and the capabilities of the models and experts to provide such information. Consequently, these awareness raising events build, as much as possible, on the planning processes as selected under Task 4.2 as operational exemplars of the use of the tools and capacity.

4.7.4. Task 4.4: Develop one knowledge product (brochure)

Part of the awareness raising strategy is the development of a brochure that explains the added benefits of LUCS modeling to support national planning processes. These brochures are targeted at relevant national level policy makers and consequently explicate in relative simple language using good practice cases the added benefits of LUCS modeling, without detailing any technical aspects.

4.7.5. Output and deliverables

Deliverable 4A (Month 12) Short document describing awareness raising strategy provided to ADB.

Deliverable 4B (Month 23) Brochure explaining the value of LUCS to support planning processes distributed by NACs to all relevant planning/policy institutes and national academic partner institutes, also made available through internet.

Deliverable 4C (Month 26) Attendance lists of awareness raising events in each of the GMS countries.

Deliverable 4D (Month 32) Factsheets on LUCS model applications in at least 2 national planning processes

4.7.6. Stakeholder suggestions to make task 4 a success

Stakeholders provided the following suggestions for making task 4 a success:

Awareness raising:
- Let governments share their use of the model.
- Awareness raising should be more than one time, to target different level of government officials (e.g. policy level, technical level).
- Establish a forum for members of the GMS countries to share information and experiences.
- Before documentation, please share and exchange information and experiences as well as ideas and opinions among LUCS capacity and relevant government agencies and stakeholders.
- Identifying academic champions in each country or province: he/she is expected to be trained and through her/his linkage with governmental policy makers influences, and capacity building at the policy level could be reached.
- Sharing good practices.
- Prepare good reality implementations in the GMS countries to show on the awareness raising workshops.
- Ensure necessary resources are provided.
- Regular communication on progress to all involved, to stimulate participation.

As suggested by several stakeholders, the awareness raising will be based on good practice examples from this project, i.e. applications of LUCS models, preferably in collaboration with national governmental agencies. As such, the awareness raising will be based on real world examples from within the GMS.

Support national planning processes:
- Support a pilot study which is the priority task of government stakeholders.
- Integrate the LUCS with a government project / Link with government institution.
- Use in CEP component 2 biodiversity landscapes and corridors.
- Cross-sectoral participation.
- ADB has to work with central government in China in this program, in order to have more official partners join/use the model. It is much easier to persuade the government to use the model.
- Engagement and commitments of partner institutions are key to success.
- Objectives based on the real needs of the government.
- A pilot for demonstration conducted by an end-user.
- Regular monitoring and follow-up
- Identify an appropriate project for LUCS application
- Focus mainly on the department of land use planning and development (MONRE), and the department of agricultural land management (MAF).

As suggested by several stakeholders, the implementation of the LUCS model will be done in close collaboration with selected governmental institutions. The exact selection of implementation projects will be done in discussion with ADB considering these suggestions.

4.8. Task 5: Management and Organization

The organization of a kick-off workshop and other project meetings as well as the semi-annual reporting are part of Task 5. Semi-annual reports will be prepared by the team leader and in collaboration with all other project partners for reporting the project progress to ADB. Reporting will be concise and include all deliverables of the other tasks above as annexes to the report. Progress reports as well as other deliverables will be presented in digital format unless otherwise stated, to save paper and allow for efficient communication. Additional mission reports will be provided as required by ADB.

The project includes several meetings in which the international project staff, the national project staff, the national academic trainers, and policy makers will get together. According to the Terms of Reference and the tasks described above these include:

- The kick-off meeting has been organized in October 2014 (due to a delayed start). In this meeting the National Academic Coordinators have been presented and selected National Academic Institutions have been proposed. In addition, the remainder of the project has been discussed with the invited stakeholders and ADB staff.

