



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

Final report

April 2017

**Improving land change simulation capacity to
reduce conflict from competing land demands
– Final Report**

Produced by the Institute for Environmental
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ACRONYMS

ADB	–	Asian Development Bank
CEP	–	Core Environment Program
DSS	–	Decision Support System
FAO	–	Food and Agricultural Organization of the United Nations
GHG	–	Greenhouse Gas Emissions
GIS	–	Geographic 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

This report is the final 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 project achievements over the entire project period from contract signing in May 2014 to the end of the contract on 30 April 2017.

Chapter 2 provides an overview of all project activities, ordered according to the project tasks as listed in the project proposal. Project tasks that were delivered before May 2016 are documented in detail in one of the four progress reports (Nov 2014, June 2015, Nov 2015 and May 2016) and will therefore be covered only briefly in this document. Tasks and deliverables delivered between June 2016 and April 2017 are covered in more detail in this document and its appendixes.

Chapter 3 Provides an overview of the resources spent on this project during the reporting period, in the context of the entire project budget.

2. Project results

This project consisted of 5 tasks with several subtasks, as described in detail in the inception report. Progress on the tasks and subtasks has been reported previously in the semi-annual progress reports that have been submitted in the context of this project, including the associated deliverables.

This chapter briefly reviews the results of each individual task in this project. For those results that have been included in previously delivered semi-annual reports, this report will only provide a brief summary. Those results that have not been reported previously will be described here in full, including the associated deliverables, either in the appendix, or as a separate file.

Task 1.1: Review of present LUCS models and functionality

A review was made of the different types of LUCS models as well as specific LUCS model software systems that are currently available. This review was delivered as an appendix in semi-annual report 1.

Task 1.2: Development of an ecosystem service demand module

An ecosystem service demand module has been developed for the CLUMondo model. This ecosystem services demand modules was implemented in the LUCS model software that has been delivered as a result of tasks 1.3 and 1.4. A detailed description of this ecosystem services demand module was delivered as an appendix to semi-annual report 1.

Task 1.3 Develop GUI and 1.4 Implement LUCS model

Overview

Because the activities in task 1.3 and 1.4 happened closely together and without always being clearly delineated, these three tasks are reported on jointly here.

Based on discussion between the LUCS modelling expert, the LUCS capacity builder, and the LUCS software developer, a first model design for including a Graphical User Interface (GUI) was developed and discussed. Based on this document, a number of mock-ups of the GUI were created and presented to the stakeholder during the kick-off meeting, taking the perspective of a model user. The approach and mock-ups were received positively by the stakeholders in the kick-off meeting, and based on their feedback the design of the LUCS software was further improved.

The improved design of the GUI was subsequently implemented in the GEONAMICA framework. Initial testable versions were produced (version numbers 1.1.X) and included all the functionality that is required to run a model, as well as the functionality to develop and parameterize a new application (including the logistic regression analysis). Based on extensive testing by the project team, revisions based on those versions were made. These revisions relate to added functionality, improved user-friendliness of the user interface, and fixing bugs that have been discovered while testing. The final version (version numbers 1.2.X) for the workshops was made.

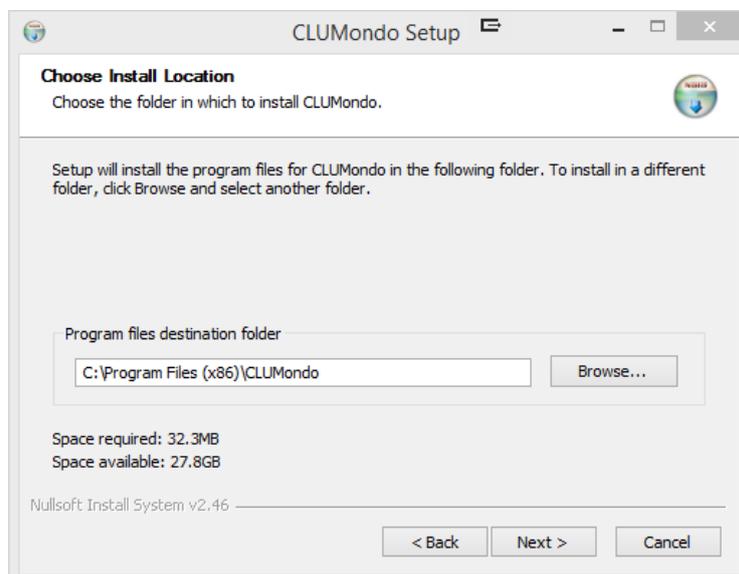
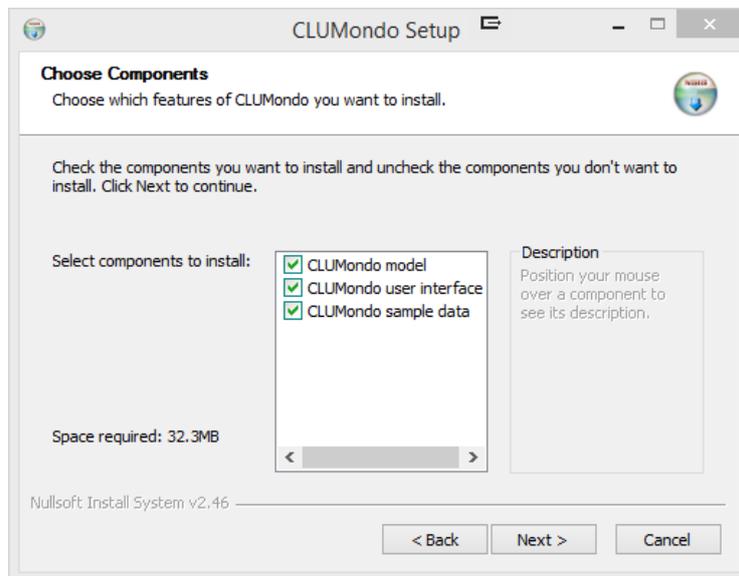
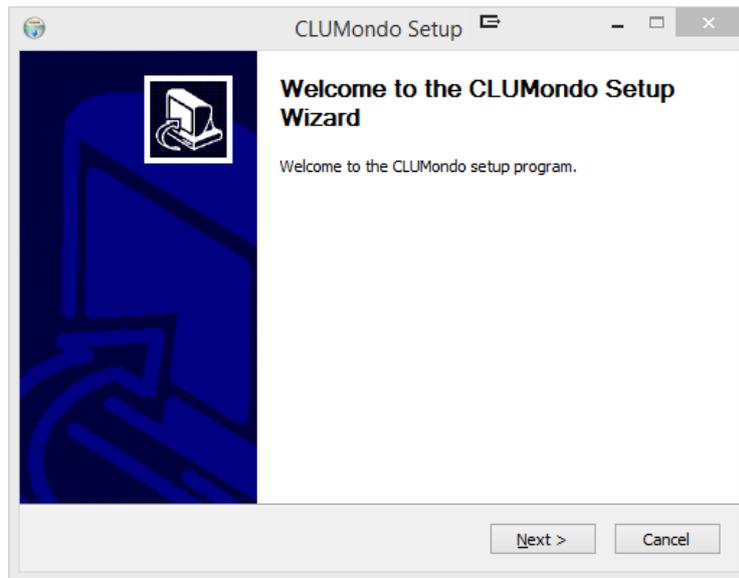
Based on the usage of version 1.2.X, and especially the feedback from the workshop participants and other users, a list of improvements was made. The requests for improvement included integrated map-previewing (GIS) functionality for all places where the user deals with maps in the user interface, and improved visualization and editing functionality for the tables that are used for introducing model parameters. These improvements were subsequently implemented leading to CLUMondo version 1.3.X, and version 1.4.0. The latter is the current version of the software, and is the final deliverable for this task. CLUMondo 1.4.0 is publicly available from the project website (<http://portal.gms-eoc.org>) as well as from the website of the Environmental Geography Group at the VU University Amsterdam (<http://www.environmentalgeography.nl/site/data-models/data/clumondo-model/>), in order to increase its visibility and its usage.

