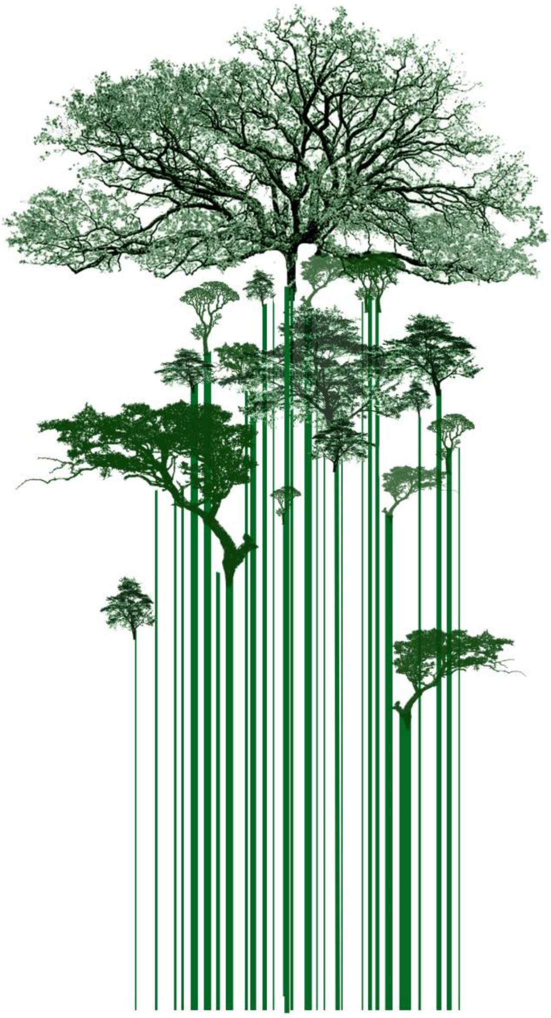

Annual Meeting 2015

Dynamic of Land Use changes and Soil Ecosystem Services (LMI-LUSES)

&

Young Teams associated to IRD (JEAI)

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Hosted by

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- *Dynamic of Land Use Changes and Soil Ecosystem Service (LMI - LUSES)*

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- *Faculty of Agricuture, Khon Kaen University and Khon Kaen University*
- *Knowledge Development for Rubber Tree in Northeast research group (KDRN-KKU)*
- *Research Group on Problem soils in the Northeast of Thailand, KKU*
- *Cultivation and Product Development Research Group of Wild Silkmoths and Economic Insects for Value Added Creation, KKU*
- *Agricultural Biotechnology Research Center for Sustainable Economy, KKU*

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Consequence of Swidden Transformation on Agriculture System of Smallholder Rubber Plantation in Luang Namtha Province, Lao PDR

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Luang Namtha province has rapidly transformed from subsistence livelihood based in swidden agriculture and gathering non-timber forest products. In the last decade, in order to increase the income of its population, replacing swidden agriculture by producing natural rubber was a priority of the Luang Namtha provincial government. Thus, the area occupied by rubber plantations increased, changing the natural environment and livelihoods of the populations. This study aims (i) To identify the typology of livelihood and agriculture system in Namtha watershed, (ii) To compare the social and economic performance of rubber-based agriculture system and swidden-based system and (iii) To examine factors that influence farming income for different agriculture system.

People in Phouphad village were agriculture based livelihood. Rice production was practiced for consumption. Income sources come from rubber, sacha peanut, rattan, cardamom and non-timber forest product.

Studied agriculture systems are:

Type of agriculture system	Number	%
Swidden and Rubber tree	6	5.08
Paddy and Rubber tree	78	66.10
Paddy and Swidden	4	3.39
Paddy, Swidden and Rubber tree	12	10.17
Rubber tree only	4	3.39
Swidden only	2	1.69
Paddy only	11	9.32
Other (sacha peanut or plukenetia volubilis L)	1	0.85
Total	**118**	**100**

The farmers manage their farm system in term of labor capacity, when rubber prices slow down, more than 3 agriculture activities were practiced on the farm. The farmers have adapted the technique to minimize labor consume especially tapping latex was practiced whenever their free from rice (year round, early morning, daytime or at night). Fertilizer was not used for any soil improvement.

In 2004-2010, rubber prices have increased continuously and begin to decline in 2011-2015. The trends of rubber plantation areas were also changed depending on prices.

The villagers have adapted the agriculture system on their farm, rubber tree cultivation were not only income activity.

