INTERNATIONAL JOINT LABORATORY

LUSES

DYNAMIC OF LAND USES CHANGES AND SOIL SOIL ECOSYSTEM SERVICES

FINAL REPORT

June 2012 –June 2016

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1. EXECUTIVE SUMMARY

Entitled LUSES for « Dynamics of Land Use changes and Soil Ecosystem Services », the LMI LUSES is an operational structure launched in 2012 by IRD and its partner institutions in South-east Asia . It is dedicated to research and trainings, contributing to the implementation of projects based on a scientific platform made of laboratories and experimental fields. This platform has a regional and international dimension seven Asian partners (listed by alphabetical order below), from Laos, Thailand and Vietnam are associated to this project with 3 French UMR. The LMI LUSES involved in 2016, partners from **France:** Mixed Research Units (UMR) ECO&SOLS, IESS and GET **Laos**: Department of Agricultural Land Management (DALaM) and Faculty of Agriculture of the National University of Laos (NUoL).**Thailand**: Land Development Department (LDD Bangkok), Faculty of Agronomy of Kasetsart University (KU) and, Khon Kaen University (KKU). **Vietnam** Soils and Fertilizers Research Institute (SFRI) and Institute of Chemistry of Hanoi (ICH). The objective of LUSES was to build capacities and carry out high quality research on the impact of agriculture on soil and associated ecosystem services (nutrient and water cycle, carbon sequestration, biodiversity conservation and lower erosion). This integrative approach was based on a multidisciplinary research team (ecologists, agronomists and soil scientist). To meet this challenge of strengthening the skills of Asian partners in the field of ecology, LUSES strategy was to (i) set up a biological analytical platform co-funded by LDD and IRD (ii) set up a network of routine and research laboratories (SEALNET) to implement quality control for soil analysis involving 19 regional laboratories (iii) organize regional collective trainings (~20) involving c. 350 Asian partners (iv) support and supervise more than 15 Asian students (8 PhD). LUSES deployed this strategy to serve the objectives of 3 scientific projects, namely (i) ECOFILTER: Effect of land use on stream-ground water interactions in the critical zone of tropical agrosystems (ii) TREE: Impact of tree plantations on soil functioning (iii) OMM: Organic Matter Management. ECOFILTER and TREE aimed to establish the environmental consequences of rapid land use change on soil and hydrological services, while OMM attempted to identify management techniques to improve soil ecosystem services. Each project (i) was co-led by a French and Asian partner (ii) involved at least 2 countries (iii) was co-funded by different institutions or project (iv) involved Asian students. The governance framework of LMI LUSES consisted of: two project directors, one from LDD (N. Suvannang) and one from IRD (A. Brauman, IRD ECO&SOLS); an executive committee in charge of the operational aspects of the project which met on an annual basis and a steering committee, representative of the partner institutions, which met 3 times along the project. Each year, a different LMI partner organized a meeting to share work progress and define guidelines the forthcoming year. This project has enhanced the scientific visibility of our partners through (i) their increased participation in scientifics projects led or co-led by LMI members (12 including 2 French ANR-funded projects) (ii) the co-publication of 35 scientific papers and presentation of 40 oral communications (iii) the co-organization of 5 congresses and international workshops. Asian partner institutions of the LMI LUSES have now fully appropriated the project and developed strong interactions, both regionally (ex: students exchange) and locally (ex: interaction between LDD and Thaie universities) and with CIRAD research platforms in partnership (HRPP and CANSEA). LUSES has also improved the access to analytical and field facilities for our partners and strengthened their scientific and technical skills (collective training, quality control process) in fields related to soil ecology, soil science and agronomy. As a conclusion, LUSES has contributed to the development of a more integrative and /or ecological view of the soil compartment In South-East Asia.

2. OVERVIEW OF THE LMI OBJECTIVES PLANNED IN 2010

2.1.BACKGROUND

The initial LMI project was based on the success of collaborative research programs between IRD and research institutes and universities in Thailand, Vietnam, and Laos. The LMI LUSES project intends to move a step forward, from a bilateral perspective to a regional scale one. The objective of LUSES is to

- gather the French research unity (IESS, ECO&SOL and GET) working in the field of soil science and ecology at the regional level
- create and then consolidate a region scale program in agronomic and ecological sciences.

This project aimed at consolidating local skills relating to the preservation of environmental and ecological soil functions

In Southeast Asia, the increase of agricultural productivity throughout the 20th century was largely depending upon breeding of high yield varieties, adoption of mono-cropping cultivation, the fallow elimination, and the high-level use of chemical fertilizers and pesticides allowing the full expression of the performances of these varieties. Apart from the increase of agronomical production, these intensive cropping systems also had long-term negative impacts on the environment. They considerably degraded soil and water resources, resulted from soil erosion, soil salinization and water contamination that led to the loss of biodiversity, ecosystem services and decrease of agricultural sustainability. In many marginal upland areas of Southeast Asia that have been converted from natural forest to these intensive cropping systems, the soil degradation and the yield decrease is now obvious. Indeed, the increased use of fertilizers and pesticides (SEA is the higher consumer of fertilizers, Ray et al., 2013[1]) seems to reach a threshold of productivity increase. In Thailand, the yields of the five main crops (cassava, rubber, Rice, Sugarcane and maize) are stabilizing and likely to decrease. The intensive agricultural system used in SEA seems to have reached its ecological and economical limits.

SEA is also considered as a benchmark because of the rapid and the amplitude of the land uses changes currently observed (food crops to cash crop essentially). In the uplands, the agriculture was largely based on “forest-subsistence agriculture” until the sixties and became a system dominated by the intensive agriculture. Such cash crops as cassava, sugar cane, and rubber are grown in large commercial plantations, smallholdings and generally expenses of high biological diversity zones like forests. In the last decades cash crops such as rubber also replaced many farming systems as traditional subsistance agriculture or commercial crops.

Nowadays, governments and public institutions are increasingly concerned about the environmental dimension of agriculture. The agricultural Research Institutes in Southeast Asia have put in their objectives, the promotion of a more “friendly” agriculture for the environment. The concept of ecological intensification has been developed as an approach of high integration of ecological processes in food production while minimizing the use of nonrenewable inputs that cause harm to the environment.

According to the specific context of land use dynamics in the Southeast Asian area described above, this current project aims to construct and consolidate Southeast Asian and French multi-lateral capacity in the analysis of ecosystem services in tropical agrosystems. Our scientific objective is to evaluate the impact of various land uses and cropping system changes on important regulating (C sequestration, regulation of water flow and soil erosion) and supporting services (soil biodiversity, soil nutrient cycles) of the ecosystems.

The core research question is therefore:

How do current Land Use changes affect soil ecosystem services in South East Asia?

Giving an ecological perspective in agronomical science is particularly relevant in SEA because ecology in general and soil ecology in particular is still poorly taught at academic level

[1] http://dx.doi.org/10.1371/journal.pone.0066428

Besides, promoting research, one of the main outcomes of this project, will be reinforcement of SEA scientific community through the reinforcement of analytical capacities and building up of a regional team to be able to address future environmental management challenges in SEA.

2.2.OBJECTIVE OF LMI LUSES: A REGIONAL SCALE PROGRAM

GENERAL OBJECTIVE

LUSES objective is to build capacities and carry out high quality research on the impact of rapid land use changes on soil and associated ecosystem services (nutrient and water cycle, carbon sequestration, biodiversity conservation and erosion control).

SCIENTIFIC OBJECTIVES

Stimulate high quality research and team complementarities on the impact of agriculture on soil ecosystem services involving in land use changes. To meet this challenge, the project LMI LUSES is organized in 3 scientific projects: (details in § 5)

(i) ECOFILTER: Effect of land use on stream-ground water interactions in critical zone in tropical agrosystem
(ii) TREE: Impact of tree plantations on soil functioning
(iii) OMM : Organic Matter Management

The main scientific goals of these projects will be:

- ECOFILTER and TREE: to characterize the impact of LUC on soil functioning and water cycles
- OMM: to identify agricultural practices able to improve ecosystem services in cultivated areas.

Capacity building OBJECTIVES

LUSES will reinforce the capacities of local academic institutions in the domain of soil sustainability and functional ecology. This objective will be achieved by:

- Developing common scientific platforms (laboratories and fields) on soil ecology and hydrology sciences. The laboratories and instruments provided by the LMI will be shared by the intuitions involved.
- Organising individual and collective trainings for researchers, technical staff and students
- Giving lectures and conference in the academic institutions (Master's, seminar, etc.)