LUCS model and software version 1.4.0

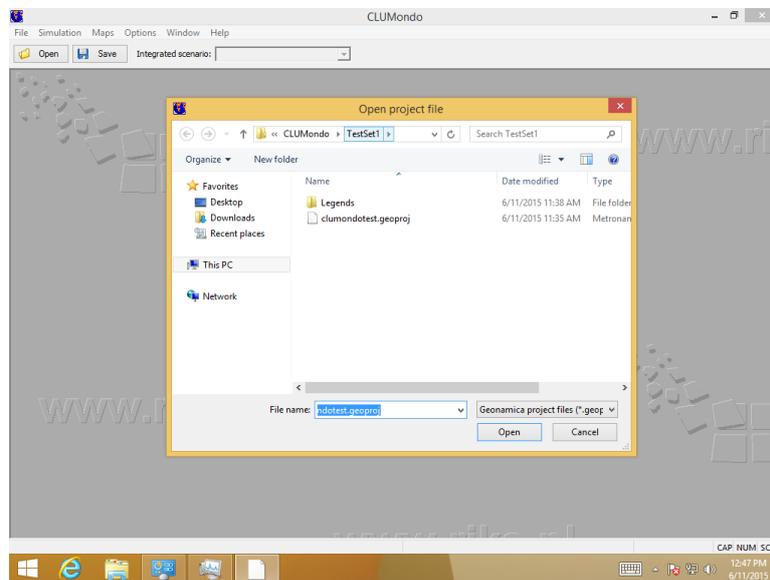
In the LUCS model, the actual land use model and the GUI are two completely separate entities. This is a deliberate design decision which ensures flexibility in the way the model is run (novices have different requirements than advanced users) and which makes it easy to adapt either the user interface or model without requiring changes in the other. The GUI addition basically comprises three entities that significantly improve the user-friendliness of the LUCS model: an installer the actual user interface, and a set-up wizard for new applications. Each of these is described here briefly, while more extensive descriptions were previously provided in the respective semi-annual reports.

The CLUMondo software is available as an executable (CLUMondo_1.4.0_setup.exe). All software components are delivered in one convenient installer package: the model itself, the user interface, and some sample data to get users up and running fast. Double clicking the executable will initiate the installer, a built-in function that guides the user to the processes of installing the software, as

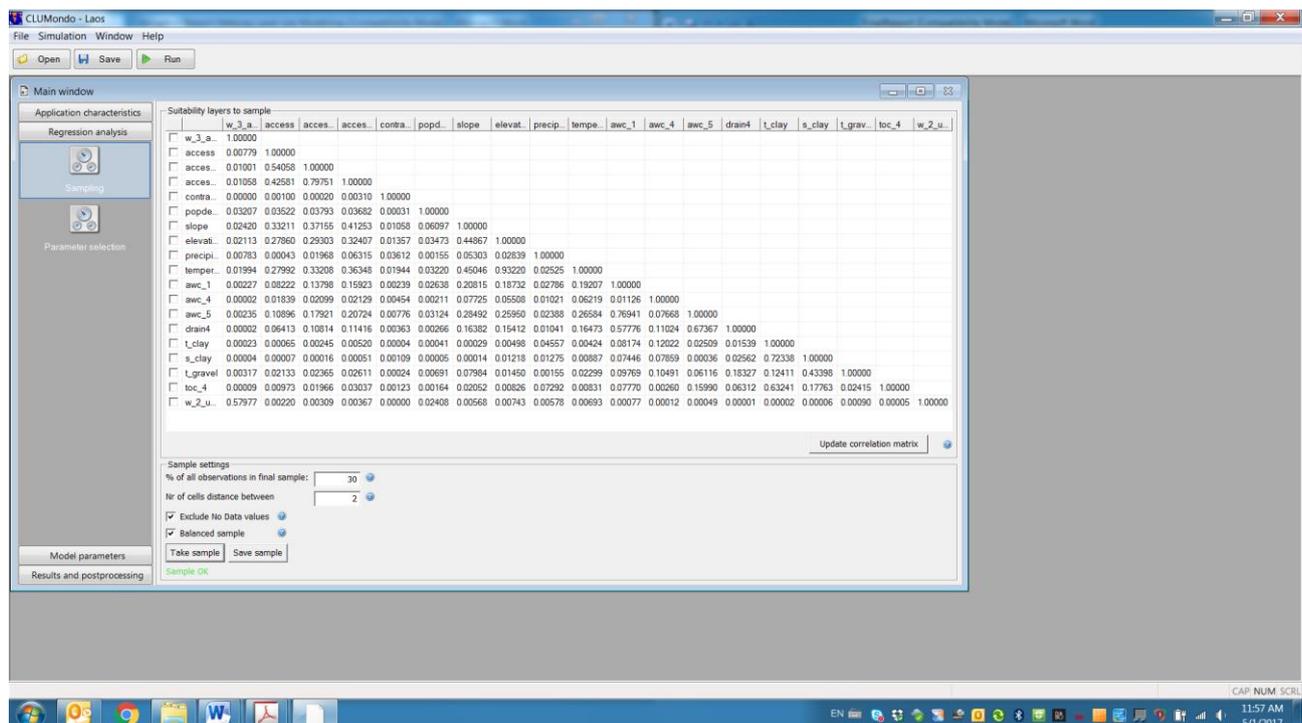
shown below. All aspects of the installation are configurable, like the installation path in this example.



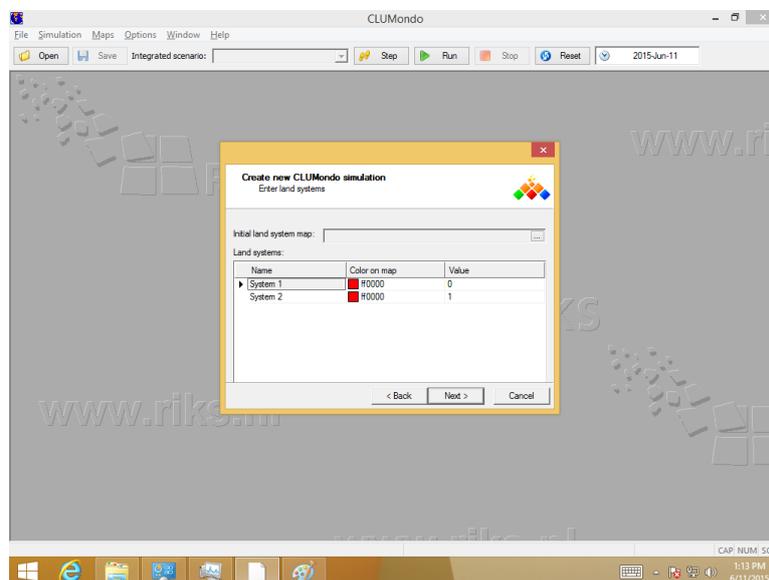
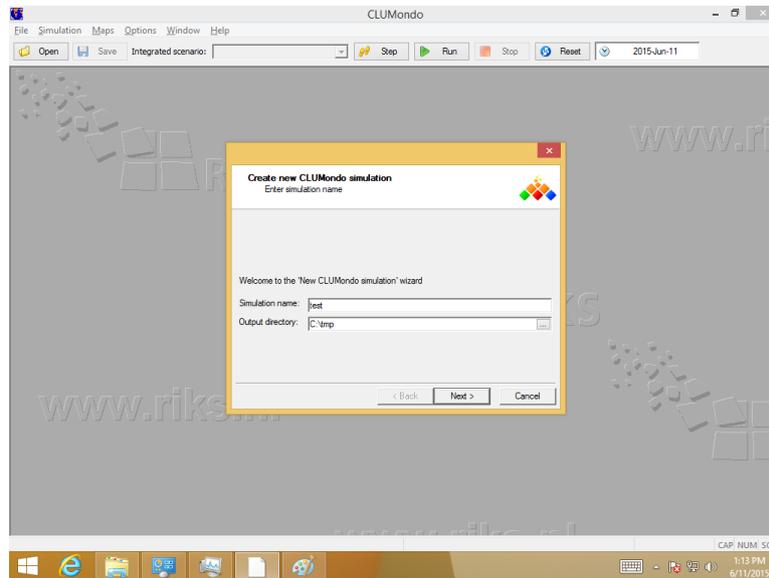
When the software is installed, CLUMondo can be opened from the start menu in Windows. When the software opens, you can select a model application, name *.geoproject. Geoproject files are stored in a standard, XML-based format that is used throughout the Geonamica framework (which is used to build the CLUMondo user interface).

