Improving land change simulation capacity to reduce conflict from competing land demands – First Progress Report

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Produced by the Institute for Environmental Studies, VU University Amsterdam for the GMS Core Environment Program (ADB TA-7987 REG)

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1. Introduction

This report is the first progress report for the Land Use Change Simulation and Training project commissioned by the Asian Development Bank under the Greater Mekong Subregion (GMS) Core Environment Program (CEP). The project aims to build capacity on land use change simulation (LUCS) modeling in the Greater Mekong Subregion, which is expected to support GMS governments in answering a variety of spatial planning questions at strategic planning levels.

This document reports on the tasks and outputs delivered during the period of May 2014 to 31 October 2014 (Chapter 2)

Chapter 3 provides an overview of the resources spent during the aforementioned reporting period, in relation to the entire project budget.

2. Project progress

This section reports on tasks and outputs scheduled for the period of May-Oct 2014. The reporting of the tasks follows their order in the contract.

Task 1.1: Review of present LUCS models and functionality

A review was undertaken on the different types of LUCS models as well as specific LUCS model software that is currently available. This review is included in this report as a deliverable in appendix A.

Task 1.2: Development of an ecosystem service demand module

An ecosystem service demand module has been developed for the CLUMondo model and will be implemented in the LUCS model software that is currently developed. A description of this module is included as a deliverable in Appendix B.

Task 1.3: Development of Graphical User Interface

Based on discussion between the LUCS modelling expert, the LUCS capacity building expert, and the LUCS software developer, a first Graphical User Interface (GUI) concept for the LUCS model software was developed, and an approach for the integration of the CLUMondo model in the GEONAMICA framework was discussed. Based on this document, a number of mock-ups of the GUI were created and presented to the stakeholders during the inception workshop (2.1.5), taking the perspective of a model user.

The approach and mock-ups were received positively by the stakeholders in the inception workshop, and based on their feedback the design of the GUI will be further improved.

Task 2.1: Identification of 7 national academic institutions

Upon submitting the proposal, only 5 out of the 7 required National Academic Coordinators (NACs) were identified. Therefore, as indicated in the proposal, the first step in this task was to identify the missing NACs. These NACs were identified in the first months of the project. Subsequently we

have identified National Academic Institutions (NAIs) in each of the countries or provinces included in the GMS in collaboration. These NAIs were presented during the inception workshop and stakeholders provided several suggestions for institutions to be added to the list. In response to these valuable suggestions we have decided that in some regions staff members from two selected institutions can participate in the train-the-trainer workshop, as long as the total number of staff included in one training stays at or below 8 persons, as this is the number of staff that can be trained by one trainer while still allowing for sufficient time for each participant. A list of all NACs, NAIs and selected staff members per GMS country or province is included in this report as deliverable in Appendix C.

Task 5.1: Inception workshop

The inception workshop was organized in Bangkok on October 6-8, 2015, and was attended by the project team, representatives from the EOC, and up to three stakeholders from the respective GMS countries and provinces. October 6 of this workshop was reserved for the project team only (international staff members, NACs, and EOC staff), and was used to discuss the contents and planning of the entire project within the project team and discuss expectations. October 7 and 8 of this workshop was used to present the outline of the project and our ideas for implementation to the stakeholders that were invited from the governmental organization of the respective GMS countries and provinces and receive their feedback. In addition, the entire meeting had a networking function as the NACs and the selected stakeholders were mostly not connected in other ways and this provided a first opportunity for further collaboration within later stages of this project. A complete list of workshop participants is provided in Appendix D, as a deliverable for this task.

The Inception workshop yielded a series of very valuable suggestions from stakeholders on topics related to the selected NAIs, the content and form of the training workshops and potential applications of the LUCS model capacity in concrete policy support projects in later stages of the project. In addition, several stakeholders indicated their interest in participating in the training themselves or in their interest to stay involved in the project in other ways. While the project initially aims to train academic staff, which can subsequently support governments with their LUCS modelling capacity, it was agreed that in each train-the-trainer workshop one day would be used to invite national stakeholders as well. This day would provide a brief training for the use of LUCS model results to stakeholders, provide the opportunity for stakeholders to provide their feedback on the project in general and the LUCS model , and to continue the development of a LUCS network and further bridge the science-policy gap. The inception report provides a more elaborate reflection of the results from the inception workshop.