3. PRESENTATION OF THE PARTNERSHIP AND GOVERNANCE

3.1 PARTNERSHIP

A. PARTNERSHIP BUILD ON A LONG HISTORY OF SCIENTIFIC COLLABORATION

As pointed out in the introduction, during the last 20 years, the institutions involved in LUSES, have established solid, long-term programs via bilateral collaboration research projects in the domain of agronomic and soil sciences research (see § A LMI project 2010). LUSES specificity is to develop these interactions at a regional scale, which fitted perfectly with the ASEAN objective of stimulating South-South cooperation. This explains why this project has been well received by the Asian institutions involved.

B. PARTNERS DISTRIBUTION

Nearly 80 individuals (mentioned in a list of partners appendix 1) from the 4 countries were collaborating in LUSES; this list included executives, which support the administrative part of the project in their respective institutions. 46 of them dedicated more than one month for the project, (see figure below)

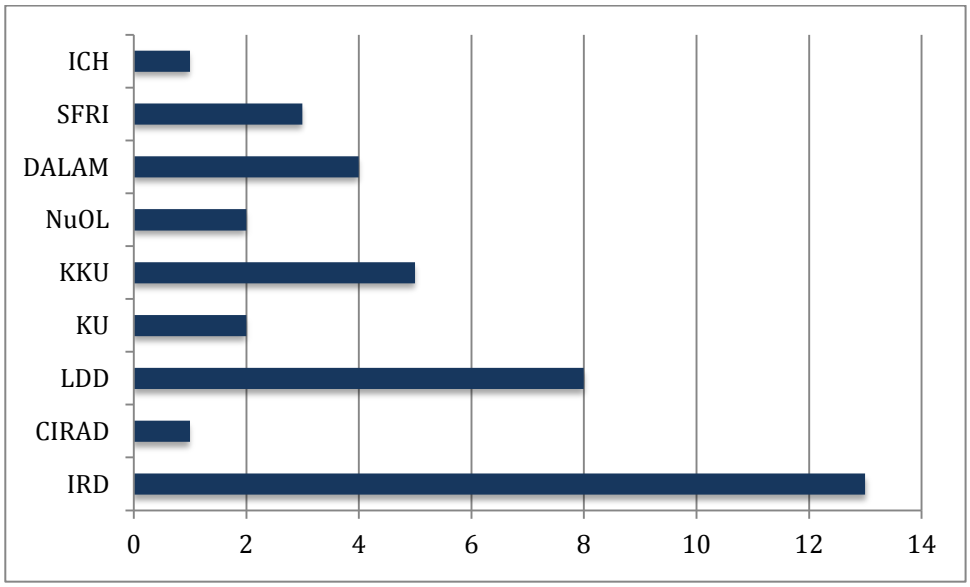

Figure 1: LMI members distribution (ETP > 1 month/ year)

**** IRD members involvement vary along the 4 years according to their posting.***

SHORT INSTITUTIONAL DESCRIPTION

FRANCE

UMR ECO&SOLS (Functional Ecology and Biochemistry of Soils and Agro-Ecosystems[2]) is a joint research unit with 70 permanent staffs from 3 research institutes (INRA, IRD and CIRAD) and one international, agricultural science centre of higher education e.g. Montpellier SupAgro), Located in Montpellier and in 7 countries from 3 continents (Africa, South America, and Southeast Asia). Research projects focus on the role of plants and soil organisms (roots, soil fauna and microorganisms) in carbon and nutrient (mainly nitrogen and phosphorus) cycles in soils and agro-ecosystems. The main research question is the impact of soil use and management and of climate change on these cycles. The main goal of our research is to propose field management techniques designed to sustain and enhance the agricultural and environmental functions of agro-ecosystems. The experimental sites are Mediterranean and Tropical agroecosystems. These agro-ecosystems are accounted for tropical tree plantations, agro forestry systems and annual crops. Different agronomic practices are tested (Intercropping, low inputs, organic farming and so on). ECO&SOLS has conducted the research in Thailand since 1995, mainly with LDD and KKU, studying on the impact of tree plantations on the soil compartment.

UMR GET (Geoscience Environment Toulouse[3]) is a large laboratory from CNRS, University of Toulouse and IRD that comprises of more than 250 people. The scientists from this laboratory are actively involved in field studies of soil, waters and plants, together with others specialist of experimental methods aiming at reproducing field observations and numerical modellers. An important aspect of GET is that strong links have been established with Laos partners incorporating in this project

UMR iEES-Paris (Ecological Institute of Science and Environment of Paris[4]) **-** iEES Paris composes of 153 researchers, teachers, technicians, engineers and administrative staff; those were grouped into 14 research teams and 4 scientific departments. iEES Paris virtually has a wide range of expertise in all areas of ecology. It is also one of the first French poles in science of soil and water, which are particularly recognized as its expertise on biogeochemical cycles, physics and soil biology or the dynamics of watersheds. They are linked to all the activities of LUSES as they assess the impact of human activities on the environment such as impacts of climate change, loss of

[2] http://www6.montpellier.inra.fr/ecosols_eng

[3] http://www.get.obs-mip.fr/en

[4] https://ieesparis.ufr918.upmc.fr

biodiversity and pollution on the quality of environment and ecosystem services, and they participate in research projects on the alternative management of ecological systems and the rehabilitation of degraded environments. On these topics, EES Paris has a long history of collaborative research in Southeast Asia countries, including Laos, Thailand and Vietnam.

THAILAND

In Thailand, IRD is collaborating since 1995 with the Land Development Department (LDD) and Khon-Kaen University and the team CIRAD of ECO&SOLS has the same long history with Kasetsart University.

Land Development Department (Co-Leader of LMI LUSES), was founded in 1963. It is now under the authority of the ministry of Agriculture and Cooperatives. LDD's missions are mainly dedicated to soil survey and classification, soil analysis, land use planning, conducting experiments and carrying out various aspects of land development and assisting farmers in soil and water conservation practices and soil improvement. There are around 3500 staff and more than 30 experimental stations in all the provinces of the country. More than 16 IRD scientists have been posted for several years to LDD since 1995 (currently 2). These researchers have been conducted in the framework of Thailand International Cooperation Agency (TICA) programs. Since 2007, the researches have focused on adaptation to the adverse edapho-climatic context of rubber tree plantations.

Khon Kaen University (KKU) was established in 1964 and is the largest public university of North-eastern Thailand. It is considered as the leader in teaching and research in the region that represents one-third of the whole country. It has an international audience kind to a curriculum that has hosted during the last decade about 100 postgraduates (MSc & PhD) from 17 countries. IRD-KKU collaboration started in 2005, focusing on rubber tree and rice agro-system agronomy and ecology. During 2005-2010, IRD has supervised five PhD students with different French universities (Universities Montpellier, aris VI etc.). This "French group" has become the core group of the JEAI ECO RUBBER launched in 2015 (Christian Hartmann and Alain Brauman co –leader from IRD).

Kasetsart University (KU) is one of the 9 National Research Universities (NRU) of the Commission on Higher Education. Its goal is to 'create knowledges of the land for the well-being of nation'. It is also entitled to further develop research programs on every aspect of agriculture and land uses. Kasetsart University has been working in collaboration with French experts since 1990 under an operation unit called the DORAS Center (Center of Thai-French Cooperation on Higher Education and Research). Kasetsart University, therefore, has developed relationships with CIRAD and other French research institutes like INRA, IRD and Montpellier SupAgro. Rubber plantations and natural rubber have become one of the main areas of such cooperation, formalized with the Hevea Research Platform in Partnership (HRPP), established in 2008.

LAOS

In Lao PDR, collaboration was initiated in 2001 to assess the effects of land use (LU) and land use changes (LUC) primarily on soil erosion, water flows and the spread of contaminants and subsequently on plant-related ecosystem services such as slope stabilization, carbon sequestration or soil structural changes

DALAM was created in 2012 as a separated institute from NAFRI (National Agriculture and Forestry Research Institute, founded in 1999) under the authority of the ministry of Agriculture and Forest and has less than one hundred staff. It purposes to undertake survey, classification, zoning, protection, rehabilitation, management and development of agricultural land. DALAM also concentrates on formulating plans and management measures to prevent causes of soil erosion, degradation of soil quality, change of the watershed ecosystem, deterioration of water sources and impacts on environment. Furthermore, DALAM is in charge of a soil and plant analysis laboratory. IRD has been collaborating with DALAM since 1998, (in 2016, 3 IRD scientist are still posted in Dalam) mainly through the MSEC observatory project (Multi Scale Environmental Changes).