Keywords: *Luang Namtha province, livelihood typology, agriculture system typology, swidden agriculture, conversion to rubber, socio-economic performance, farmer income.*

Long Term Impact of Rubber Plantation on Soil Biodiversity and Activity

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Rubber plantations represent a widespread and expanding planted forest system, supplying half of the world's latex demand. Studies on rubber plantations environmental impacts on soil functioning remain scarce, despite their economic and ecological importance. In south Thailand, rubber tree plantation has been planted since early 1950, and still now the long term impact on soil biodiversity and services related has not been studied. The aim of this study was to assess the long-term impact of such plantations on the soil ecosystem with a special emphasis on soil biodiversity and its effect on soil organic matter. To do so, the impact on soil biodiversity of three successive rubber tree rotations (first rubber crop following forest, 1st and 2nd rotations) representing 80 years of monoculture was assessed in Suratthani province, Thailand. Our results indicated that long term rubber monocropping has two main effects on soil (i) Over one independent cycle, rubber tree harvesting was found to trigger a decrease in the majority of the measured components (physic-chemical and biological ones) while evolution of the rubber plantation to a mature stage lead to a partial recovery of some factors. (ii) Despite this partial recovery, a general decrease occurs over the complete chronosequence of 80 years. We observe a decline of the microbial activities and macrofauna density which could be explained by the decrease of their main resources (litter supply and organic matter), while opportunist organisms such as nematodes, ants increased and benefit from the ecosystem disturbance.

Keywords: *Hevea brasiliensis, monocropping, sustainability, soil fertility, macrofauna, organic matter*

Implementation of a quality system in the Soil Biotechnology laboratories Preparation for certification ISO 17025: 2008 scheduled for 2016

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Laboratories quality aims to produce accurate, reliable and reproducible analysis' results. The laboratory's results have to be as accurate as possible. All aspects of laboratory's activities have to be reliable and require correct results in order to be published. In a quality management system, all aspects of laboratories activity, including structure management, methods, and procedures have to be analyzed to ensure the quality.

The Soil Biotechnology department of the LDD is involved in a quality process ISO 17025/2008: to guarantee, analyses traceability and results reliability for the control of its products (super LDD 1 to 12) and to comply with safety rules in the laboratory. The improvement of the quality is a common concern of the different LDD laboratories (Soil Biotechnology, Soil chemistry…).

The approach to undertake is as following: (i) to ensure with a collective approach, the management, the information and the animation required to continuously improve the management system efficiency. (ii) To monitor analytical rooms and equipments and to insure they are conformed with quality regulation in place in the laboratory of molecular biology. (iii) To ensure that the rules regarding good professional practices and guarantying quality results are applied.(iiii) To ensure that quality practices are communicated within the laboratory, understood and adhered to by all laboratory user.

To achieve this objective a training was organized for all the Soil Biotechnology staff, to explain the principles of a quality system in a laboratory, to identify the problems (uncalibrated of the equipments contamination of the analyses…) and to distribute work. The first task was to create the quality documents. The management quality system is organized around 4 documents categories: a quality manual which describes the whole quality management system, the standard operating procedures (SOPs) associated to the quality manual, the operating modes which describe Laboratory's equipments use and maintenance and the record documents related to quality manual and SOPs. After that a second training should be organized in December to explain the new procedure and implement the news document in the laboratories.

Keywords: *quality, biotechnology, traceability, laboratory*

Abstract of JEAI

Do tree plantations improve soil health? The case of Rubber tree plantations in Thailand

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The concept of ecosystem services has been developed in the 90's to define the benefits people obtain from ecosystems, i.e. various contributions of ecosystems to human well-being. Soil organisms supply soil health, which is an integrative soil property, reflecting the capacity of soil to support continuously agricultural production and further ecosystem services. Soil biota plays a major role for soil health as it controls organic matter turnover rates, nutrient cycling and soil structural stability. Soil organisms are able to adapt to environmental changes, such as agricultural practices or climate change, at a higher rate than the abiotic soil components. We hypothesize, that soil health is a direct expression of soil organism's assemblage, which in turn depends on the physical and chemical conditions of soil as a habitat. Soil health status was investigated in Rubber plantations in Thailand, as a model of a perennial cash crop because (i) tree plantations are often denigrated for their negative impact on biodiversity (ii) the impact of climate change on soil biodiversity could be addressed, thanks to the rapid extension of those plantations in all Thai regions during the last decade. The general objective of this study was to determine the respective impacts of plantations age and land use changes, taken as main drivers of soil alteration, on key soil functions assumed by soil biota. To address this question, we investigated 2 sites in Thailand, positioned along a rainfall gradient ranging from 2000 mm to 1300 mm near the cities of Surat Thani in the South and Chachoengsao in the Centre. Along chronosequences from young to mature plantations, we measured the occurrence of three major groups of soil organisms: macrofauna, nematofauna and microorganisms. We chose these groups according to their respective importance for key soil functions: litter decomposition, C and N transformations, nutrient cycling and soil structural stability. Our results showed (i) soil biodiversity was mainly controlled by the age of the plantations, the changes from annual crop to perennial tree plantation was only a secondary driver (ii) compare to cassava, rubber plantations have a more positive impact on soil health (soil biodiversity, SOM quality, biological activities, C storage) (iii) old mature rubber plantation (> 25 years) harbor a highly specific and less diverse biodiversity than 15 years plantations which question its sustainability. Moreover, after 80 years of rubber monocropping in the south, we observed a general decrease of most of the biological and soil physic-parameters measured. After 80 years of rubber cultivation, the capacity to restore their biodiversity, OM and nutrients contents seem deeply altered. Our results suggested that if rubber plantation could be a suitable solution to restore some altered soil (case of soil under cassava cropping) in the short term, continuous cultivation seems to alter soil health and fertility.