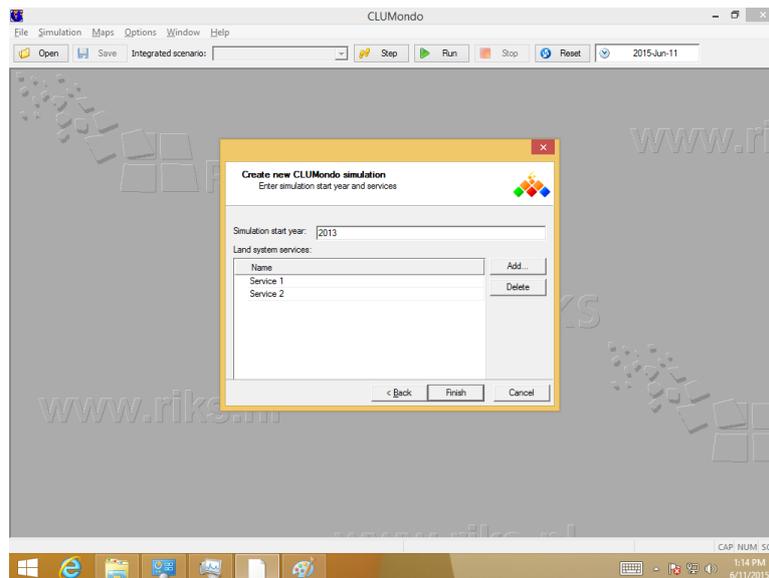


Users organize simulations and scenarios in clear structures with a settings file at the root, and any data next to it. Data can be shared across geoproject files to minimize duplication and to build scenarios that share common data. After opening a simulation, the user interface takes the user through the steps to run a simulation shown on the left. The user interface is organized based on the four steps that are typically included in developing and running a model: Application characteristics, Regression analysis, Model parameters, and Results. Within each section, multiple different tables and functions are included. For example, a user can now conduct the entire regression analysis required to set-up an application without using additional software:



In addition, to using readily available model applications (such as the application for Lao PDR, which is automatically included in the installer, users can make use of an integrated wizard to set up a new application. This wizard asks for the fundamental parameters an application is made up of. There are three steps to go through. In the first step, the user enters the name of the simulation and the directory where to store it. Then the user defines the land systems. They are derived from a map; after selecting the map, the user specifies what the values in the map signify and how they should be visualized (their color on the visual representation). Then in the final step, the user specifies the simulation start year and the land system services to include in the model:

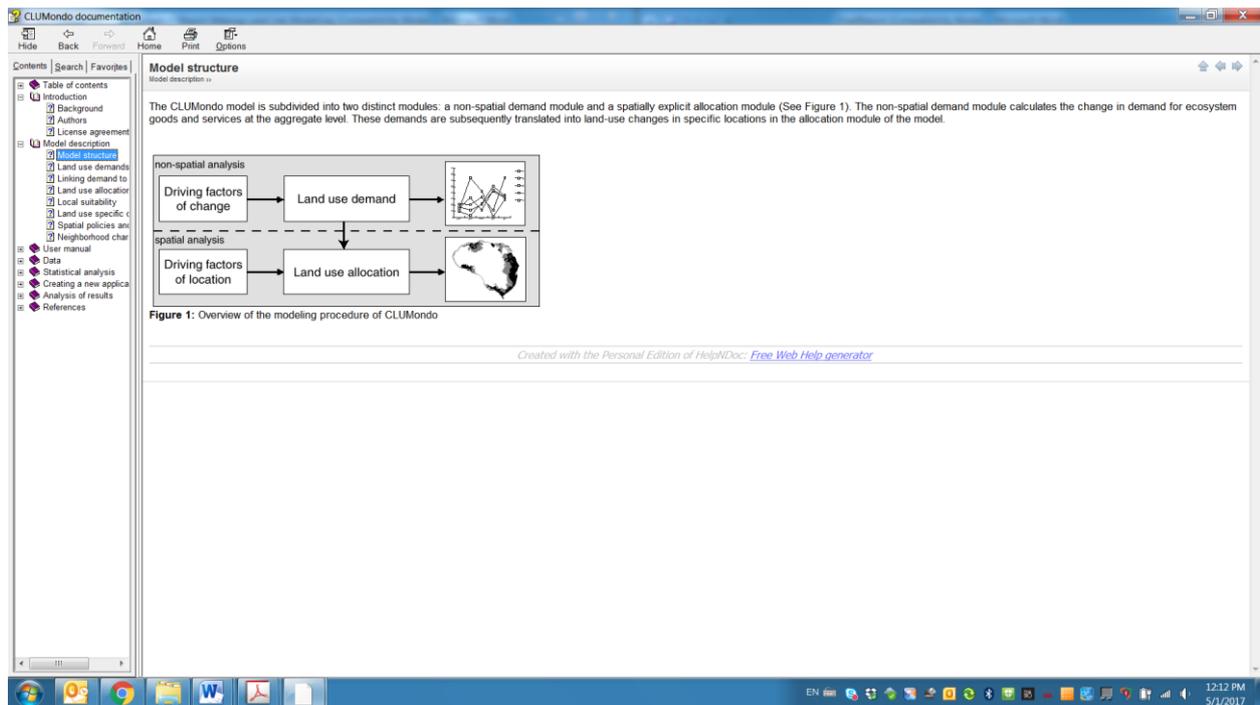




Task 1.5 Document model approach and software design

The documentation of the CLUMondo model and the GUI consists of two parts: the model documentation and the user manual. The model documentation is both a conceptual and a technical document that details how the CLUMondo model works, including equations, parameters and files that are used in the model. The user manual adopts an “how-to” approach in describing how to handle the software, but also how to set-up a new model application and how to do a statistical analysis.