The **National University of Laos (NUOL)** was founded in 1995 and is still the pilot university with 11 faculties and around 2,000 staff. NUOL is cooperating with various international universities from Australia (University of Sydney and University of Greenland), Thailand (Khon Kean University, Chiang Mai University, etc.), Vietnam (Hanoi Agriculture University), Philippine (University of Los

Banos), etc. NUOL has not provided PhD diploma yet. Which explain the interest of the partnership with Thai or Vietnam Universities

VIETNAM

The Soils and Fertilizers Research Institute (SFRI) is a research institution from the Vietnamese Academy for Agricultural Sciences (VAAS) established on 1969 It belongs to the Ministry of Agriculture and Rural Development (MARD). Its function is researching and transferring advanced technologies on soil, land, fertilizer and microbiology to serve agriculture and rural development in the whole country. SFRI includes five research departments and four regional research centers. SFRI has collaborated with many international organizations and such research universities, , as IPI, CIAT, IRRI, IWMI, IRD, Oxfam, AIT, Luven University -- interested in promoting the agriculture and rural development, environmental protection in Asian countries -- studying soil, fertilizers, water resources and have promoted the sustainable development in the rural areas in mountainous provinces. SFRI has been involving in the benchmark research on watershed management with IRD since 1999 under the collaborative international research network MSEC.

Institute of Chemistry ICH under the Vietnamese Academy of Science and Technology was established on September 16, 1978. ICH has 136 permanent staff including 6 full Prof., 15 Ass. Prof., 32 Ph.D. The objective is (i) to carry on targeted fundamental research towards problems that are important for Vietnam in different areas of chemistry such as Organic Chemistry, Biochemistry, and Environmental Chemistry (ii) to build up relations and develop collaborations relating to the research, development and training activities with higher educational institutions and with other research and industrial establishments, both in Vietnam and abroad.

3.2. GOUVERNANCE

A- DESCRIPTION

The International Joint Laboratory LUSES was an operating tool of the IRD based on a common scientific project that was constructed and directed with our local partners. The International Joint Laboratory was characterized by shared governance with our local partners

B- DIRECTION

The direction of the LMI was organized around two co-directors (French-Asiatic) at the same hierarchical level. The two directors of LUSES were Mr. Alain Brauman, Director of Research at IRD posted at the Land Development Department since the 1st of September 2011 and Mrs.Nopmanee Suvannang in charge of the director of the « Soil Analysis Technical Section, Office of Science for Land Development ». The directors distributed the budget, organized collective trainings and annual meetings, write an annual report and develop communication tools (website *www.**luses**.ird.fr*, Facebook LUSES). They also assure an administrative and operational support (with the help of the LMI assistant) to all the LMI members. They visit each year, all the LMI partners (see report visits on *www.**luses**.ird.fr*)

C- CHANGES IN THE LUSES GOUVERNANCE ORGANIZATION IN 2014

Since launching LUSES in June 2012, the governance of this project was organized around the two project directors, a Scientific Committee and a Steering Committee. One of the main weaknesses of this organization was an unclear distinction of respective rules of these two committees. So we follow the suggestions of the steering committee meeting (cf. report S.C. Hanoi 2013, www.**luses**.ird.fr*)* and modify the governance of the project by

- Replacing the scientific committee by an Executive Committee (EC) composed of LMI members including the French Research Unity leaders of UMR IESS, ECO&SOLS and GET
- The executive committee is in charge of all the operational aspects of the project relating to the funding, organization and functioning of the partnership. The executive committee will meet on an annual basis.
- The composition is based on the following points:
    - To remains slight (no more than 14 members)
    - Members must be scientific experts;
    - Maintaining a good balance between French and Asian experts

- Representation of most of the institutions involved in the project
- Replacing the Steering Committee by an Institutional Committee

- Composition: The Institutional Committee (IC) composed of 9 members representative of the 7 Asian and 2 French institutions involving in the project. The directors will be invited to attend it, whenever necessary. The 3 French Research Unity leaders will be invited or others external scientific experts.
- Role: To approve the scientific orientations of the project and check the regularity between these orientations, trainings and teaching programs. The Institutional Committee will be in charge of renewing the directors and will meet 3 times along the project (beginning, midterm and end)

Conclusion: The LMI governance is more simple and operational and has not change till the end of the project.

4. SCIENTIFIC ORGANIZATION

4.1- AN ORGANIZATION WHICH EVOLVES DURING THE PROJECT

The LMI objective is to promote synergies between the partners on the impact of agriculture practices on soil ecosystem services, relating to the land use changes. To achieve this objective, LUSES was in the first two years (from 2012 to 2014), organized in 4 Work Packages related to main ecosystem services (WP1: nutrient cycling, WP2: biodiversity, WP3 C sequestration and WP4 the water cycle and erosion (see project LMI 2010) We do not dedicate a specific budget for the WP, but we choose a bottom up approach, through a launching of an annual internal call, to subsidise the WP.

However, after two years, it appears that the WP organization was not operational as no specific budget was dedicated to each WP (even if we could observe a well balanced distribution of internal calls among the WPs). So, during the first two years, LUSES has made a focus on partner's capacity building via the organization of collective trainings and the implementation of a biological platform. When this capacity was strengthened. LUSES has to go forward and need to reinforce the research part of the project at a regional scale. Based on these statements, in 2014, the directors of LUSES proposed to the Steering Committee of LUSES to dedicate more than half of IRD budget on the 3 following projects.

Table 1: LUSES projects title and leaders

TITLE	Organic Matter Management	Env. Impact of Tree plantation	Ecofilter (Land uses and stream ground) water)
ASIAN Leader	**Thuy Thu DOAN**** (*SFRI Vietnam)*	**Supat Isarangkool (KKU Thailand)**	**Oloth Sengtahevanghoung** *(NAFRI Laos)*
France Leader	**Nicolas Bottinelli*** (IRD IESS)	**Alain Brauman** (IRD ECO&SOLS)	**Olivier Ribolzi** (IRD GET)

- in 2014 and 2015 C. Hartmann was in charge of the project
- In 2014 Dr. Tran Duc Toan (retired in 2015) was in charge of OMM

Each project must respect the following specifications:

1- Have a regional perspective (included at least 2 countries involved in LUSES)
2- Be co-led by an Asian and French scientists
3- Be Co-funded (institutions, scientific projects)
4- Involve Asian students at MSc or PhD level

5. RESEARCH ACTIVITIES AND RESULTS

LUSES research has been undertaken through the following 3 research projects.

5.1 ECOFILTER: effect of land use on stream-ground water interactions, overland flow genesis and the related ecosystem services of the critical zone in tropical agro-ecosystems

LEADER: ASIAN AND FRENCH

Oloth Sengtaheuanghoung (KKU), Laos, Department of Agricultural Land Management (**DALaM**) – Agricultural Land Use Planning Centre (ALUPC) - Ministry of Agriculture and Forestry (MAF).

Olivier Ribolzi France, Institut de Recherche pour le Développement (**IRD**) – Géosciences Environnement Toulouse (GET)

LMI PARTNERS

LAOS: DALaM, NuOl ; **THAILAND**: DNP, LDD; **Vietnam:** SFRI; **France** UMR GET, UMR IESS-Paris

SCIENTIFIC PROJECT

CONTEXT

In a context of rapid land-use change, **preserving the ecosystem services** of food production systems requires to design and implement innovative agricultural practices that favour rainfall infiltration and soil water storage, and **limiting stream water contaminations** and soil and fertility losses by overland flow.

OBJECTIVE

Provide new scientific knowledge on the **filtration of overland flow by soil and vegetation along hillslopes and in the riparian zone** in montane agro-ecosystems of Asia.

Enhance **capacity building** through the training of colleagues from Thailand, Laos and Vietnam on the research methodologies implemented during the project and their interpretation, i.e. water quality measurements, hydro-dynamic parameters of soil measurements, tracer-based approaches, etc

CONCEPTUAL SCHEME

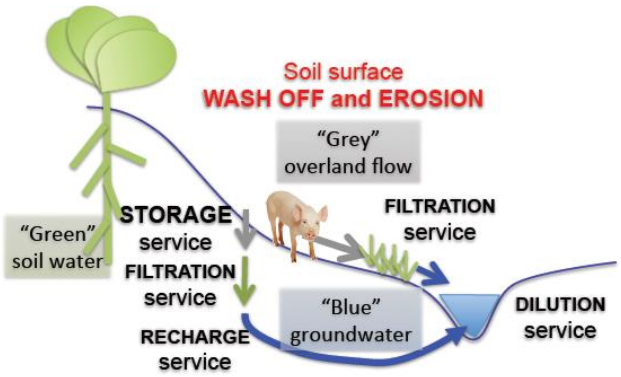

Figure 1

Conceptual diagram showing the expected ecosystem services

RESEARCH QUESTIONS OR HYPOTHESIS

Main question (Figure 1): What plot patterns (landscape mosaics and land-use) should be implemented on slopes and along waterways, to ensure that sustainability and productivity are maximized/optimized *via* a rational management of "green" waters (i.e. soil water available for evapotranspiration), "blue" waters (e.g. groundwater and streamwater) and "grey" waters (e.g. overland flow contaminated with fecal pathogens) ?