Keywords: *Soil biodiversity, soil macrofauna, nematofauna, soil microorganisms, agricultural practices, ecosystem services*

Impact of Agricultural Practices on Soil Diversity and Activities in NE Thailand

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The impact of agricultural practices and age of rubber plantation on soil functional biodiversity was investigated in rubber plantations in Khon Kaen province. The main objective of this work is to evaluate the impact of agricultural practices on soil biodiversity and activity of 3 major groups of soil biota involved in soil functioning (macrofauna, nematofauna and microbiota). We hypothesized that in an unfavorable pedo-climatical context for Rubber Plantation, practices, which preserve soil biodiversity and activities, are a key to maintain soil functions and thus soil sustainability. To do so, we select 12 rubbers plantations with two levels of intensity of practices, high and low, and two levels of rubber plantations age, immature and mature (based on tapping or not). High (H) intensity of practices modality was characterized by intercropping during the immature stage, number of weeding per year, chemical fertilization per year and intensity of tillage. Macrofauna abundance and diversity was assayed using the Tropical Soil Biology and Fertility conventional method, nematodes diversity was characterized at the family level and classified into functional groups to calculate functional index (Bongers et al., 1990). Catabolic fingerprint of microbial and fungal communities was assayed by MicroRespTM (Campbell et al., 2003). Macrofauna taxonomic density, diversity and structure did not show significant variations between level of intensity or age of the plantations. On the contrary, macrofauna activity (earthworm casts, skeletonized litter) was clearly limited by high level of soil management of the plantations. Plantations age represented a strong driver of nematode structure, as it was more impacted by the agricultural practices in immature stage of rubber cultivation. The structure of nematodes' population changed according to both age and intensity of practices. Compare to macrofauna, nematodes' population showed a higher level of resistance than macrofauna one. Highest bacterial biomass and a broadest microbial catabolic specter was found in mature low managed plantations. A strong relation was found between bacterivorous nematodes and soil microbial community structure and functional ratio. Our results suggest that intensive agricultural practices had generally negative effect on soil biota, homogenizing microbial catabolic structure, nematodes functional structure and restricting functional diversity for all groups of organisms.

Keywords: *agricultural practices, age of plantation, soil biodiversity, macrofauna, nematofauna, microbiota*

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Distribution and Role of Earthworms on Soil Properties under Rubber (*Hevea brasiliensis*) Plantations in Northeast of Thailand

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Rubber plantation has been successfully introduced as economic crop in Northeast of Thailand. Population dynamics, diversity and distribution of earthworms in soil ecosystems have received attention in recent years because earthworms play an important role in maintaining soil fertility, ecosystem function and production (Edward CA et al, 1995)[1].Thus earthworms can be used as a tool in monitoring the effects of the rubber plantation practices on soil ecosystem. The aims of this study were to study the influence of different practices in rubber plantations on the earthworm distribution in Northeast of Thailand. The distribution and characteristics of earthworm cast, *Pheretima* sp. between organic and conventional rubber plantation for 10 years were assessed in rainy season (August-September 2012) in Kanuan District, Khon Kaen, Thailand. Earthworm populations varied and significantly difference among systems ($p<0.05$). The average numbers of earthworm cast were found 10.33±4.24 casts per square meter in organic rubber plantation but no earthworm cast found in conventional rubber tree plantation. The earthworm cast's height and the earthworm cast's width were 5.58± 2.80 and 4.26±0.99 centimeters, respectively. For the biological, physical and chemical soil properties analysis in the studied soil samples and earthworm cast, the results showed that the biological soil property as soil respirations in soil samples in soil and cast were 3.575 mgCO2/day and 15.492 mgCO_2/day, respectively. The results also showed that some chemical and physical properties (such as total N, bulk density) in soil samples from organic rubber tree plantation were better than soils from the conventional rubber tree plantation significantly different ($p<0.05$).