The model documentation was developed in a generic way, so that it can be published as a word, PDF, CHM and HTML document at once. As a consequence, the documentations exists both as a PDF and as a built-in help function. Both are installed automatically together with the software. The help file can be opened directly from the user interface, while the separate PDF file can be opened on screen or printed as desired. The PDF and CHM helps files will be identical in terms of the information provided, but differ in their usability and can be selected according to the preferences of the user. An illustration of the built-in help functionality is provided below:

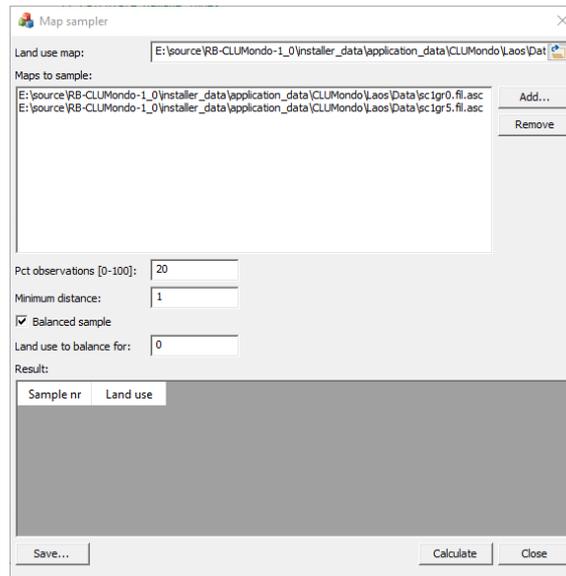


Task 1.6 Fix software bugs

During the use of the previous versions of CLUMondo (1.2.X, 1.3.X) in the workshops and afterwards, issues and bugs that were found were collected and processed. Throughout the reporting period, test data sets were developed and the software tested against them, bug fixed, the installer maintained, performance and conformance tests done and small fixes applied in many places. These issues ranged from textual clarifications to problems with running the software on certain computer configurations and fixing the way the underlying model is called when certain parameters or combinations of parameters are set. The current version (1.4.0) is therefore the result of tasks 1.3 and 1.4, in combination with the bug fixes under task 1.6.

The list below provides an overview of the recent improvements and bug-fixes (i.e. included since semi-annual report 4). Earlier bug-fixes have been reported in semi-annual reports 1, 2, 3, and 4, and the results of that are now included in the model as described under tasks 1.3 and 1.4.

- The most important improvement in this reporting period relates to the re-development of the map sampling component. The previous way the map sampling was done, was based on an algorithm that made some assumptions on the way the data was provided to it, which made it incompatible with the way the user interface works. As a side-product of this redevelopment, a separate tool was built that lets the user do map sampling as a separate step so that advanced analysis can be carried out in external statistics software if needed. This separate map sampling tool is included in the CLUMondo installer, and when in use, looks like this:



- Making text labels in the GUI internally consistent
- Fix the display of suitability maps (due to a bug, some suitability maps were no longer visible in previous versions after other suitability maps had been removed from the model)
- Allow user to add units to land system properties when setting up the model (i.e. 'hectares' of urban land, or 'tons' of food produced)
- Show a progress box when running the model, to better indicate to the user that the model is running, rather than crashing)
- Show scrollbars when necessary in the main window, to make software fit on smaller screens (i.e. to ensure the scenario parameters remain accessible)
- Better default values for certain model parameters, to reduce the risk for crashes in newly developed model applications
- Enable copy/paste functionality in tables, so that model parameters can be transferred to other software relatively easily
- Speed improvements when writing .CSV files

Task 2.1: Identification of 7 national academic institutions

One National Academic Institution (NAI) was identified in each of the countries or provinces included in the GMS in collaboration. These NAIs were presented during the kick-off meeting and stakeholders provided several suggestions for institutions to be added to the list. In response to these suggestions we decided that in some regions staff members from two selected institutions could participate in the train-the-trainer workshop, as long as the total number of staff included in one training remained at a level that could be instructed by one person during the workshops. A list of all National Academic Institutions, including proposed staff, was provided in semi-annual report 1.

Task 2.2 Develop the train-the-trainer program

The train-the-trainer program consisted of one week of training in each of the GMS countries. Each week basically comprised 4 days of training for selected staff of NAIs as well as selected staff from

governmental institutions in the region. These 4 days were directly followed by an awareness raising workshop on day 5, in which a larger number of stakeholders were invited. During these awareness raising events, the trained staff acted as trainers, and as such the awareness raising was designed as an integral component of the train-the-trainer workshops.

The train-the-trainer program had two different aims: on the one hand it aimed to teach participants the basic theory of land use, land use change and land use change modeling, while on the other hand, it aimed to familiarize participants with the LUCS software that is being developed in this project, so that they can start applying it in their own projects, teaching or research. The program for the train-the-trainer program is presented in the table below, while a detailed program was provided in Semi-annual report 3.

Day and theme	Activity
Monday: Land use and land use change.	Lecture on land use and land use change (including drivers, consequences, land use classifications, land use intensity). Computer exercises to get familiar with the LUCS software, run a model and look at the results.
Tuesday: Land use change modeling.	Lecture on concepts of LUCS modeling in general, the role of different types of land use models in policy analysis. Computer exercises to analyze the effect of different model parameters, including change in demand (as a different scenario).
Wednesday: Land use scenarios	Lecture on the idea and concepts of designing a scenario study or a policy analysis, as well as on analyzing scenario results through indicators. Exercises in defining a scenario study independently and analyzing the results.
Thursday: Creating a new application	Lecture statistical analysis of land use changes, model calibration and model validation. Exercises on setting up an own application, including data preparation, statistical analysis and model definition.
Friday: Awareness raising event	Lecture on the use of LUCS models in policy support: what do you want to assess, what answers can be expected from a LUCS model, what data and information would be needed for that. Exercises in designing a new project: Stakeholders are subdivided in smaller groups, each of which is supported by a trainer that followed the train-the-trainer workshops. Together these groups design a LUCS project for a relevant case in their country, and subsequently present this proposal to the larger group.

Task 2.3 Train academic staff in all GMS countries on LUCS modeling

In the period August to October 2015, selected government staff and academic staff in all countries and provinces of the GMS were trained. This training followed the program as developed in task 2.2. Below is a brief reflection on each of the workshops (this is a selection of the more comprehensive reflection, including attendance lists, provided in semi-annual report 3).

Hanoi, Viet Nam: 3-7 August 2015

The workshop in Hanoi included participants from both Ho Chi Min City and Hanoi. Despite intensive testing before the training, we experienced quite some problems related to the software. Part of this was expected, as every computer is installed differently, and it is impossible to anticipate this in advance. Despite that, running the software proved a more substantial challenge than what was expected in advance. At the same time, the software developed was available all week, and already during this course a new version was released and distributed was solved part of the problems, while other issues were resolved as soon as possible afterwards.

Bangkok, Thailand: 10-14 August 2015

The National Academic Coordinator for Thailand, prof. Trisurat, has already been working with a predecessor of the LUCS model since 2006. This proved to be a large advantage for the training of trainers, as it allowed him to explain things in Thai instead of English which was notably easier for participants to understand. All participants completed the entire workshop enthusiastically, and enthusiasm was also reflected in the awareness raising workshop: after the general introduction, the ToT participants sat together with the other participants in the awareness raising to design possible LUCS modeling exercises in Thailand, which yielded a few interesting proposal. In addition, the LUCS software functioned much better due to an additional number of bug fixes and other improvements in response to the feedback from the first ToT workshop.

Phnom Penh, Cambodia: 17-21 August 2015

The ToT in Phnom Penh benefitted from the experience in the earlier two workshops as both the program and the software ran without any problems. While two academic participants were in the position to introduce LUCS modeling in their curricula, two others were very junior (about to graduate as a Master), and hence not in a position to implement the knowledge obtained in their teaching. The awareness raising event in Cambodia was attended by both academics and government officials, and a relatively large number of them was genuinely interested and proposed a number of good project implementation suggestions. One of which has already led to a more concrete follow-up proposal.