Three main research actions were implemented in 2016 and set up in Laos, Thailand and Vietnam: **(1)** Compare the hydrological behaviour of studied catchments (i.e. overland flow genesis, groundwater inflows…) during storm and inter-storm periods; **(2)** Study the dissemination during floods of free and particle-bound faecal contaminants; **(3)** Quantify the trapping efficiency of the riparian zone depending on the vegetation cover types.

METHODODOGICAL PRINCIPLE

The methodological approach is two folds: **(1)** Surface flow measurements (water, SL, *E. coli*) using micro-plots and Gerlach trough, **(2)** Overland flow quantification at the catchment scale using a tracer-based approach for the separation of storm hydrographs.

MAIN RESULTS

At the plot scale: Estimate of hydraulic conductivity of sub-surface soil horizons (see MSc. by Kampaseuth XAYATHIP), quantification of runoff coefficients and soil detachment rates. These observations were conducted under different land uses and are being processed for the catchments in Laos, Thailand and Vietnam.

At the catchment scale: The monitoring of Electrical Conductivity (EC) both in overland flow (sampled at the plot scale) and stream waters at the outlets of catchments. Estimate of Hortonian overland flow using EC-based separations of storm hydrographs were implemented in the different countries after the rainy season (see workshop in Luang Prabang 26-30/10/2015).

MAIN OUTPUTS

A key outcome of the project this year is the **writing of a collective paper[5] involving partners from the three asian countries** (Thailand, Laos and Vietnam), which was submitted in February 2016 (see below).

5.2 BIODIV-TREE: IMPACT OF TREE PLANTATION ON SOIL BIODIVERSITY AND SOILS FUNCTIONS

LEADER: ASIAN AND FRENCH

Dr. Supat Isarangkool (KKU), Tree physiologist, specialist of water cycles in Rubber, Associate Dean for Special Affairs, Faculty of Agriculture, faculty of Agriculture of Khon Kaen University.

Dr. Alain Brauman Institut de Recherche pour le Développement (**IRD**) – UMR ECO&SOLS, LMI Director, Land Dept. Development. Bangkok. Thailand

LMI PARTNERS

LAOS: NuOl ; **THAILAND**: KKU, LDD, KU, **France** UMR IESS-Paris, UMR ECO&SOLS: CIRAD, UR 34 UMR CEFE

SCIENTIFIC PROJECT

CONTEXT

Southeast Asia concentration produced more than 92 % of the world production of natural rubber. In the last decades, rubber plantations did not replace many farming systems such as traditional subsistence agriculture or commercial crops but also encroached into and replaced large areas of natural forests, especially in the Greater Mekong Sub region (GMS). Despite the economic and agronomic importance of Rubber, studies on the influence of rubber trees plantations on the environment and more specifically on the main soil ecosystem services remain scarce

OBJECTIVE

General: To characterize the impact of rubber tree plantation on soil biodiversity and related soil ecosystems services such as nutrient cycling and C sequestration

Methodological: To set up a set of functional tests to characterize the following functions: OM mineralization, nutrient cycling and maintenance of soil structure

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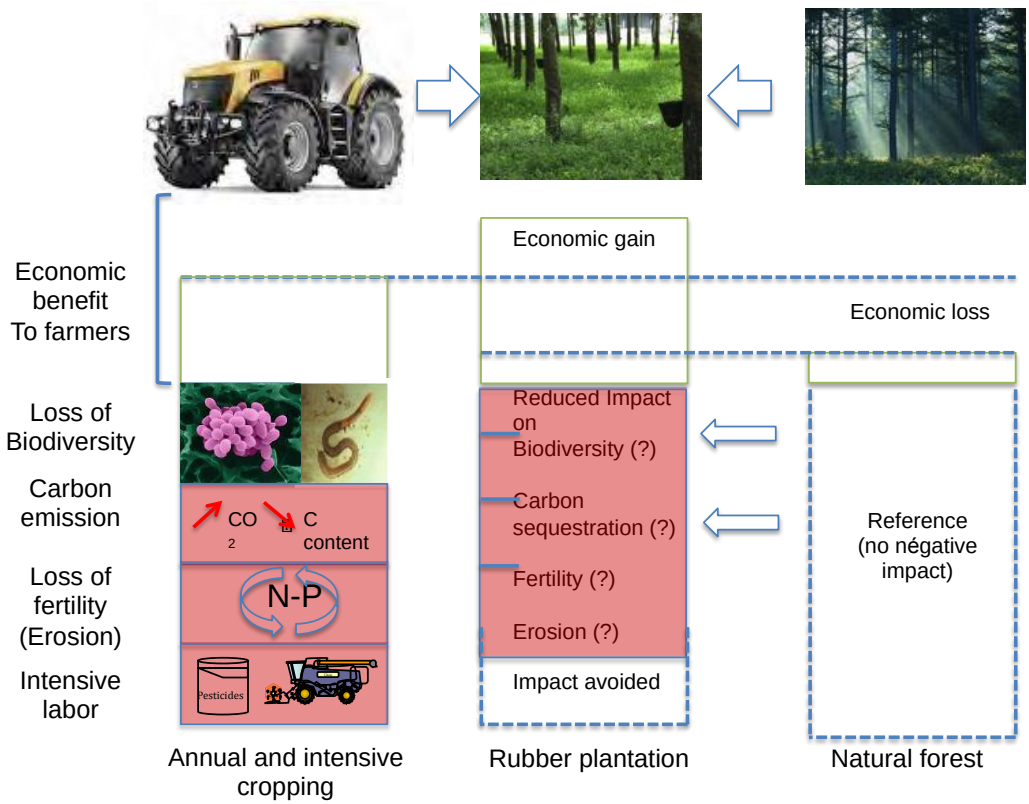
[5] Emma Rochelle-Newall[1], Marion Viguier[2], Chanthamousone Thammahacksa[2], Norbert Silvera[2], Keooudone Latsachack[2], Rinh Pham Dinh[3], Piyapong Naporn[4], Hai Tran Sy[3], Bounsamay Soulileuth[2], Nikom Hmaimum[4], Pem Sisouvanh[5], Henri Robain[1], Jean-Louis Janeau[1], Alain Pierret[2], Laurie Boithias[6], Olivier Ribolzi[6] - Effect of land use and hydrological processes on *Escherichia coli* load in streams of tropical headwater catchments. **Scientific Reports** (minor revisions).

CONCEPTUAL SCHEME

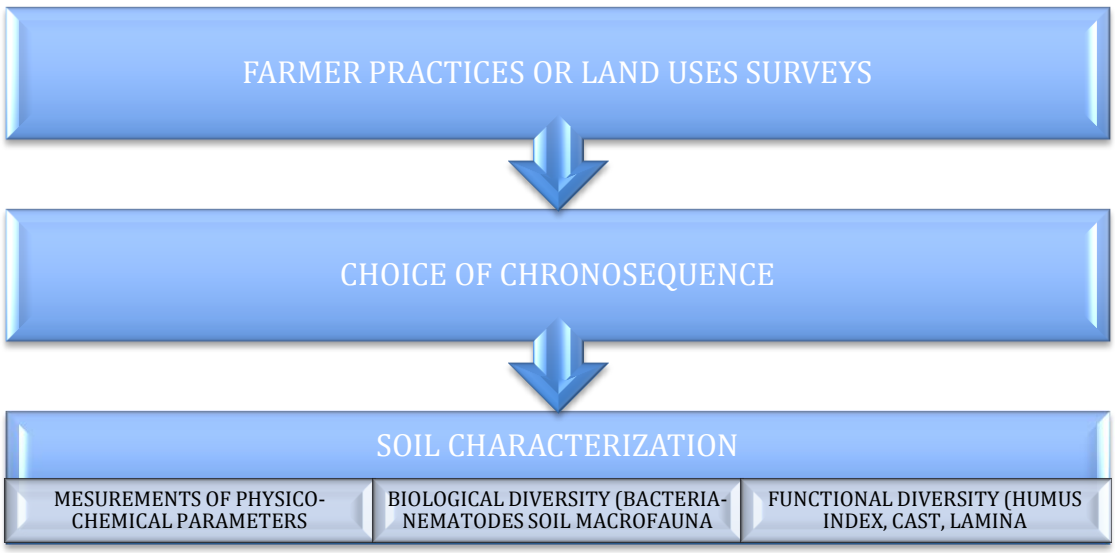


We hypothesis that the impact of rubber plantations on soil biodiversity and related ecosystem services will first depend on the former land use and farmers practices

RESEARCH QUESTIONS OR HYPOTHESIS

1. Thailand What are the main drivers (Land Use Change, Tree age, agricultural practices etc.) of soil biodiversity changes
2. Laos: What are the consequences of rubber tree plantations extension on land use functioning and farmers' income in Northern Lao PDR

METHODODOGICAL PRINCIPLE



MAIN RESULTS

Q1: importance of plantation age versus land use change on the soil biodiversity.