- Halfway 2015 a training-tour will be organized in which the LUCS capacity builder will visit each of the national academic institutions for a week to present the LUCS model and the user interface, train the academic staff in these institutes, and further discuss the related academic curriculum. In each of these meetings, one day will be used to discuss efficient ways to implement the model for policy support, together with invited stakeholders and NACs.

- Towards the end of 2016, a LUCS model network meeting will be organized in Bangkok, which assembles policy makers and scientists from the project and further advance the LUCS modeling science and application in the GMS. This meeting will build on good practice examples from the project and will be attended by the international and national project staff. MSc and PhD students that are conducting their thesis research in the context of this project are explicitly invited to join this meeting.

- During the project each NAC will organize at least one national awareness rising event in which policy makers and national academic staff can discuss the application of the LUCS model in their planning process and to foster the advancement of an efficient policy-science interface. This meeting is included in Task 4.3.

5. Project management and implementation

5.1. Project planning and management

The team for this project consists of both international professional staff and national professional staff. The international professional staff is represented by experts from the Institute for Environmental Studies (IVM) of the VU University Amsterdam, the Netherlands, in conjunction with the Research Institute for Knowledge Systems BV (RIKS), The Netherlands. The national professional staff includes one expert from the each of the countries and provinces in the GMS. Table 1 below introduces the national and international project staff and their roles in the project. A short bio of each key expert is provided in Appendix A.

Table 5: Key experts involved in this project

Main role	Professional staff assigned
LUCS modeling expert (Team Leader)	Prof. Dr. P.H. Verburg, IVM (IVM)
LUCS Capacity building specialist	Dr. J. van Vliet, IVM (IVM)
LUCS Software programmer	Roel Vanhout, Research Institute for Knowledge Systems bv
NAC Thailand	Prof. Dr. Yongyut Trisurat, Kasetsart University
NAC Cambodia	Dr. Sarann Ly, Institute de Technologie, Cambodge
NAC Vietnam	Dr. Nguyen Thi Van Ha, Ho Chi Min City University
NAC Yunnan, China	Prof. Dr. Li Yongmei, Yunnan agricultural university
NAC Guangxi, China	Dr. Xin Nie, GuangXi University
NAC Lao PDR	Dr. Thatheva Saphangthong, Council for Science and Technology
NAC Myanmar	Prof. Dr. San Win, University of Forestry

Besides the key experts involved in the project, there is an important role for selected national institutes as well as for stakeholders in the region representing governmental institutions. As the program will be implemented through staff members and curricula of the selected national academic institutes, they play the role of knowledge brokers: the link between the project staff and the eventual stakeholders (i.e., governmental organizations in the GMS). The main links between the key participants in this project is depicted in Figure 6.