Vientiane, Lao PDR: 14-18 September 2015

The NAC in Lao PDR is very well connected, both in the university and in the government, which can create some leverage when it comes to the implementation of LUCS modelling as a policy support tool. This became apparent in the awareness raising meeting as well as in the training, as it provides an incentive for participants to take things more seriously. However, the participants themselves indicated that the workshop was challenging, which could hamper further implementation of LUCS modeling in Lao PDR.

Kunming, Yunnan province, PR China: 21-25 September 2015

The ToT participants in Yunnan were notably more senior than in other workshops, which could increase the likelihood of applying the LUCS model in either university courses or in government projects. On the other hand, the participants found the English language material more challenging than participants in other countries. The awareness raising even was kindly hosted by the Yunnan Institute for Environmental Studies (see picture below), and attracted a relatively large crowd, including a number of higher ranked officials.



Nanning, Guangxi Zhuang Autonomous Region, PR China: 28 September – 1 October

Due to a week of national holidays in the PR China, this workshop started with the awareness raising event, which could therefore not benefit from the knowledge of the participants of the ToT. However, one person attending the awareness raising event decided it was so interesting that he asked to join the complete ToT as well. The motivation for participants in the ToT seemed lower than in other workshops, except for the one participant that decided last-minute.

Nay Pyi Taw, Myanmar, 5-9 October 2015

The attendants of the ToT in Myanmar had less background in ICT, but more than compensated with diligent study to learn both about land-use change and about LUCS modeling. This attitude was also reflected in the attendance of the awareness raising event, which attracted more participants than originally planned, and all participants actively participated in the break-out groups as well as the discussion. The importance of LUCS modelling was repeatedly emphasized by the National Academic Coordinator as well as several participants, due to the recent changes in international relationships of Myanmar, and the possible consequences for the land-use in Myanmar.



Task 2.4 Translate self-teaching manual in 6 GMS languages.

The manual that was developed in English for the delivery of the LUCS model software (task 1.5) was revised thoroughly and provided to the National Academic Coordinators as a template for translation. The English text has subsequently been translated into the 6 languages of the GMS, and these translated manuals have been delivered to GMS-EOC as pdf's in a zip-file. Translated manuals are all available from both the GMS-EOC project website and the CLUMondo website of the VU University Amsterdam (i.e. those websites that also host the LUCS software itself).

Task 3.1 Designing a student training course in LUCS modeling

During the training-of-training workshops, implementation of the LUCS modelling in the curricula of the respective National Academic Institutions was discussed elaborately with the academic staff that participated. During these discussions it was found that the curricula, background and courses differed widely. Therefore, training material on LUCS modelling was provided in small chunks, rather than a complete pre-designed course, so that teachers could use the parts that deemed fit for their students and courses and implement in a way that is most suitable.

These chunks of teaching material consist of a set of exercises, (scientific) literature on land use and land use modelling, and a large number of presentations (provided as original power point presentations, to facilitate re-use). The material was first distributed to all staff directly following the training-of-trainer workshops. Subsequently, after the network meeting in Bangkok, all stakeholders and NACs were provided an additional set of presentations, including both updated material and new material.

All exercises included in the course, are also part of the manual that was translated in the 6 languages of the GMS as part of task 2.4. Therefore the basic exercises for the student training

courses are available in English as well as in the languages of the GMS. The overview below presents the academic activities towards implementing LUCS modelling in the curricula in the respective GMS countries:

Thailand

- Faculty of Forestry, Kasetsart University in Bangkok, Thailand: Four courses for graduate students (MSc and PhD) have been offered at the Faculty of Forestry, Kasetsart University in which LUCS modeling (CLUMondo) has been incorporated since 2015 (building on earlier courses that include the CLUE model). These courses consist of Forested landscape ecology, Advanced landscape ecology & biodiversity modeling, Advanced GIS for watershed management and Integrated land use system management and planning. The first two courses are taught by Prof. Yongyut Trisurat at the Department of Forest Biology and the remaining courses are offered at the Department of Conservation and taught by Thai colleagues who attended the training-of-trainers workshops held in August 2015, Bangkok.
- Other universities: Beside Kasetsart University, LUCS modeling (including CLUMondo) has been used in other universities such as Asian Institute of Technology (AIT) for Land Evaluation System subject, Suranaree University of Technology for Application of Geoinformatics.

Lao PDR

- LUCS modelling was included as holistic knowledge for the BSc. on Forest Management and Integrated Watershed Landscape Management courses, as well as at postgraduate level. Institute: the Faculty of Forestry, National University of Laos; Teacher: Assoc. Prof. Sithong Thongmanivong; date: December 2016.
- The NAC is also working on awareness raising at the Faculty of Agriculture to encourage the Land Use Planning course to incorporate the CLUMondo into the curriculum from 2017 onwards. The same process was done at the faculty of Environmental Sciences to encourage the CLUMondo to include in the Strategic Environmental Assessment and Environmental Economy courses from 2017 onwards. In both faculties, the responsible teacher has not yet been identified.

Cambodia

- Institute of Technology of Cambodia; Programme: Engineer's Degree in Water and Ecological Engineering (new curriculum); Course: Land Management; Teacher: Dr. Sarann Ly; Description: 16h for the basics LUCS modelling including theory and computer exercises; Status: implementation is planned from 2018 onwards.

Myanmar

- No course implementation activities have been reported yet

Viet Nam

- University: Ho Chi Minh city University of Natural Resources and Environment; Programme: Bachelor of GIS (Land information management), bachelor of Environmental management (Land resources management; environmental modelling); Teacher: Dr. Nguyen Thong

Nhat; Dr. Nguyen Lu Phuong; Description: In this courses, 1-3 studying hour units is spent to teach the basics of LUCS modelling and the potential application of CLUMondo; Status: LUCS modelling has been introduced to students and this course component will be further developed into a full course.

Yunnan province, PR China

- University: Yunnan Agricultural University; Programme: Bachelor of Land Resources Management;
- Course 1: Land Use Planning; Teacher: Ms WANG Rong; Description: In this course, 4 hours talk will be given to the basics of LUCS modelling, mainly the theory of CLUMondo; Status: LUCS modelling is planning to be included in the first semester of 2017-2018 academic year.
- Course 2: Software Application of GIS; Teacher: Ms ZHANG Dian; Description: In this course, a full week will be given to introduce and practice CLUMondo software, mainly the computer exercises using CLUMondo; Status: LUCS modelling is planning to be included in the second semester of 2017-2018 academic year.

Guangxi Zhuang Autonomous Region, PR China

- University: Guangxi University; Programme: Master of land use management; Course: Land Use Planning; Teacher: Xin Nie; Description: In this course, 25% of the time is spent to teach the basics of LUCS modelling including theory and computer exercises using CLUMondo; Status: LUCS modelling has been included since September 2015.

Task 3.2 Supervision of 2 MSc or PhD students

In order to further support the implementation of LUCS modelling in academic research in the GMS, this project included the supervision of at least 2 students in their research involving LUCS modelling. This supervision was intended and implemented as a joint effort between the international project staff and the home universities in the respective GMS countries. Due to the sequential nature of this project (i.e. NACs and staff were first trained, before any students could start their projects on LUCS modelling), this supervision is to a large extent 'ongoing work', which will continue also after the project has officially ended. The list below indicates all student projects that have started in the context of this task. The contribution of the project staff to these projects varies over the different projects. In most cases project staff was assigned as thesis supervisor, while the international staff provides assistance on technical as well as conceptual aspects on demand. In one case, the project leader (Prof. Peter Verburg) served as a committee member of the resulting PhD thesis, while the candidate herself also participated in the training-of-trainer workshop.