- Plantation age has a deeper impact on soil biodiversity and soil functions than the shift induced by land uses changes (from cassava to rubber)

- Rubber tree has a less detrimental on soil (bio) functioning than cassava

Q2: impact of different level of soil management on soil functional diversity

- Intensive agricultural practices generate a high level of perturbation due to the narrowing of functional diversity for all groups of organisms studies (bacteria, fungi, nematodes, soil fauna).
- Plantations with low intensity practices were characterized by an higher level of stability (more complex food web) and an increase of biomass of all groups studied (soil engineer, bacterial biomass, nematodes fungal feeders)

Q3: main drivers of litter decomposition in Rubber plantation

- Litter decomposition decreases with age of plantation; this pattern originated from a:
    - Change in soil fauna composition, mesofaunal activities was high at the onset of the chronosequence while macrofauna activities and biomass, especially earthworms, increased in old plantations.
    - Litter quality change -- young litter -- (6y) has an higher content of labile compounds (more dissolved organic carbon, less lignin than old litter) (25y).

Q4: Consequences of rubber tree plantations extension in N. Laos. The production of latex has significantly impact livelihood, which switches from subsistence to semi-subsistence. However, rubber is not yet their main economic income, and the recent steep decrease of the latex price has had a disastrous impact on households

MAIN OUTPUTS

We clearly demonstrate during this project that rubber tree plantation

- ❖ Represents a suitable alternative in terms of soil rehabilitation when it replaces an annual crop such as cassava (but only after 12 to 15 years)
- ❖ Represents a risk for soil fertility in adverse soil ecological context when farmers use intensive practices
- ❖ Agricultural practices such as cassava or pineapple intercropping has generally negative effect on soil biodiversity
- ❖ It takes over 20 years to reach the same C content than cassava; the extension of rubber lifespan planation could be a good way to increase soil C in this context of low fertility soil.
- ❖ 80 years of mono-specific plantations strongly affect soil food web, resilience and sustainability of the soil ecosystem.
- ❖ Functional index seems a more reliable indicator of soil ecosystem disturbance than ecological index based on taxonomical affiliation

VALORISATION (COMPLETE LIST CF. APPENDIX 2.1)

9 papers in peer review journal (4; 6; 7; 15; 16 ; 17 ; 18 ; 19 ; 20), 8 papers in national journal, 41 presentations in International and National Congress, 8 student reports (master and gap year internship)

Nota bene: most of the publications involving in this project have not been published (which explain the unbalance ratio between Congress and papers). We expect to publish at least 7 papers in the next two years linking to the current PhD thesis on this topic.

STUDENTS INVOLVED (COMPLETE LIST CF. APPENDIX 2.4)

6 PhD students and 7 master or gap year internship students

COLLECTIVE TRAINING LINK TO THE PROJECT. : 10

Because the operational cost of the project was funded by others projects such as IFC and ANR Heveadapt, most of the budget were devoted to the organization of (i) collective training (10 in 4 years) on soil biodiversity, soil microbial activities (microresp techniques), biofunctool (set of tools easy to use in the field) etc. (ii) individual support of students (4 asian PhD students involved in the project)

5.3 OMM: organic matter management: respective effect of compost and vermi-compost on soil and plant.

LEADER: ASIAN AND FRENCH

Dr. Thuy Doan Thu, soil microbiologist, researcher at the Soils and Fertilizers Research Institute (SFRI)

Dr. Nicolas Bottinelli, soil ecologist, researcher at the Institut de Recherche pour le Développement (IRD) – UMR iEES

LMI PARTNERS

LAOS: NuOl; **THAILAND**: LDD; **VIETNAM**: SFRI; **INDIA**: LMI-CEFIRSE; **FRANCE:** UMR IESS-Paris

SCIENTIFIC PROJECT

CONTEXT

Soil structure plays a key role in the ability to fulfill essential soil functions and services (e.g., root growth, gas and water transport and organic matter turnover). The soil structure development depends largely on (i) soil organic carbon content and (ii) plant roots and soil macrofauna. Usually considered as one of the most important macrofaunal organisms in soil, earthworms are very sensitive to soil physical characteristics. If earthworms can resist to soil pollution, they cannot resist soil physical degradation. Rather than applying organic wastes in a field that contains the insufficient earthworms population, a more efficient option could process the organic waste by earthworms outside the soil (vermicomposting) and (ii) apply the transformed wastes (vermicompost) to cultivated soils. The vermicompost is already largely developed in many countries and regions worldwide. If many studies have reported an increase in crop yield with the vermicompost compared to compost fertilization, the inherent processes involved will have rarely been identified.

OBJECTIVE

The aim of OMM is to better understand the effects of the vermicompost as compared to compost on soil properties, plant development and resistance to drought.

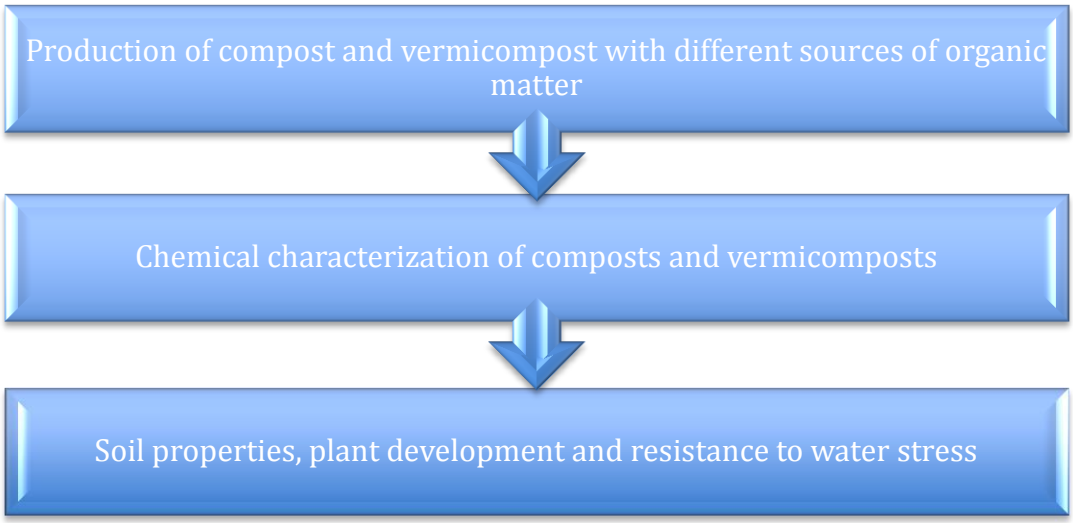
QUESTIONS

- What are the optimal conditions produce vermicompost?

- What are the main chemical differences between compost and vermicompost?

- What are the benefits of using vermicompost as compared to compost in term of plant development and resistance to water stress?

METHODODOGICAL PRINCIPLE



MAIN RESULTS

Q1: What do the optimal conditions produce vermicompost?

- The air temperature needs to be maintained between 24-27^{0}C and substrate moisture between 65-77%.

- It takes longer to produce vermicompost with *Eisenia andrei* (90 days) than *Eudrilus eugeniae* (45-50 days).

Q2: ***What are the main chemical differences between compost and vermicompost?***

- A total of 9 composts and vermicomposts was studied. Compost and vermicompost were obtained from different raw materials: buffalo, cow dung and farmyard manure, biogas slurry, vegetable wastes such as eucalyptus, vegetables, coconuts and mushrooms, among others (pure and mixtures in different proportions). On average, vermicompost had less TOC content (by 8%) and lower pH (by 3%) than compost. Conversely, it had more P_2O_5 (by 4%) and K_2O (by 15%), and similar TN content.

- Differences in total nutrient content between compost and vermicompost varied, according to the source of organic matter, without clear consensus (C/N, type of OM).

- Water-soluble fractions (DOC, COND, K^+, NO_3^-, Ca_2^+, SO_4^-, Cl^-, Mg_2^+) studied from 5 raw materials (eucalyptus, biogas slurry, vegetables, vegetables farmyard manure and farmyard manure) were always higher in vermicompost than in compost.

Q3: What are the benefits of using vermicompost as compared to compost in term of plan development and water stress?

- Shoot and root biomass of maize and coffee are usually similar to vermicompost and compost fertilization.

- First results of the resistance of coffee to water shortage show no difference between compost and vermicompost.