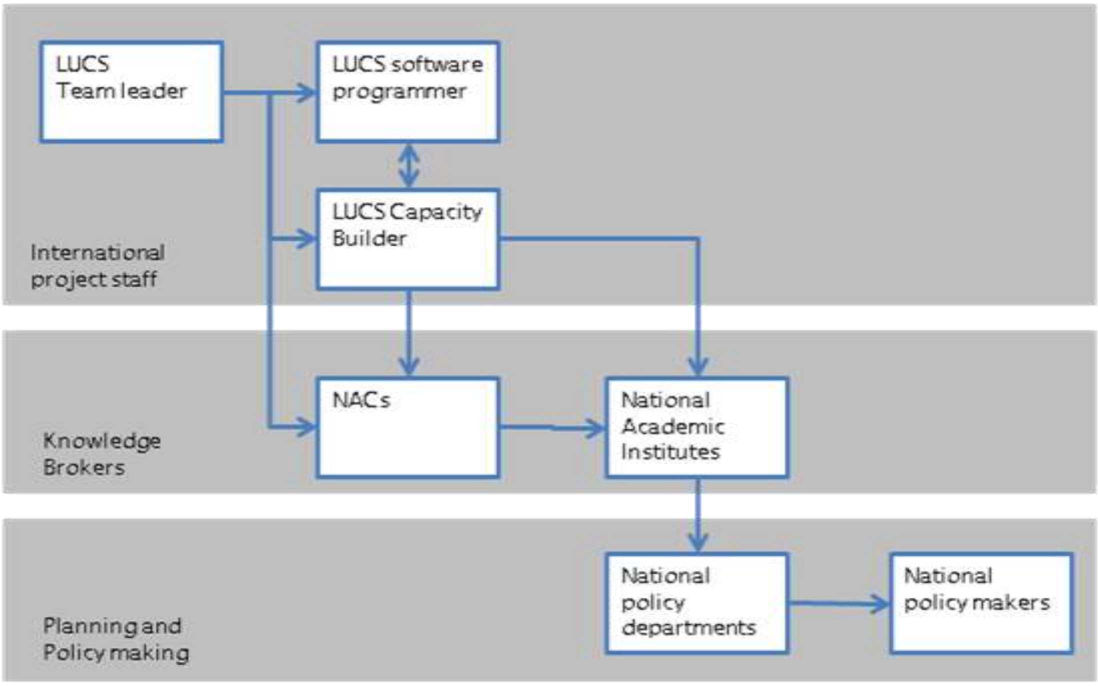

Figure 6: Relation between key persons and institutes within the project

5.1.1. Project planning

An updated work schedule is provided in Appendix B. The schedule indicates which tasks and subtasks have been completed, which tasks and subtasks are ongoing, and which task are still ahead. The schedule is adjusted relative to the proposal mainly due to the late start of the project.

5.2. National Academic Institutes

The National Academic Institutes (NAI) play a pivotal role in the implementation of this project, as they host the trainers that will be trained in LUCS modelling and provide future courses in LUCS modelling. NAIs have been proposed by the respective NACs during the inception meeting, and stakeholders from the respective countries have provided their suggestions and feedback on this proposal. This feedback has been processed in the final selection as presented below:

5.2.1. National Academic Institute Thailand

Kasetsart University has been selected as the university through which this project will be implemented in Thailand. The university has already a number of courses that are closely related to land use modelling at both undergraduate level (including Principles of land use and applied GIS in forest engineering) and at master level (including Advanced GIS for watershed management and Integrated land use management and planning). In addition, the university has a research program in the field of land use and land cover change, which facilitates the uptake of this program. The following faculties will participate in the train-the-trainer program:

- Dr. Suprattra Thueksathit, Department of Conservation
- Dr. Piyapong Tongdeenok, Department of Conservation
- Dr. Khanchai Prasanai, Department of Forest Engineering
- Ms. Weerana Sompeewong, Department of National Parks, Wildlife and Plant Conservation

- Ms. Sansanee Arunwas, Land Development Department

5.2.2. National Academic Institute Cambodia

The Institute of Technology of Cambodia (ITC) and Royal University of Agriculture (RUA) are selected for the implementation of LUCS modelling course in Cambodia. These two institutions have a number of courses that can be beneficial with the implementation of land use modelling course. The following lecturers will attend the LUCS modelling course:

- Ms. Phoeurn Chanarun, lecturer of GIS and Environemental Eng. (Department of Rural Engineering, ITC)
- Mrs. Hang Leankhena, lecturer of GIS, Remote Sensing and Environemental Eng., (Department of Rural Engineering, ITC)
- Mr. Chanthy Sochiva, lecturer of Hydrology, GIS, (Department of Rural Engineering, ITC)
- Mr. Song Layheang, lecturer of Hydrology, Hydraulics, GIS, (Department of Rural Engineering, ITC)
- Mr. Kim Soben, lecturer of Wood technology, Utiliza.Forest Pathology, GIS (Faculty of Forestry, RUA)
- Mr. Sum Dara, lecturer of GIS (Faculty of Forestry, RUA)
- Mr. Seng Soksan, lecturer of GIS and land management (Faculty of Land Management and Land Administration, RUA)

Since the thematic coverage of both institutions is complementary rather than overlapping, and since both institutions have good contacts with government agencies, including both was the best option for capacity building in Cambodia. Since both institutions are located in Phnom Penh, teaching both can be combined in one workshop.