Thailand

- University: Kasetsart University; Supervisor: Yongyut Trisurat; Student: Thamrong Ruensukhon (PhD); Title: Valuation of Ecosystem Services in Klongchumphon Watershed, Ranong and Chumphon Province; Status: completed.

- University: Kasetsart University; Co-supervisor: Yongyut Trisurat; Student: Sansanee Arunyawat (PhD); Title: Land use change impacts on ecosystem services at Wang Thong Watershed in Petchabun and Phitsanulok provinces; Status: completed.
- University: Kasetsart University; Supervisor: Yongyut Trisurat; Student: Suramongkol Siriphol (MSc); Title: Impact of land use change on Asian elephant habitat at Salakpra Wildlife Sanctuary, Kanchanaburi Province; Status: completed.
- University: Kasetsart University; Supervisor: Yongyut Trisurat; Student: Nattinee Munchana (PhD); Title: Highland Community Development for optimized forest conservation in a small watershed in Nan provinces; Status: on-going.
- University: Kasetsart University; Supervisor: Yongyut Trisurat; Student: Ploychart Raksapol (MSc); Title: Habitat Corridors of Wild Elephant (*Elephas maximus*) at Salakpha Wildlife Sanctuary and Vicinity Areas, Kanchanaburi Province; Status: on-going.

Lao PDR

No student project has started in Lao PDR yet

Cambodia

- University: Institute of Technology of Cambodia; Supervisor: Sarann Ly; Student: Svay Chhaly; Title: Application of CLUMondo model in forecasting landuse change in Stung Chrey Bak river catchment, Cambodia; Status: graduated 2016
- Country: Cambodia and The Netherlands; University: Institute of Technology of Cambodia and VU University Amsterdam; Supervisor: Jasper van Vliet, Kong Chhuon and Sarann Ly; Student: Joost Ruiten (MSc); Title: Application of CLUMondo model in forecasting land-use change and hydrological impact in Tonle Sap Great Lake Basin, Cambodia; Status: on-going.

Myanmar

No student projects have started in Myanmar yet.

Viet Nam

- University: Ho Chi Minh city University of Natural Resources and Environment; Supervisors: (i) Pham Thi Diem Phuong and Nguyen Thi Van Ha; Student: Nguyen Thai Nam; Title: Apply CLUMONDO to Predict the land use change for Phu Yen Province to 2020 to adapt to climate change impacts; Status: finished.
- University: Ho Chi Minh city University of Natural Resources and Environment; Research Proposal: Impact of climate change on land use changes and water needs in Mekong Delta Vietnam and measures to adapt; Description: proposal proposes three objectives: Predict land use changes in the context of climate change impacts and assess the need of water usage with such changes; Propose solutions to adapt to climate changes for water and land resources conservation and utilization; and Provide the tools to support decision making on land and water management; Status: looking for the funding sources to carry out the proposal.

- University: Ho Chi Minh city University of Natural Resources and Environment; Research Proposal: Apply CLUMondo to predict land use change to climate change for Phu Yen Province; Description: use the CLUMondo to predict land use changes in Phu Yen Province in 2020 and 2030 to adapt to the climate change impacts. Status: This is a topic for a Master thesis in search for financial support.

Yunnan province, PR China

- University: Yunnan Agricultural University; Supervisor: LI Yongmei; Student: XIN Meiyang; Programme: Master of Land Resources Use and Protection; Title: projecting land use changes and their consequences in Yunnan Province under various scenarios of environmental policy; Status: will start in Sept. 2018.

Guangxi Zhuang Autonomous Region, PR China

- University: Guangxi University; Supervisor: Xin Nie; Student: Kailin Chen; Title: Study on Land Use Change in Coastal Zone Based on Clumondo Model: A Case Study of Beibu Gulf in Guangxi; Status: ongoing.

Task 3.3 Writing a scientific paper

The scientific paper for this task will present the application of the LUCS model for land use change projections in the Greater Mekong Subregion. As these workshops were organized only in February 2017, the model applications have not been finished yet, and therefore the paper has not been submitted yet. In fact, as scenario workshops were organized in two countries (Lao PDR and Cambodia), two scientific papers are foreseen for this project. The model application for Lao PDR is almost finished, and a draft manuscript is available (and submitted with this report). The model application for Cambodia is still under development, and therefore no manuscript is available yet. Preliminary titles:

- Debonne, N., van Vliet, J., Heinemann, A., Hett, C., and Verburg, P.H. Representing large-scale land acquisitions in land change projections for the Lao PDR. In preparation for Applied Geography.
- Debonne, N. van Vliet, J., and Verburg., P.H. When the trees are gone: alternative scenarios for large-scale land acquisitions in Cambodia. In preparation for the Journal of Land Use Science.

In addition, Prof Yongyut Trisurat, the NAC of Thailand has already published two scientific papers on land-use modelling during the course of this project:

- Trisurat, Y., Eiwpanich, P. and Kalliola, R. 2016. Integrating land use and climate change scenarios and models into assessment of forested watershed services in Southern Thailand. Environmental Research 147: 611-620.
- Trisurat, Y., Kanchanasaka, B., and Holger, K. 2014. Predicting potential effects of land use and climate change on mammal distributions in northern Thailand. Wildlife Research 41(6), 522-536.

Task 3.4 Conference presentation of GMS applications

The LUCS capacity builder, in collaboration with GMS-EOC, has organized and chaired a conference session on “Trade-offs and synergies of land-change trajectories in southeast Asia” during the Global Land Project’s Open Science Meeting, in Beijing, 24-27 October 2016. During this sessions, a presentation was given entitled: Project land system changes in the Greater Mekong Subregion (van Vliet, Verburg, Linde, 2016). Below is the abstract of this presentation:

Although land change is a global phenomenon, its manifestations differ from one location to the other. We present a land systems characterization and a land system change projection for the Greater Mekong Subregion. The land systems classification is tailored to this region by including specific agricultural systems and mixed systems, including swidden, permanent agriculture, and large scale land acquisitions. The land systems projections are simulated based on different drivers for land products, including urban areas and food production. Moreover, the different land systems allow changes in land use intensity as well as area, depending on the origin of the demand (local communities or international markets), land availability, and land use management. Simulations will be analyzed in terms of forest cover changes as well as food security.

Task 4.1 Design LUCS awareness raising strategy

A LUCS awareness raising strategy was developed that targets multiple different audiences using a range of documents, information outlets and activities, each tailored to the specific audience. The awareness raising for LUCS modelling was based on three pillars: 1) A co-design strategy in which stakeholders of this project are actively involved in throughout this project; 2) Good practice examples that show the advantage of LUCS modeling for planning and policy making, rather than explaining their hypothetical use, and 3) Open and freely accessible material that can be used by academic staff and students throughout the GMS, in the selected National Academic Institutions as well as in other institutions. Semi-annual report 2 provides the complete awareness raising strategy, detailing the various pieces of information material, the activities organized to raise awareness and how these target the different groups of users.