MAIN OUTPUTS

- Total nutrient contents (OC, N, P and K) of composted organic matter are less sensitive than water-soluble fractions to differentiate vermicompost and compost.

- There is no evidence that vermicompost is more suitable than compost in terms of plant development and resistance to water shortage in laboratory conditions.

5.4 VALORIZATION

Year	Ref. journal	Non. Ref journal	Communications	Students Reports
2012-2016	26	9	58	15

The completed list of publications linking to the project is presented in appendix 2.1). Since LUSES was still a young project (4y) and mostly devoted to ecological studies at field scale, we could expect that most of the papers engaging in the currents projects will be published in the next two years (2017 and 2018)

6. TEACHING AND TRAINING ACTIVITIES AND RESULTS

This represent one of the main asset of the LUSES project is to reinforce the strength of LMI partners on the field of soil ecology. We elaborate 3 steps of strategy:

1. Reinforce their analytical skill by implementing new biological platform and develop soil quality control at regional scale (SEALNET network) (see § 7)
2. Focus on the first two years of the project on collective training to strengthen scientific skills
3. Increase with time individual supports for students (PhD) mainly with the help of the JEAI ECO-RUBBER

6.1 ORGANIZATION OF COLLECTIVE TRAINING

This was one of the main specificities of this project. Collective training was found to be the most proper way to (i) foster the linkage (or to create it) between the different LMI partners at the national and international scale and (ii) strength their skill in the different disciplines linking to soil ecology (soil biology, water cycle, eco-physiology, soil physic etc.). The discipline is still in its infancy in ASE.

Since the launch of LUSES in June 2012, 20 collective training has been organized involving around 320 participants (some participants participated to more than one training). The training could be split in 3 categories.

Technical Training: the goal is to learn a specific technic (ex: measure of microbial activity using micro-respirometric technique).

Vocational Training: the goal is to initiate the candidates to a given scientific thematic such as "impact on land use on stream water faecal contamination" (ECOFILTER project) or "measurement of soil bio-functioning" (Biofunctool project link to the tree plantations).

Valorisation: the goal is to develop the skill on data analysis (statistics with R, database management) and writing process to foster the valorisation of their work.

Most of the technical trainings (essentially lab trainings) were organized in Thailand due essentially to the facilities found in Thai institutes and due to the highest number of LUSES Thai partners. Most of them were co-organized and co-funded with others projects such as the DP CIRAD HRPP, DP CANSEA LMI CEFIRSE, or with LMI partners.

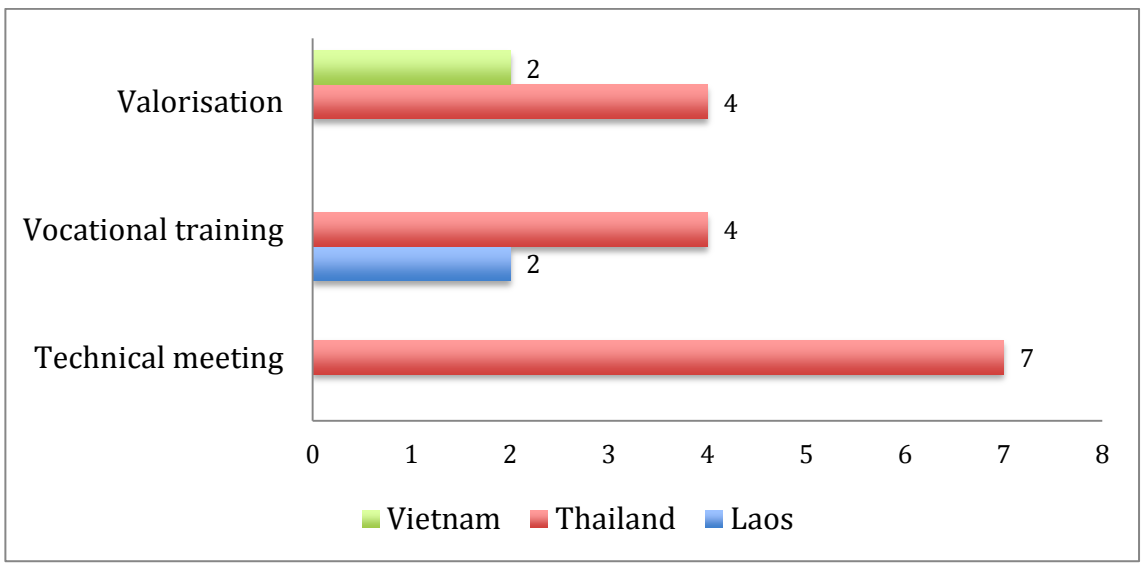
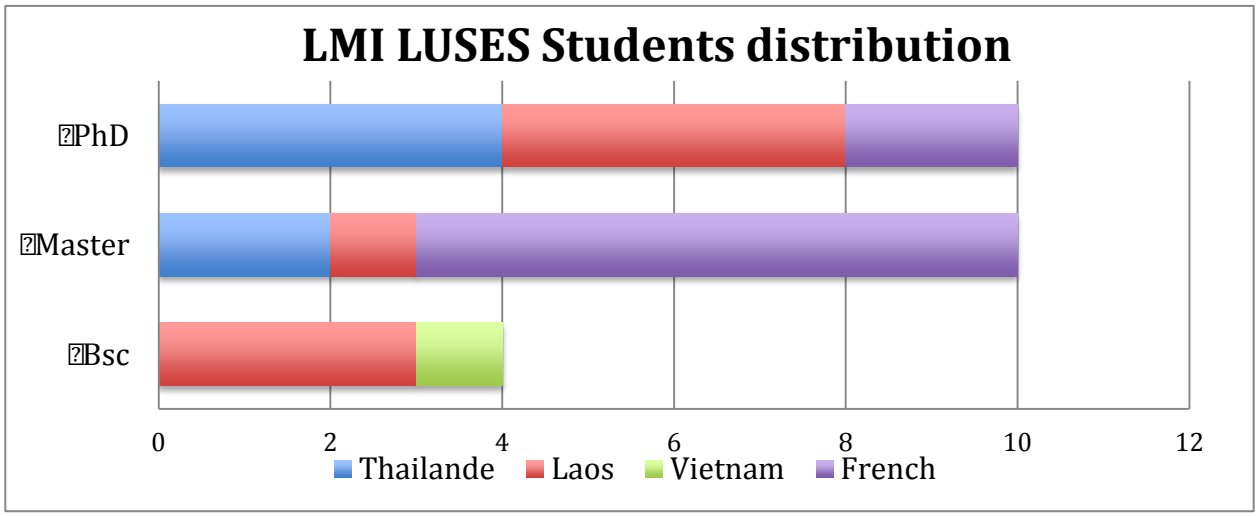


Figure 2 Training typology and localisation

The complete list of training with their title and number of participants is given in appendix 2.2.

6.2 INDIVIDUAL SUPPORTS

Another specificity of the LMI LUSES was to dedicate a part of the budget to the support of students (24 with 10 PhD listed in appendix 2.4) and individual researcher or students for lab fees, tuition fees, field trip, participation to collective training and etc. From 2012 to 2014, the budget for to these supports was around 10.000 euros by year (2016 not included). Some French students (mainly master or gap year internship) are included in this list as they do participate to the project, but the LMI LUSES policy was to support only Asian students while the French students were supported by other fundings (ANR Heveadapt, French Institute of Rubber etc.).



One drawback is the lack of students from Vietnam. This specific point, concerning about Vietnam participation, is specifically discussed in the asset and weakness section.

6.3 TEACHING ACTIVITIES

Due to the scarcity of international English Master in the field of Soil or Ecology in the SEA area, most of the teaching activity of LUSES members were given through the USTH[6] master "Advanced Hydrology" coordinated by Didier Orange from IRD UMR IESS for 50h per year[7]. Since 2015, D. Orange has also been a coordinator of the UE "Ecological Engineering" (50h/y).

In Thailand and Laos, LMI French scientists gave different conference relating to soil sustainability, soil as a living ecosystem and soil biological indicators at the master level in the different university involving in the LMI (KU and KKU and Nuol)

7. INNOVATIVE ACTIVITIES AND TECHNOLOGY TRANSFER AND RESULTS

Soil Ecology focuses on the interaction between the abiotic and the biotic components of the soil. This means that improving the skill of LUSES partners on this field implies to produce a good data set of both biological and physical-chemical parameters. To do so, we set up (i) a biological platform within our main partner the LDD to assess soil microbial molecular diversity (DNA sequencing) and activity (microresp) in the soil (ii) a soil laboratory network (SEALNET) to increase the quality and liability of soil analysis within the regional framework of LUSES.