5.2.3. National Academic Institute Vietnam

Two institutes are identified as suitable entry points for the implementation of the LUCS modelling course in Vietnam: HCMC University of Natural Resources and Environment and University of Natural Science and University of Agriculture in Hanoi. Two different universities were selected due to their different approaches and different relations with regional and national governments. Both institutions have a wide range of relevant topics, given their focus on natural resources and the environment. It is the aim to bring selected staff from both universities to one location for this training course. Selected staff members include

- Dr. Nguyen Lu Phuong – lecturer on environmental models of HCMC University of Natural Resources and Environment, Faculty of Environment.
- Dr. Vu Xuan Cuong – Lecturer on land survey and mapping, land planning and management, of HCMC University of Natural Resources and Environment, Faculty of applied GIS and Information Technology.

- Dr. Le Phat Quoi – visiting lecturer on land resources management of HCMUNRE – Chairman of Scientific and Technology division – Department of Science and Technology in Long An Province.
- MSc. Nguyen Thanh Ngan – lecturer on applied GIS and remote sensing on environmental management of HCMC University of Natural Resources and Environment, Faculty of Environment.
- Pham Xuan Canh – Faculty of Geography- National University of Natural Science, Hanoi, teacher in remote sensing and applied GIS.
- Nguyen Xuan Linh - Faculty of Geography- National University of Natural Science, Hanoi, lecturer in GIS and land administration
- Tran Nguyen Bang - Faculty of Environment - Vietnam National University of Agriculture (VNUA), lecturer in environmental management.

5.2.4. National Academic Institute Yunnan province, P.R. China

Yunnan Agricultural University has been selected for the implementation of this project in Yunnan province, PR China. The university has 20 colleges, including the colleges of Resources and environment, topical crops and water conservancy, hydroelectricity and architecture, which qualify for the implementation of this project. In addition, the university hosts several key provincial laboratories, including the Yunnan provincial research center for land resources and protection, making it a very suitable university for teaching LUCS modelling for policy support. Relevant courses have been identified in relation to the bachelor for land resource management (including land information systems, land resources inventory and evaluation, land use planning, and GIS software applications). The following teacher will participate in this project:

- Dr. Zhang Dan, Lecturer in Geography.
- Dr. Su Youbo, Associate professor in agricultural resources and environment.
- Mr. Fan Maopan, Lecturer in agricultural resources and environment.

5.2.5. National Academic Institute guangXi province, P.R. China

The selected university in GuangXi province is QuangXi University. This is the oldest and largest university in GuangXi province and provides Master level courses in amongst others Land Management, Land Use Planning, Land Economics, Urban Planning and Management, Regional Tourism Development and Planning and Environmental Economics, and is as such well equipped to accommodate a curriculum in LUCS modeling. The following teachers have been selected to participate in the train-the-trainer program:

- Dr. Xin Nie, who teaches Land Use Planning
- Dr. Gao Wei, who teaches Urban Planning
- Dr. Wang Han, who teaches Regional Tourism Development and Planning

5.2.6. National Academic Institute PDR Lao

The National university of Laos (NUoL) has been selected for the implementation of the train the trainer program in Lao PDR. Within this university, the program will be implemented in the faculty of Forestry, which amongst others teaches courses in Forest Management, Integrated Watershed Landscape Management, and Ecotourism and Conservation. In addition, the faculty has a large number of research projects on land use management, agricultural development and forestry, which ensure a connection with ongoing research and a number of knowledgeable researchers. The following teachers have been selected for the train the trainer course:

- Ass Prof. Dr. Sithong Thongmanivong, Lecturer in Forest Resource Management, Management Watershed Landscape Management
- Mr. Vongphet Sihapanya, Lecturer in GIS/RS and Modelling
- Ms. Somvilay Chanthalounnavong, Lecturer in Forest Management

5.2.7. National Academic Institute Myanmar

This project will be implemented in Myanmar through the University of Forestry in Yezin, which is administered under the guidance of the Ministry of Forestry of Myanmar. This close relation between the university and the policy makers is reflected in the fact that there are many exchanged between staff members and employees of the ministry and that many employees of the ministry have studied at this university. The following teachers will participate in the train-the-trainer program:

- Ms. Khin Kyi, Head of the Botany department
- Ms. Myanm Hnin Hlaing, Assistant lecturer at the Botany Department
- Ms. Phyu Phyu Han, Demonstrator at the Department of Forestry
- Mr. Aung Myo Win, Assistant lecturer at the University of Forestry

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Appendix A. Detailed CV of staff members included

LUCS modeling expert and team leader

Prof. Dr. Ir. Peter Verburg is a professor of Environmental Spatial Analysis and head of IVM's Environmental Geography department. He has strong experience with the quantification and mapping of ecosystem services, spatial analysis and modelling of land use and land cover, biodiversity, ex-ante assessment models and landscape ecology. Peter Verburg is a core member of the Ecosystem Service Partnership (ESP) and has contributed to „The Economy of Ecosystem Services and Biodiversity (TEEB)“ assessment. He has participated and coordinated various research projects in different parts of the world including the EU FP6 SENSOR and FARO projects and the EU FP7 RUFUS, TURAS, VOLANTE and CLAIM projects. He is developer of the CLUE/CLUE-scanner model, a well-established, spatially explicit methodology for simulating land use change, which has been applied to many different countries and regions worldwide. He has (co-) authored over 100 peer-reviewed scientific papers and serves in the editorial boards of the journals Landscape Ecology, Environmental Modelling and Software, Environmental Management and the Journal of Land Use Science. Peter is module leader of the VOLANTE FP7 project that will address the relation between changes in the land system and provision of ecosystem services and has been scientific leader in the DG ENV project „Land Use Modelling – Implementation“. In addition, he is the chair of the Global Land Project a core project of IHDP and IGBP bringing together the largest international network in the field of land change from different (disciplinary) perspectives.

Peter Verburg has spent 6 months in Vietnam, 4 months in China, 3 months in the Philippines and has made short missions to various countries in the South-East Asia region. He has guided CLUE model applications in Thailand, Malaysia, Vietnam and Laos and is currently involved in an academic project on land use change analysis in Laos. He has provided trainings to academic staff and policy makers in Central America, China, Taiwan, Japan, Kenya, Romania and other places worldwide.

LUCS Software programmer

Roel Vanhout is a software engineer with degrees in applied computer science and law and has over 15 years of experience in designing, implementing and marketing complex software systems. Applying sound principles of user interaction and emphasizing the functions and business cases software systems are designed to supply over technology for the sake of it, he has been working on advancing the state of the art in applied spatial decision support systems for more than 10 years. At RIKS, his work has revolved around implementing reusable components for modelling in policy making and translating requirements from the policy domain into functional modelling- and software solutions, as well as translating technological innovations into market-ready solutions.

Roel has written large parts of the Geonamica software framework, the Metronamica generic land-use model and most of the land-use related software in projects carried out by RIKS in the last 10 years. These projects typically comprise the development of spatial decision support systems including land use change models as well as other model components. Some recent examples include Xplorah, a spatial decisions support system for Puerto Rico, LUMOCAP, a system to assess land use changes in the European union under different policy alternatives, and creating futures, an integrated policy support system for the Waikato region in New Zealand.