Task 4.2 Provide LUCS input to 2 national planning processes

After consultation with GMS-EOC, we decided that the case studies will be developed for Lao PDR and for Cambodia. The NACs of the respective countries have been informed and are contacting their national institutions to align the LUCS modeling exercise with ongoing policy developments. An application of Lao PDR has already been developed for the train the trainer workshops. From June 2016 onwards, additional data was collected and the application was further adjusted in consultation with the National Academic Coordinator for Lao PDR, and the relevant governmental institutions. In parallel, a CLUMondo application was developed for Cambodia. As each application starts from a land system maps, this development mainly involved the collection and processing of data towards the starting map. Moreover, the National Academic Coordinator, and coworkers from his home institution (ITC) contacted governmental stakeholders already for the implementation of this in the relevant departments.

Error! Reference source not found. provides a detailed report on both scenario workshops, including the agenda, participants and workshop results for both workshops. Some pictures of the workshops are included below:



Task 4.3 Organize awareness raising events in 6 GMS countries

Awareness raising events were organized as an integral part of the train-the-trainer workshop in order to facilitate the development of a LUCS modelling network with both scientists and

practitioners. The awareness raising events were visited mostly by governmental stakeholders at a higher level and therefore the focus was on the concept and application of LUCS modelling, rather than the technical details and usage of the software. Each awareness raising event started with a presentation by the LUCS capacity building expert, in which several LUCS applications in the context of policy support were presented. Subsequently, the participants were subdivided into smaller groups, with a task to discuss and design a LUCS application in their country that is relevant for policy support. Finally, the trainers, each of which was assigned to one break-out group, presented this proposal to the rest of the participants and all participants provided feedback. Semi-annual report 3 provides more detailed reports on the awareness raising events, including the participants lists in each of the GMS countries.

Task 4.4 Develop a LUCS modelling brochure

A brochure on LUCS modelling for policy support was developed which explains in relatively simple (i.e. non-scientific) terms the potential of LUCS modelling for policy support. The brochure presents the CLUMondo model as a tool, without providing technical details. The brochure is included in **Error! Reference source not found.** of this report and also provided as a separate PDF

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. The inception report provides a more detailed reflection of the kick-off meeting.

Task 5.2: Semi-annual progress and financial reports

During the project, an inception report, four semi-annual progress reports and this final report have been submitted, complemented by the respective financial reports and claims. Section 3 of this final report provides the current status of the project finances.

Task 5.3: Organize LUCS model network meeting

A LUCS network meeting was organized in Bangkok on March 7 to 9, 2017. The meeting was attended by the project leader, the LUCS capacity building specialist, the NACs of the respective GMS countries, EOC representatives selected governmental stakeholders from each of the GMS

countries and a number of observers from other organizations that are active in the region. The first day of the workshop was for the project team only (project leader, capacity building specialist, and NACs), and served to reflect on our activities in the project as well as to prepare the rest of the LUCS network meeting. March 8 and 9 was used to present the result of this project to the wider audience and build a LUCS modelling network that includes both academics and governmental stakeholders.

In addition the goals as described above, the network meeting also served to discuss the potential follow-up to this project, in terms of proposals for new projects, joint academic-governmental modelling projects, and other activities. The list below provides an overview of the ongoing and planned activities in the GMS countries that relate to this project, and that were presented during the LUCS network meeting. In addition, **Error! Reference source not found.** provides the complete list of participants and the meeting agenda.

Thailand

- University: Kasetsart University; Principle investigator: Yongyut Trisurat; Title: Assessment of adaptation measures to climate change and development of co-design method; Status: on-going.
- University/Institute: 1) Kasetsart University and Royal Forest Department, Thailand, 2) Forest Administration in Cambodia, and Champasak University in Lao PDR; Project: The Emerald Triangle Protected Forests Complex to Promote Trans-boundary Biodiversity Conservation between Thailand, Cambodia and Lao PDR Project; A brief description: This project have been funded by the International Tropical Timber Organization (ITTO) since 2003. The project aims to conserve trans-boundary biodiversity, especially landscape wildlife species roaming across the tri-national boundaries. LUCS modelling (CLUE, the predecessor of CLUMondo) was employed to predict land use changes based on different scenarios, then the extent and magnitude of each land use change scenario on wildlife distributions were determined. The results of land use change and species modeling were used to strengthen protection and management of protected areas located in the project areas and to raise awareness of local communities. Status: project phases 1-3 were completed and the proposal for phase 4 was submitted in 2016.
- University: Kasetsart University, Tokyo University and Nagoya University and relevant agencies in Thailand (Royal Forest Department, Land Development Department); Project: Forest landscape restoration and adaptation to climate change (sub-sector under the project called Assessment of adaptation measures to climate change and development of co-design method); A brief description: This project is funded by JICA. The project aims to determine optimum land-use/land-cover to maintain forest ecosystem services (water yield, sedimentation, retention, nutrient retention and biodiversity conservation). Nan province in northern is dominant with high topography. However, forest cover of the province has been gradually deteriorated due to poor enforcement, expansion of cash crop (maize) cultivation and para-rubber plantation. CLUMondo model will employed to predict land use changes based on different scenarios. InVEST and GLOBIO models are employed to quantify ecosystem services derived from various future land use scenarios. Then the extent and magnitude of each land use change scenario on the selected ecosystem services will be determined. Optimum land use will be recommended and priority areas for landscape restoration in accordance to payment for ecosystem services (PES) and optimum investment are expected. Status: on-going (2010-2016).

Lao PDR

- The international project staff is preparing a proposal on the trade-offs towards achieving Sustainable Development Goal 2 (no hunger). The project proposal will be submitted towards the end of May 2017 and will include LUCS modelling and build on the LUCS modeling network developed in this project

Cambodia

- No concrete projects related to LUCS modelling are foreseen yet.

Myanmar

- No concrete projects related to LUCS modelling are foreseen yet.

Viet Nam

- Several opportunities to get funding for follow-up projects are being explored; no concrete projects related to LUCS modelling are foreseen yet.

Yunnan province, PR China

- University: Yunnan Agricultural University; Project: Can we change the hollowed village into better countryside in China?; A brief description: Rural China has experiencing a rapid depopulation now, thus many dwellings left unoccupied either seasonally or permanently. At same time, the associated farm land is less cared or abandoned. This situation is worse in Yunnan province, especially for ethnic villages. We want to choose Chengzi ancient village in Yongning Township, Luxi County as a case study. The proposed project will simulate the land use changes in this village for the time period 2000-2030 using a combination of spatial analysis and land use modelling techniques. Projections will specifically focus on the influence of depopulation, and different subsidy policies for agriculture to control this trend. Consequences of this depopulation will be assessed in terms of agricultural production, species of ethnic herbs and important landscape ecological parameters. Status: the proposal is under preparation now.
- Land use is undergoing rapid change in China due to economic development. For the university students majoring in land resource management, it is crucial to understand the consequences of different land use changes. Therefore, we are planning to invite Dr. Jasper van Vliet from VU university of Amsterdam to deliver training course of a week for our students in late 2017 when he is available

Guangxi Zhuang Autonomous Region, PR China

- University: Guangxi University; Project: Multi-scenario Simulation and Policy Regulation of Dynamic Change of Coastal Habitats and Farmers' Land Use and Livelihood Strategy: A Case Study of Beibu Gulf in Guangxi; A brief description: Due to the significant dynamic change of coastal habitat, Beibu Gulf of China, located in Guangxi Province, was selected as the research target in this study. From the perspective of farmers who use coastal land for their living strategy, based on data from field investigation, multi-period remote sensing image, statistical data and other sources, by using the method of GIS, spatial statistics, etc. the spatial and temporal divergence of habitat dynamics in the coastal area of the Beibu Gulf was depicted, and the spatial pattern of the important time slots was identified. In

addition, the key indicators for the dynamic changes of coastal habitats and the influential factors of farmers' land use strategies were developed, and from there the interaction between those two was further disclosed. Furthermore, CLUmondo and MAS model was used to construct an intelligent simulation model at macro and micro levels. Finally, a model was constructed to predict the changes and trends of coastal habitats in different scenarios, controlling factor sets were built, key factors were obtained and priorities for the management of coastal habitat were set. The findings of this project can be used by the central government and other relevant departments for policy making. This project is a multi-disciplinary study which is based on the knowledge of management, geography, and environmental science. It uses mathematical models to simulate the interaction between Beibu coastal habitat changes and farmers' land use strategy. The project aims to respond to our country's policy of environmental protection and ease the conflicts between the coastal zone habitat protection and framers' livelihood. Thus, findings of this project are good references for the innovation of costal management institutions.. Status: The application is submitted March 2017.