[6] Université des Sciences et Techniques de Hanoi

[7] (Orange Didier (30h/y), Christian Valentin (6h/y), Emma Rochelle-Newall (4h/y), Olivier Ribolzi (3h/y), Jean-Louis Janeau (8h/an),

7.1 SETTING UP OF A MODERN BIOLOGICAL PLATFORM

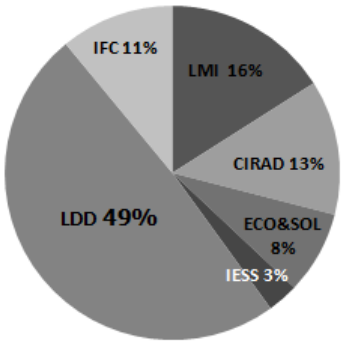
Under the framework of the LMI LUSES a new biological platform within the department of Biotechnology of the LDD was implemented in 2014. It has been officially opened on 22 May 2014 by the LDD DG.(see LMI website). Since 2012, this laboratory has been

benefited from nearly 145000 € of equipments (5.8 millions bath), 50 % from IRD, French UMR and scientific projects (mentioned in table 2 and list of equipment in appendix 2.3) and 50% from LDD (LDD has gathered in this laboratory whereas others equipment's originated from its former laboratory of biotech). This laboratory was, at first, under the responsibility of Dr. Didier Lesueur (CIRAD, LMI LUSES) and Mrs. Dararat Hotaka from LDD. It has been reinforced by the posting in 2014 of an International Volunteer from IRD (Mr. Pascal Alonso) in charge of setting up the different lab techniques and quality protocols.

The platform was used to (i) host collectives training (4 trainings), (ii) implement new techniques such as molecular fingerprinting, DNA extraction for soil diversity analysis and measuring soil microbial biomass and metabolic profiles using microresp^{TM} (iii) host LMI students (~8) from Lao, Vietnam and Thai institutes.

Table 2: List of institutional contribution to the LMI-LDD Platform

	Equipment (€)	**%**
LMI	23 500	16%
CIRAD	18 300	13%
ECO&SOL	11 000	8%
IESS	4 800	3%
LDD	71 200	49%
IFC	16 000	11%
TOTAL	144 800	



7.2 THE IMPLEMENTATION OF A SOIL LABORATORY NETWORK SEALNET

As many countries' governments are introducing the rule, the orders for environmental and ecological analyses should only be given to laboratories that are accredited for this type of work. For accreditation, 'Quality Management' is an essential aspect. Many 'small' laboratories often do not have the necessary resources and incentives to engage in a comprehensive effort done by larger laboratories for seeking accreditation, and proper training as well as refresher courses may be neglected. Moreover, 'small laboratories' have often developed their own analytical methods that can provide significantly different results when compared to standard procedures. Thus, this is why LUSES launched in 2013 is entitled a SELNET network with the main objective to implement a soil quality control involving the main partners of LUSES in order to improve their performance through inter-laboratory sample exchanges and a statistical evaluation of the analytical data. This is the general objective of SEALNET. The complementary objective is the harmonization of analytical methods between the different laboratories in order to reach standardization at the regional scale. This project is led by Nopmanee Suvannang, co-director of LMI and Director of Soil Analysis technical group, and Christian Hartmann, soil scientist form IRD posted in DALAM. Pascal Alonso, IRD, LDD Bangkok gives a technical assistance. This project is also shared with the LMI CEFIRSE, and we benefit from the expertise in quality control of JL Duprey, IRD posted in Bangalore INDIA.

7.3 EXAMPLE OF TECHNOLOGY TRANSFERT DONE WITH LUSES SUPPORT

LMI LUSES through collective training has transfered a lot of new techniques, such as the measurements of overland flow and using electric conductivity in the three countries (see ECOFILTER report) where the project was active. In this report, we will take the implementation example of a new technique like the microrespTM method, at first, in Thailand then further in the different country of LUSES to illustrate this feature.

Because microbial communities are known as a key component of the soil functioning, the assessment of their activities remains an important challenge to better understand the impact of a given land uses on the soil microbiota. This microespTM technique (Campbell et al., 2003) allows to determine both the soil metabolic profile and the soil microbial biomass. After a first installation in 2013 in the LMI LDD lab, two international training has been organized (2014 and 2016) involving all countries of LUSES in the LMI platform. Now, this technique

- is being used in routine within the LDD biotech staff
- is shared by the different institutes of the LMI (KKU, KU, SFRI and NuOl) and LMI project (OMM and TREE)
- will be implemented in others regional labs such as Dalam (Lao) and Cambodia (Royal University) within the project FIRST funded by CANSEA

8. ADDED VALUE OF THE LMI IN TERMS OF PARTNERSHIP STRENGTHENING

Within this last 4 years, what could be specifically attributed to LUSES? This complex question could be answering at two levels

8.1 CAPACITY BUILDING

The LMI LUSES LDD Platform. Even if the LDD has already a small biological laboratory, the initial contribution of LUSES of 24.000 € in 2011 devoted to molecular equipment (PCR, DGGE etc.) has decided the partner (LDD Biotech) to build a new platform to post all this equipment. This completely new platform is now fully operational and will continue to be an important component of the putatively second phase of LUSES.

SEALNET network. This network of soil laboratory analysis was launched in 2014 with the help of JL Duprey from LMI CEFIRSE with the sole budget of LUSES. This network gathers now 19 laboratories of the SEA (not only country of Luses but also others countries such as Cambodia are interested by this network). SEALNET has been recognized by the Asian Soil Partnership program led by the FAO (the last workshop in 2015 was entirely supported by the FAO), and 5 labs obtain a free access to the ASPAC Australian network of soil survey.

8.2 PARTNERS LINKAGE

Most of the partners of LUSES did not work together and even did not know each other at the beginning of the project. The high number of collective training together with LUSES meeting organized each year in one partner institution contribute to a real strengthening of partner's linkage. There are some recent events such as self-organizing training hosted by the partners without LUSES support (case of training on paper's writing) and the sending of students (bachelor degree) from KKU (Thailand) to Dalam (Laos) and SFRI (Vietnam). The increasing number of partner who uses the LMI – LDD platform for bacterial analysis etc. demonstrate that LMI LUSES partners have now fully appropriated the project and developed strong interactions both locally and regionally.

8.3 LEVERAGE CAPACITY:

Since the launching of LUSES, nine projects (see table 5) have been sponsored from a total budget of 1.424.319 € 5 being led by LMI LUSES scientists, and three are led by CIRAD colleague from UMR ECO&SOLS and AIDA who have a strong interaction with LUSES. This success could not be attributed to not only LUSES but also the highly scientific capacity, first, of LUSES members in finding research budget. However, for most of them, the support of the LMI LUSES in terms of operational facilities (laboratory supports, easier field access) capacity building (training

organization, networking at ASE scale) was clearly mentioned. The LMI LUSES gives a higher visibility of the scientific network of Asian and French scientists around soil ecological science. It also highlights on the significant leverage capacity of the different network between IRD and Asian partners such as the Regional Pilot Program (PPR) SELTAR, the Soil Erosion Consortium (MSEC), the Thailand International Cooperation Agency (TICA) projects (KU and LDD) and HRPP (Hevea research Platform in Partnership).

Table 5: list of project funded during LUSES Phase 1

Acronyme	Title	LUSES projects link	Year of submissi	Fundin agen	Total amou	Coordinat	leadership by LUSES membe
BIODIV-HEVEA	Impact of Rubber tree plantation on soil biodiversity	e Plantation and OI	2013	IFC	130000	A. Brauman.	Yes
NUCOWS	Nutrient Cycles and Contaminants in Waters in SEA	ECOFILTER-	2013	USTH	30000	D. Orange	Yes
TecItEasy	Combined effecTs of trEe plantation expansion and	ECOFILTER-	2013	ANR	298505	O. Ribolzi	Yes
YARA -RUBBER	ertilization of mature rubber plantatio	Tree Plantation	2013	YARA	133315	F. Gay	Yes
CRHYD	Growth and water constraints in Rubber tree	Tree Plantation	2014	IFC	93500	Do F.	Yes
Hevea-Adapt	How tree-based family farms can adapt to global challenges?	All	2014	ANR	492000	P. Thaler	Yes
Vertical Drainage	Agronomic performance improvement of water stressed rubber	ECOFILTER-	2014	MAE	20000	R. Angulo	No
ECO-RUBBER	Soil functioning changes under tree cultivation:	Tree Plantation	2015	IRD	200000	C. Hartmann	Yes
FIRST	Functional IndicatoR of Soil ecosystem	Tree Plantation	2016	AFD	27000	P. Lienhard	No

8.4 ADDING VALUE OF LUSES ON ONGOING PROJECT:

The budget contribution of LUSES could be seen as rather low (≤ 10%) compared to annual budget of French ANR projects or even national project such as IFC ones. However, LUSES budget contributes specifically to:

- Add a regional scale to local project. ANR TECITEASY, ANR HEVEADAPT, IFC BIODIVHEVEA were focus on one country (Laos for the first one, Thailand for the two others). LUSES gave them the opportunity to develop their project at a regional scale (Vietnam and Thailand for TECITEASY, Laos for ANR HEVEADAPT, IFC BIODIVHEVEA).
- Subsidize specific, important elements for partners but difficult to fund. This was a key point as some expenses such as students university fees, congress participation, specific training or equipment not pre-listed in the project, etc. were difficult to subsidise. LUSES contribution facilitates the scientific life of our partners involving in the project.