LUCS model capacity building specialist

Dr. Ir. Jasper van Vliet is a researcher at the Institute for Environmental Studies (IVM) and the Amsterdam Global Change Institute (AGCI) where he masses drivers for land use change in multiple different locations and scales. He holds a PhD in land-use modeling from Wageningen University. His PhD research focused on the calibration and validation of land-use change models. His current work includes research in land use change and land use change modeling, as well as teaching the theory and practice of spatial analysis to Master students in Environment and Resource Management, Master students in health sciences and Bachelor students in Earth and Economics, all at VU University Amsterdam. Jasper is also involved as science officer in the Global Land Project.

Previously Jasper worked as a researcher and consultant for the Research Institute for Knowledge Systems, where he developed and applied land-use change models and trained professionals and scientists in the use of these models for scenario studies and policy support. In that position he worked in projects that include land-use model development and related capacity building for the Puerto Rico Planning Board in Puerto Rico, Environment Waikato in New Zealand, the European Spatial Planning Observatory (ESPON) in Europe and the European Directorate General for the Environment. In addition Jasper has worked on several international research projects, including the LUMOCAP and DeSurvey FP6 projects and PLUREL and VOLANTE FP 7 projects.

National academic coordinator Thailand

Prof. Dr. Yongyut Trisurat is the Head of the Forest Biology department and head of the biodiversity centre, both at Kasetsart University. He holds a doctorate from Asian Institute of Technology in Natural Resources Conservation, and has about 15 years of experience in research and teaching topics related to biodiversity, landscape ecology and land use modelling in Thailand. His previous projects include the implementation of the CLUE model in Thailand, and he has ample experience with model based studies, including InVest, GLOBIO and species modelling. Yongyut has served on a number of spatial analysis projects that advised governmental agencies in the region (Royal Forest Department, Thailand; Mekong River Commission) as well as a number of non-governmental organization (ITTO (International Tropical Timber Organization); UNDP/Department of National Park, Wildlife and Plant Conservation; IUCN (International Union for Conservation of Nature and Natural Resources); ADB).

National academic coordinator Viet Nam

Dr. Nguyen Thi Van Ha is a Dean of Environment Faculty of Ho Chi Minh City University for Natural Resources and Environment which belongs to the Ministry of the Natural Resources and Environment of Vietnam. She has strong experience with the coordination tasks of the capacity building for different sectors, including modeling in Vietnam. She is also a short term consultant on Safeguard and environmental for the World Bank, an independent environmental expert for Asian Development Bank (ADB), for Ministry of Planning and for Black and Veatch international consultant (BVI). Moreover, she is a founder and team leader of Center of Excellence (CoE) on renewable energy and energy efficiency for Swedish Energy Agency – SIDA funded project.

National Academic Coordinator Cambodia

Dr. Sarann Ly is a lecturer/researcher of GIS, surveying and some courses relating to Water Resources Engineering and Deputy Head of Department Rural Engineering at Institut de Technologie du Cambodge. He also involved with many development and research projects with government institutions, NGOs and private companies in the field of geospatial and water/natural resources management. Sarann has developed several types of complex geostatistical interpolation algorithms applied to rainfall. He has supervised several student theses including recently remote sensing based mapping of land cover in a sub-catchment of Tonle Sap Basin. He has been working as a leader, team leader and coordinator of various development and research projects related to water resources engineering and environmental studies including research on improving water governance and climate change adaptation in Cambodia. He has extensive experiences in working with local governmental staffs, communities, NGOs, and international organizations and universities

National academic coordinator Myanmar

Dr. San Win is the pro-rector of the University of Forestry, Yezin, Myanmar. He Holds a Msc. And a PhD. In Forest Management, both from the University of Tsukuba, Japan, and his key expertise include Forestry and forest management, shifting cultivation and agroforestry, and climate change adaptation. San Win has ample international experience, participating in workshops, seminars and conferences related to Rio+20, COP-15, UNFCCC, ASEAN agreements and other related organization. Previously he has worked for the ministry of forestry in Myanmar serving as director and joint secretary of the national commission for Environmental Affairs, and as project director of several projects related to forestry and land use in Myanmar