3. Resources and project management

The tables below indicate per team member the number of days spent on the respective tasks in this project during the first reporting period (start of the project until October 2014). The percentages in the bottom row indicate the percentage of time used so far, relative to the total project budget. In addition, the final table provides an overview of the other reimbursable expenses used in this project.

Prof. Dr. Peter Verburg – Team Leader and LUCS modeling expert

Task	Description	Period	Days spent
1.1	Review LUCS models	April-June 2014	2
1.2	Develop ES module	June-September 2014	2
2.1	Identify NACs and NAIs	April-October 2014	1
5.1	Organization of the Inception workshop	May-October 2014	2
5.1	Participation of the Inception workshop	6-8 October 2014	4
Total			**11 (17%)**

Dr. Jasper van Vliet – LUCS Capacity building expert

Task	Description	Period	Days spent
1.1	Review LUCS models	April-June 2014	3
1.2	Develop ES module	June-September 2014	3
2.1	Identify NACs and NAIs	April-October 2014	7
5.1	Organization of the Inception workshop	May-October 2014	15
5.1	Participation of the Inception workshop	6-8 October 2014	4
Total			**32 (18%)**

Roel Vanhout – LUCS Software developer

Task	Description	Period	Days spent
1.3	Develop a Graphical User Interface	May-October 2014	5
5.1	Preparation of the Inception workshop	May-October 2014	3
5.1	Participation of the Inception workshop	6-8 October 2014	4
Total			**12 (14%)**

Prof. Dr. Li Yongmei – National Academic Coordinator Yunnan province, PR China

Task	Description	Period	Days spent
2.1	Identify NACs and NAIs	August-October 2014	2
5.1	Preparation of the Inception workshop	July-October 2014	5
5.1	Participation of the Inception workshop	6-8 October 2014	5
Total			**12 (18%)**

Dr. Xin Nie – National Academic Coordinator Guangxi Zhuang Autonomous Region, PR China

Task	Description	Period	Days spent
5.1	Organization of the Inception workshop	August-October 2014	3
5.1	Participation of the Inception workshop	6-8 October 2014	5
Total			**8 (12%)**

Prof Dr. Yongyut Trisurat – National Academic Coordinator Thailand

Task	Description	Period	Days spent

2.1	Identify NACs and NAIs	August-October 2014	4
5.1	Preparation of the Inception workshop	July-October 2014	4
5.1	Participation of the Inception workshop	6-8 October 2014	0
Total			**8 (12%)**

Dr. Nguyen Thi Van Ha – National Academic Coordinator Vietnam

Task	**Description**	**Period**	**Days spent**
2.1	Identify NACs and NAIs	August-October 2014	4
5.1	Preparation of the Inception workshop	July-October 2014	3
5.1	Participation of the Inception workshop	6-8 October 2014	5
Total			**12 (18%)**

Dr. Sarann Ly – National Academic Coordinator Cambodia

Task	**Description**	**Period**	**Days spent**
5.1	Inception workshop Bangkok	6-8 October 2014	3
2.1	Identify NACs and NAIs	August-October 2014	8
Total			**11 (17%)**

Dr. Thatheva Saphangtong – National Academic Coordinator Lao PDR

Task	**Description**	**Period**	**Days spent**
2.1	Identify NACs and NAIs	August-October 2014	3
5.1	Preparation of the Inception workshop	July-October 2014	3
5.1	Participation of the Inception workshop	6-8 October 2014	5
Total			**11 (17%)**