8.5 PARTNERS SCIENTIFIC VISIBILITY

By stimulating interactions with different others regional or local projects with

- DP CIRAD HRPP[8](http://hrpp.ku.ac.th): led by P. Thaler from CIRAD who belong to the same research Unity that A. Brauman (French leader of LUSES). Since HRPP and the TREE plantation project has focused on the same plant model and the rubber tree, LUSES has developed this project along with a long and fruitful cooperation. LUSES brings its expertise on the soil compartment while HRPP gives us their knowledge on the plant physiology and agronomic part. HRPP gives the LMI LUSES partners a full access to their long-term observatory like the CRCC (Chachoengsao Rubber Research Center). HRPP and LUSES, thus, have developed common actions (workshop, training, scientific conferences[9], supervision of

[8] Hevea Research Platform in Partnership.

[9] International Soil conference with LDD (http://www.ldd.go.th/WEB ISC2015) which gather more than 400 researchers in August 2015 with nearly 20 posters and oral presentations made by LUSES partners and IRD scientists),

International conference on Rubber with Taksin University)

PhD students) and shared the scientific projects, such as the ANR Heveadapt. Their interactions increase the visibility of the French research on the rubber plantation and give them potentiality to develop international collaborations with other important groups such as the SURUMER project (https://surumer.uni-hohenheim.de) 2 international workshops on sustainability of the rubber plantation (organized in 2014 in Laos, in 2016 in China).

- DP CANSEA (*www.**cansea**.org.vn)* the interaction with the DP CANSEA is more recent. It firstly develops collective trainings (soil biodiversity, Biofunctool) where several CANSEA partners were trained. LUSES and CANSEA share the same goal in order to study and promote more sustainable agriculture in the SEA context (see the introduction). In this context, one project co-written by scientists of LUSES and CANSEA has been accepted by a recent call launched by AFD.

9. IMPACTS ON THE NORTH-SOUTH SCIENTIFIC COMMUNITY ON DEVELOPMENT ISSUES.

This project responds the following thematic priorities of the Sustainable Development Goal indicators (http://unstats.un.org/sdgs), especially those concerns:

Goal 2 Food security and promote sustainable agriculture: LMI LUSES develops research on both the impact of intensive agricultural practices on soil ecosystem services and alternative and more sustainable practices improving soil quality (such as vermicompost, biochar and agroforestry)

Goal 4.Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. The collectives trainings, the support of master and PhD students and the organisation of annual scientific meeting increase the skill of the partners on sustainable development, relating to topics (4.7 of OD), among others for sustainable development

Goal 6. Ensure availability and sustainable management of water and sanitation for all. For MSEC, through the long-term multiscale monitoring of upland watershed in SEA, LUSES participates the protection of water related ecosystem such as steep lands (6.6 of OD).

Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably managed forests, halt and reverse land degradation and halt biodiversity loss. LMI LUSES promotes the integrated regional approaches to these issues (through MSEC network) and promotes the research on the reduction of soil vulnerability. LUSES studies light shed on soil biodiversity loss due to agricultural practices in Thailand and Laos. It also tackles the social and environmental impact of deforestation (supplanting forest with rubber plantation) in NE Lao and promotes the use of alternative practices (compost, vermicompost, Biochar) for soil restoration.

10. ASSET AND WEAKNESS OF LUSES

9.1 MAIN ASSETS OF LUSES

- Stimulation of high quality research through involvement of partners in international projects (ANR), scientific congress, PhD Students (8), training on data analysis and writing process.
- Capacity building through laboratory implementation, laboratory network (SEALNET), common field works and reinforcement of field observatory (MSEC)
- Partners linkage through collective training, annual meeting, common projects and sharing students
- Project appreciation and increasing visibility of soil ecology through co-organization of meetings and stimulation of relation with other regional projects such as DP CANSEA, SURUMER

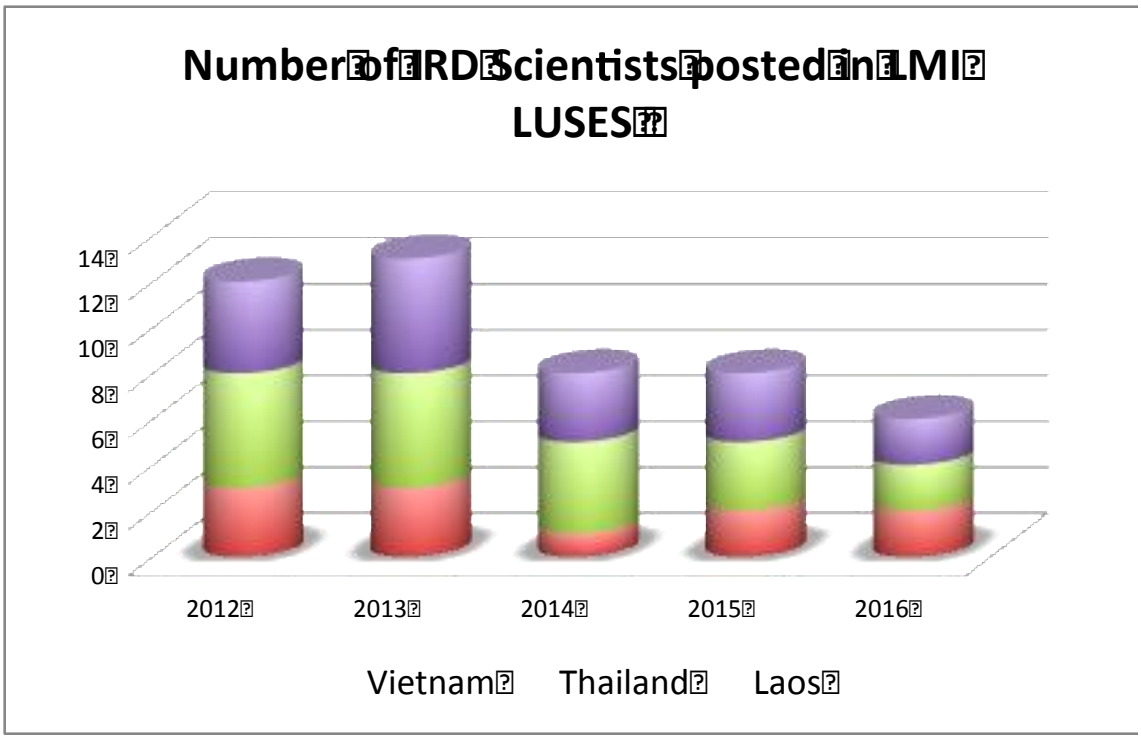
9.2 MAIN WEAKNESS OF LUSES

- **Valorisation:** if 26 papers in 4 years could be examined as correct, this number would not reflect the importance of the ecological data collected and original studies at field scale done during these years. As most of ecological project, most of the papers will be published after the end of the project.
- **Vietnam participation.**

Vietnam partners' involvement in the project does not reach the expected level resulted from

- Few Vietnamese students involving in LUSES student (no PhD)
- Lack of funded project led by Vietnam partners
- Few collective trainings taken place in Vietnam

This is one of the main weaknesses of this project. There are several reasons, which explain this statement, such as the decrease of IRD scientist posted in Vietnam during LUSES (see figure below and appendix 2.1) and the relative low number of Vietnam researchers involving in soil ecology (most were involving in hydrological or water science). However, this statement starts to evolve positively in the last year as 2 IRD scientists has been posted recently, and one of them now leads the OMM project with a SFRI partner. SFRI is also very involved in the SEALNET project.



- <u>Lack of SEA funded project at regional projects</u>

Most of the projects funded by LUSES (see table 5) was the national level despite the setting up of ASEAN in 2015. There are very few funding agencies which could fund regional project. However, there are some such as APN (Asia pacific network,) or BIO-ASIA. The added value of the LMI LUSES in the next years ***will submit project at a regional level, which will be funded at the national scale.*** This will give the specific value to the project as the similar project will be able to produce crossing and generic results and the important feature for the current problems such as global warming, sustainable agriculture etc.