National academic coordinator Lao PDR

Dr. Thatheva Saphangthong is a senior natural resource management specialist with much experience in community land use and watershed management planning, environmental and social impact assessment, and participatory upland development. He obtained his PhD in Southeast Asia Area Studies at Kyoto University, Japan in 2007, majoring in land use dynamics in the Northern Lao PDR. He has been involved in several community land use planning and watershed management projects both locally and internationally as principal investigator or project leader and trainer for the past 9 years. At the same time he has been managing and facilitating the information knowledge management of the agricultural sector and cross-sectors integration within Lao PDR for more than 10 years. Currently, he was promoted to be a deputy director general of the Council for Science and Technology, Ministry of Agriculture and Forestry, Lao PDR. He is working closely with the Lao agricultural and forestry research and development to support evidence-based decision to the policy level.

National academic coordinator Yunnan province, China

Prof. Dr. Li Yongmei is professor of soil science and plant nutrition and director of international cooperation and exchange department in Yunnan Agricultural University, P. R. China. She gained her Ph.D in soil science from the University of Wolverhampton, UK. Li Yongmei has participated in various research projects founded by EU FP5 and FP6, GEF, Chinese science foundation and Yunnan provincial science foundation. She was project manager for EU FP 5 SHASEA and gained a lot experiences in international project management. Li Yongmei has served as independent experts for EU proposal evaluation for several times. Her research areas are mainly focusing on soil conservation and agricultural sustainability, agricultural pollution control, land use change and soil quality. She has supervised 26 Master degree and 5 Ph.D students, and author/co-authored 86 refereed papers and chapters.

National academic coordinator Guangxi province, China

Dr. Xin Nie is an associate professor at the College of Public Administration, University of Guangxi, Nanning, China. He holds a PhD in land resources management and a MSc in population resources and environmental economics, both from Huazhong Agricultural University. His current research focusses on land resources and spatial development in the context of planning regimes, and is funded by the National Science Foundation of China. Previously he has conducted a number of studies on land use planning and policies in the province of Guangxi.

Appendix B. Updated work schedule

The tables below show the updated work schedule, followed by an updated list of deliverables. The updates mainly relate to the delayed inception of the project, and duration and submission dates for deliverables are adjusted accordingly.

List of deliverables

1A – Review of LUCS models and selection of LUCS model for this project
1B – Implementation of a module which allows to steer land use change by the demand for ecosystem services
1C – LUCS model software available for use in GMS, including ecosystem services demand module and graphical user interface
1D – Full documentation of the LUCS model and software available from a website

2A – Listing of 7 national academic institutes and 7 NACs submitted to the ADB.
2B – Document describing the program for training academics in national academic institutions provided to ADB.
2C – Manual for the application of the CLUMondo model available in English and 6 GMS languages available from the website.
2D – Academics from national academic institutes in 7 GMS countries are trained in the independent application of the LUCS model.

3A – Document describing the detailed outline of the student training course provided to ADB.
3B – Student training course included in the curriculum of 3 institutions.
3C – Scientific paper on the improved LUCS model and its GMS application submitted to an ISI rated peer-reviewed journal.
3D – GMS model results are presented in an international conference or symposium.

4A – Short document describing awareness raising strategy provided to ADB.
4B – Brochure explaining the value of LUCS to support planning processes available and distributed by NACs to all relevant planning/policy institutes and national academic partner institutes, also made available through internet.
4C – Awareness raising event organized in each of the GMS countries.
4D – Factsheets on LUCS model applications in at least 2 national planning processes in the GMS.

5A – Inception workshop.
5B – Semi-annual progress and financial reports delivered to ADB.
5C – One LUCS model network meeting organized with participation of academics and government representatives from all GMS countries.
5D – Mission reports (as required).