Dr. San Win – National Academic Coordinator Myanmar

Task	**Description**	**Period**	**Days spent**
2.1	Identify NACs and NAIs	August-October 2014	3
5.1	Preparation of the Inception workshop	July-October 2014	2
5.1	Participation of the Inception workshop	6-8 October 2014	5
Total			**10 (15%)**

Other resources spent for the project

Item	**Reimbursamble expenses**	**Costs**	
1156	Per diem project staff (Inception workshop)	4590	[USD]
1172	International air travel project staff (Inception workshop)	5607	[USD]
1300	Accomodation Inception workshop	9143	[USD]
1300	Air travel stakeholders	11373	[USD]
	Total	**30713**	**[USD]**

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

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 behavior, 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 liberalization 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 urbanization 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.

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 types 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

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 behavior 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.

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 km² 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, 1km² at the local level	RIKS, Maastricht	Forecasting tool to simulate and assess integrated effects of planning measures on urban and regional development

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).

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 behavior. 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.

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.

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.

Appendix B. Ecosystem services demand module

The Ecosystem services demand module that is developed for implementation is developed as an extension to the well-known Conversion of Land Use and its Effects (CLUE) model. The 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: Philippines (Verburg et al., 2006), People's Republic of 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 can provide 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.

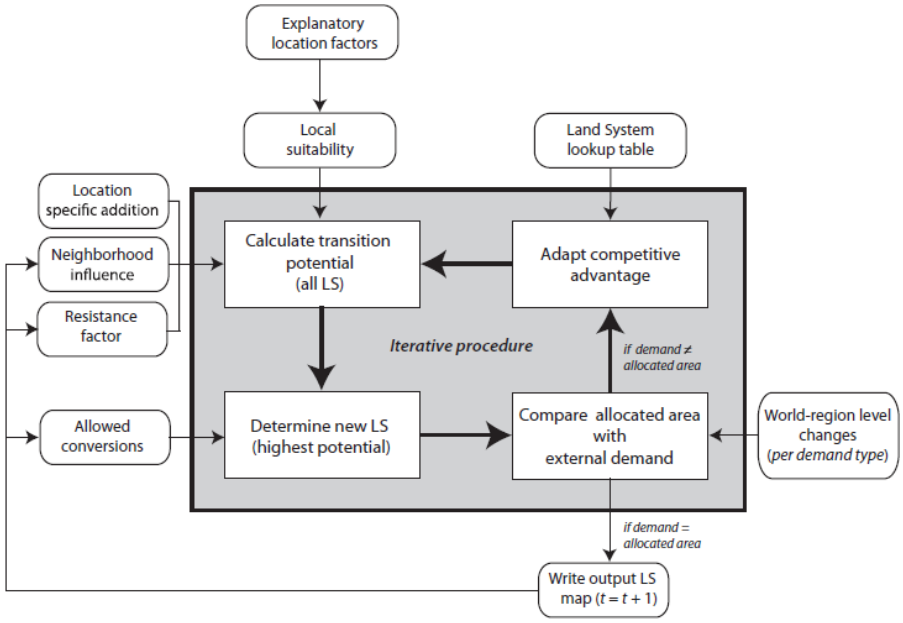

Figure 1: Model structure of the CLUMONDO model.

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.

Appendix C. NACs and National Academic Institutions

National Academic Coordinators

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, PR 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, PR China. She gained her PhD 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 PhD students, and author/co-authored 86 refereed papers and chapters.

National Academic Coordinator Guangxi Zhuang Autonomous Regin, PR China. Dr. Xin Nie is an associate professor at the College of Public Administration, University of Guangxi, Nanning, PR 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.

A description of the institutions here 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:

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

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.

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.

National Academic Institute Yunnan province, PR 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.

National Academic Institute Guangxi Zhuang Autonomous Region, PR China. The selected university in Guangxi Zhuang Autonomous Region is Guangxi University. This is the oldest and largest university in GuangxiZhuang Autonomous Region 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

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

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

Appendix D. List of participants of the inception workshop

Table 5 below present a list of participants in the inception workshop. The inception report provides an elaborate report of the workshop itself.