Task 5.4: Mission reports

All project activities have been reported formally in the semi-annual reports following the period in which these activities took place

3. Resources and project management

The tables below indicate per team member the number of days spent on the respective tasks in this project in the period 1 may 2016 until the project end (31 April 2017), in addition to the time spent in the previous reporting period. In addition, tables providing and overview of the payment milestones and other claims for this project are provided.

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

Task	Description	Period	Days spent
3.3	Writing a scientific paper	Throughout	6
4.2	Input for case study applications	Jan-17	4
4.4	Develop a LUCS brochure	Apr-17	1
5.2	Progress and financial reports	Apr-17	3
5.3	Organize LUCS network meeting	Feb-17	4
5.3	Participate in UCS network meeting	7-10 March 2017	5
x	Previous reporting period		47
Total			70 (100%)

Dr. Jasper van Vliet – LUCS Capacity building expert

Task	Description	Period	Days spent
3.3	Writing a scientific paper	Throughout	2
4.2	Case study workshops	January / February 2017	10
4.4	Develop a LUCS brochure	April 2017	2
5.2	Progress and financial reports	April 2017	5

5.3	Organize LUCS network meeting	Oct. 2016 - March 2017	15
5.3	Participate in UCS network meeting	7-10 March 2017	5
x	Previous reporting period		161
Total			200 (100%)

Roel Vanhout – LUCS Software developer

Task	Description	Period	Days spent
1.3	Software development (fixes & minor changes to user interface; Progress indicator)	6-16 June 2016	4
1.3	New map sampling algorithm	18-19 Aug 2016	2
1.3	Make new, separate map sampling application	19-22 Sep 2016	2
1.6	Improvements to map sampling	7-8 nov, 22 nov 2016	2
1.6	Issues with user interface in specific circumstances	Jan 2017	1
x	Previous reporting period		88
Total			99 (112%)

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

Task	Description	Period	Days spent
3.1	Networking with TOT trainees	Throughout 2016	5
3.1	Exploring LUCS modeling as course component	12-13 Sept 2016	2
4.2	Exploring LUCS modeling as project component	5-7 Dec 2017	3
5.3	Preparing Network meeting in Bangkok	Feb/March 2017	3
5.3	Network meeting in Bangkok	7-10 March 2017	5
X	Previous reporting periods		51
Total			69 (100%)

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

Task	Description	Period	Days spent
3.1	Arrange a meeting with teachers	25-26 Jan 2017	2
3.2	Guide students research	November - Jan	3
4.2	Prepare research proposals	October 2016	3
5.2	Prepare the final report	Apr 2017	1
5.3	Communicate and maintain LUCS network	Throughout	2
5.3	Prepare and attend network meeting	Feb/Mar 2017	8
X	Previous reporting periods		50
Total			69 (100%)

Prof Dr. Yongyut Trisurat – National Academic Coordinator Thailand

Task	Description	Period	Days spent
3.2	Supervise MSc and PhD students	June-October 2016	7
4.2	CLUMondo training for Land Development	21-23 November 2016	3

	Dept.		
4.2	Promote CLUMondo for projects (JICA, ITTO)	December 2016 - January 2017	3
5.2	Assist in preparation of final report	5-6 April 2017	2
5.3	Arrange and prepare LUCS model network meeting	1-3 March 2017	2
5.3	Attend LUCS model network meeting	7-11 March	5
X	Previous reporting period		48
Total			70 (100%)

Dr. Nguyen Thi Van Ha – National Academic Coordinator Vietnam

Task	Description	Period	Days spent
3.2	Guide the master and bachelor students	Throughout	2
4.2	Arrange a meeting	25 January 2017	2
4.2	Prepare the research proposals	throughout	3
5.2	Prepare the final report	April 2017	2
5.3	Study the CLUMondo manual	20-21 February 2017	2
5.3	Communicate and maintain the network	Throughout	2
5.3	Prepare and attend the workshop in Bangkok	7-11 March 2017	7
X	Previous reporting periods		49
Total			69 (100%)

Dr. Sarann Ly – National Academic Coordinator Cambodia

Task	Description	Period	Days spent
4.2	Develop LUCS case proposal	January 2017	5
4.2	Arrange scenario workshop	January/February 2017	4
4.2	Scenario workshop Cambodia	16 17 Feb 2017	2
5.3	Attend LUCS network meeting	7-11 March 2017	5
X	Previous reporting period		55
Total			71 (103%)

Dr. Thatheva Saphangtong – National Academic Coordinator Lao PDR

Task	Description	Period	Days spent
3.1	Coordination meeting with the Faculty of Forestry, NUOL for incorporation CLUMondo to the existing curriculum of Forest Management and Integrated Watershed Management courses	2016 December 5-9	6
3.1	Awareness raising meeting with the Faculty of Agriculture, NUOL on CLUMondo to seek for opportunity for incorporation to the existing curriculum of the Land Use Planning course	2017 January 9-11	3
4.3	Awareness raising meeting with the Faculty of Environmental Sciences, NUOL on CLUMondo to seek for opportunity for	2017 January 16-18	3

	incorporation to the existing curriculum of the Strategic Environmental Assessment course		
4.2	Coordination and preparation arrangement	2017 February 7-10	4
4.2	Scenario workshop	2017 February 13-14	2
5.3	Preparation for the Network meeting	2017 January 19-21	3
5.3	Network meeting	7-11 March 2017	5
X	Previous reporting periods		45
Total			70 (100%)

Dr. San Win – National Academic Coordinator Myanmar

Task	Description	Period	Days spent
3.1	Discussing LUCS implementation in curriculum		5
3.2	Postgraduate courses at University of Forestry		3
3.1	Preparing teaching material		3
3.2	Providing LUCS lectures		12
5.2	Input to final report		2
X	Previous reporting period		44
Total			69 (100%)

Overview of payment milestones (in US Dollars). Claims are adjusted according to the contract variation No. 1, dd. 14 -07-2016.

Payment milestone	Status	Costs
1 Mobilization report	Claimed	36 774
2 Inception report	Claimed	73 549
3 Semi-annual report 1	Claimed	36 774
4 Semi-annual report 2	Claimed	36 774
5 Semi-annual report 3	Claimed	36 774
6 Semi-annual report 4	Claimed	36 774
7 Approval of LUCS model	Claimed	55 162
8 Approval of final report	Not yet claimed	40 203
9 Approval of statement of eligible costs	Not yet claimed	18 700
Total		371 484

Other resources spent for the project (in US Dollars)

Invoice	Status	Costs
Kick-off workshop	Claimed	26 776.52
Training-of-trainer workshop	Claimed	27 614.25
Scenario workshops	Claimed	7 637.30
LUCS network meeting	Claimed	24 763.36
Total		86 791.43

Appendices: see separate PDF