The updated schedules on the following pages indicate in green those tasks that have been completed, in yellow those tasks that are ongoing, and in grey those tasks that are planned to start later.

Year 2014

N°	Activity	2014 Months											
		0	0	0	0	1	2	3	4	5	6	7	8
1	**LUCS development and documentation**												
	Review LUCS models and identify gaps and challenges										1A		
	Develop an ecosystem services demand module										1B		
	Develop a Graphical User Interface												
	Implement all model functions in LUCS model software												
	Document model approach and software design												
	Fix software bugs												
2	**Training of national academic institutions**												
	Identify 7 national academic institutions										2A		
	Develop the train-the-trainer program												
	Train academic staff in all GMS countries on LUCS modeling												
	Translate self-teaching manual 6 GMS languages												
3	**Develop academic curriculum to maintain LUCS capacity**												
	Design student training course												
	Supervise 2 MSc or PhD students												
	Writing a scientific paper												
	Conference presentation of GMS application												
4	**Foster policy-science and operationalize LUCS capacity**												
	Design LUCS awareness raising strategy												
	Provide LUCS input to 2 national planning processes												
	Organize awareness raising events in 6 GMS countries												
	Develop a brochure on LUCS modeling for policy support												
5	**Management and organization**												
	Inception workshop										5A		
	Semiannual progress and financial reports												
	Organize LUCS model network meeting												
	Mission reports												

Year 2015

N°	Activity	Months											
		9	10	11	12	13	14	15	16	17	18	19	20
1	**LUCS development and documentation**												
	Review LUCS models and identify gaps and challenges												
	Develop an ecosystem services demand module												
	Develop a Graphical User Interface						1C						
	Implement all model functions in LUCS model software						1C						
	Document model approach and software design						1D						
	Fix software bugs												
2	**Training of national academic institutions**												
	Identify 7 national academic institutions												
	Develop the train-the-trainer program						2B						
	Train academic staff in all GMS countries on LUCS modeling										2C		
	Translate self-teaching manual 6 GMS languages												2D
3	**Develop academic curriculum to maintain LUCS capacity**												
	Design student training course												3A
	Supervise 2 MSc or PhD students												
	Writing a scientific paper												
	Conference presentation of GMS application												
4	**Foster policy-science and operationalize LUCS capacity**												
	Design LUCS awareness raising strategy				4A								
	Provide LUCS input to 2 national planning processes												
	Organize awareness raising events in 6 GMS countries												
	Develop a brochure on LUCS modeling for policy support												
5	**Management and organization**												
	Inception workshop												
	Semiannual progress and financial reports						5B						5B
	Organize LUCS model network meeting												
	Mission reports												

Year 2016

N°	Activity	Months											
		21	22	23	24	25	26	27	28	29	30	31	32
1	**LUCS development and documentation**												
	Review LUCS models and identify gaps and challenges												
	Develop an ecosystem services demand module												
	Develop a Graphical User Interface												
	Implement all model functions in LUCS model software												
	Document model approach and software design												
	Fix software bugs												
2	**Training of national academic institutions**												
	Identify 7 national academic institutions												
	Develop the train-the-trainer program												
	Train academic staff in all GMS countries on LUCS modeling												
	Translate self-teaching manual 6 GMS languages												
3	**Develop academic curriculum to maintain LUCS capacity**												
	Design student training course												3B
	Supervise 2 MSc or PhD students												
	Writing a scientific paper												3C
	Conference presentation of GMS application						3D						
4	**Foster policy-science and operationalize LUCS capacity**												
	Design LUCS awareness raising strategy												
	Provide LUCS input to 2 national planning processes												4D
	Organize awareness raising events in 6 GMS countries						4C						
	Develop a brochure on LUCS modeling for policy support			4B									
5	**Management and organization**												
	Inception workshop												
	Semiannual progress and financial reports						5B						5B
	Organize LUCS model network meeting										5C		
	Mission reports												