Title	Name	Institute	Country	Title
Mr.	Peter Verburg	LUCS modelling expert and team leader, Institute for Environmental Studies, VU University Amsterdam, The Netherlands	The Netherlands	Mr.
Mr.	Roel Vanhout	LUCS software developer, Research Institute for Knowledge Systems bv, The Netherlands	The Netherlands	Mr.
Mr.	Jasper van Vliet	LUCS capacity building expert, Institute for Environmental Studies, VU university Amsterdam, The Netherlands	The Netherlands	Mr.
Mrs.	Koh Sotheavy	Forestry Administration of the Ministry of Agriculture, Forestry and Fisheries	Cambodia	Mrs.
Mr.	Aong Sothearith	National Committee for Land Management and Urban Planning of the Ministry of Land Management, Urban Planning and Construction	Cambodia	Mr.
Mr.	Khin Mengkheang	General Department of Administration of Nature Conservation and Protection	Cambodia	Mr.
Mr.	Mr Qiu Wei	Yunnan Environmental Protection Department	Yunnan, China	Mr.
Ms.	Ms Xu Yunhua	Yunnan Environmental Protection Department	Yunnan, China	Ms.
Ms.	Yang Liqiong	Yunnan Institute for Environmental Science	Yunnan, China	Ms.
Dr.	San Oo	Ministry of Environmental Conservation and Forestry Myanmar (MOECAF)	Myanmar	Dr.
Mr.	Korn Manassrisuks	Royal Forest Department	Thailand	Mr.
Mss	Rapeephorn Baiya	Department of National Parks, Wildlife and Plant Conservation	Thailand	Mss
Mrs.	Sutara Yindeerod	Land Development Department	Thailand	Mrs.
Ms.	Pham Thi Ha	Institute of Strategy and Policy on natural resources and environment	Vietnam	Ms.
Mr.	Nguyen Huy Duc	General Department of Land Administration - MONRE Viet Nam	Vietnam	Mr.
Mr.	Vu Anh Tu	National Institute of Agricultural Planning and Projection (NIAPP) - MARD Viet Nam	Vietnam	Mr.
Mr.	Lin Weidong	Guangxi Environmental Protection International Cooperation & Exchange Center	Guangxi, China	Mr.
Ms.	Lin Bingmei	Guangxi Environmental Protection International Cooperation & Exchange Center	Guangxi, China	Ms.

Ms.	Wu Linqiao	Guangxi Forest Prospecting and Designing Institute	Guangxi, China	Ms.
Mr.	Ekvinay Sayaraj	Land planning of MONRE	Lao PDR	Mr.
Mr.	Sonthasinh Sysoupan	Land planning of MONRE	Lao PDR	Mr.
Dr.	Thavone Inthavong	National Agriculture and Forestry Research Institute	Lao PDR	Dr.
Dr.	Sarann Ly	NAC Cambodia	Cambodia	Dr.
Dr.	Xin Nie	NAC Guangxi, China	Guangxi, China	Dr.
Prof.	Li Yongmei	NAC Yunnan, China	Yunnan, China	Prof.
Dr.	San Win	NAC Myanmar	Myanmar	Dr.
Dr.	Thatheva Saphangthong	NAC Lao PDR	Lao PDR	Dr.
Dr.	Nguyen thi Van ha	NAC Vietnam	Vietnam	Dr.
Dr.	Sathaporn Monprapussorn	Department of Geography, Faculty of social sciences, Srinakharinwirot University	International	Dr.
Mr.	Pheerawat Plangoen	Department of Civil Engineering, Faculty of Engineering, Siam University	International	Mr.
Mr.	Ben Vickers	FAO	International	Mr.
Mr.	Kenichi Shono	Natural Resources and Environment Group, FAO Regional Office for Asia and the Pacific	International	Mr.
Mr.	David Ganz	USAID LEAF	International	Mr.
Mr.	Sean Austin	USAID	International	Mr.

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