Keywords: *earthworm, rubber plantation, soil quality, organic farming, ecological service*

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The impact of different farmer practices on soil quality by using nematodes as bio-indicator in rubber plantations?

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Free living nematodes are very important and play a main role in soil function such as nutrient cycling, carbon transformation, biological regulation and modification of soil structure [3] (Villenave C et al, 2001). Serving as one of the best soil-indicator, nematodes can be classified into functional guilds which directly respond to soil environmental perturbations such as agricultural practices[1] (Bongers T et al, 1999). Therefore, the objective of this study was to assess the impact of different farmer practices on soil environmental conditions in rubber plantation by using nematode as soil indicator. The experiment was divided into two different farmer practices (high intensity and low intensity) with immature (5-7 years old) and mature stage (8-10 years old) in Khon Kaen province, northeast Thailand. The results revealed that nematode density and diversity were significantly different among all treatments. The abundance of Bacterial and fungal feeders refer to high level of soil perturbation and stability respectively [2] (Neher D.A, 2001), which is consistent with our results. Large numbers of bacterial feeders were found in immature than mature while high density of fungal feeders were found in low intensity. In addition, the mature plantation with low agricultural practice showed greater value of Maturity Index (MI) and Structure Index (SI) which imply the condition of less disturbed and stable environments. According to our results, we can now consider nematodes as one of a good tool to assess soil quality.

Keywords: *Nematodes, soil function, bio-indicator, agricultural practice intensity*

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Carbon stock assessment under different ages of rubber tree plantations

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Para rubber is an important economic crop which has created economic value of Thailand. Soils act as important components of the global carbon cycle as they store large amounts of organic carbon. In addition, soil organic carbon and soil organic matter are crucial for soil quality and productivity. However, they are probably sensitive to plant age, ecosystem management and climate change. The objective of this study was to investigate the effect of different rubber tree plantation ages on carbon stock, including 1) 3 years rubber tree plantation (3Y), 2) 11 years rubber tree plantation (11Y), 3) 17 years rubber tree plantation (17Y) and 4) 27 years rubber tree plantation (27Y) on carbon stock. The result suggested that different age of para rubber tree plantation has an effect on carbon stock. The highest soil carbon stock was found in 17Y (9.98 $ton.ha^{-1}$), but showed no significant difference when compared to 27Y. The greatest above ground biomass was observed in 27Y (130.33 $ton.ha^{-1}$). Interestingly, younger age of para rubber showed that soil carbon stock was sequestered in the form of microbial biomass carbon, due to lowest qCO_2 determined.

Keywords: *Carbon stock, plantation age*

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Abilities of Phosphate solubilizing Bacteria isolated from different ages of Rubber tree plantations in Northeast Thailand to solubilize insoluble Phosphates and to produce IAA under in vitro conditions

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Nowadays rubber is cultivated worldwide, the production is heavily concentrated into Asia, where over 90 % of the world's natural rubber is being produced. Moreover, rubber plantations are now expanding in Asia thereby contributing to a major land use change. In Northeast Thailand rubber replaces other cash crops like cassava or sugar cane, in Laos the new plantations are often implemented to the detriment of natural spaces. Rapid expansion of rubber causes large-scale loss of forest resources, watershed destruction, soil quality changes, the capacity of soil to function within ecosystem boundaries to sustain biological productivity and maintain environmental quality. To address impact of land use change on Ecosystem Services in rubber plantations the absence of knowledge on the influence of agricultural practices over biological processes within the soil. The present study described results on PSB isolated from different ages of rubber tree plantations in Northeast Thailand where soils are mainly sandy and P deficiency. PSB isolates were tested by using different P sources [Tri-calcium Phosphate ($Ca_3(PO_4)_2$) and Ferric Phosphate ($FePO_4$)] on specific culture media (National Botanical Research Institute Phosphate Growth Medium, NBRIP) under controlled conditions. Our results showed that PSB isolated from different ages of rubber tree (5, 11 and 22 years) significantly ($P \leq 0.01$) solubilized a higher amount of $FePO_4$ and $Ca_3(PO_4)_2$ respectively. The highest activity of solubilization was achieved for $FePO_4$ which is the main form of insoluble phosphates in acidic sandy soils. IAA production was also observed in different ages and locations of rubber plantation. These results highlight variability of specific PSB isolates from different rhizospheres and provide essential information for the management of soil fertility.

Keywords: *Auxin, Bacteria, Phosphate Solubilization, Rubber*

Seeking Security through Rubber Intercropping

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A major constraint of smallholder farmer to plant their rubber is the sources of income for their subsistence during 6-7 years from planting until the rubber enter production. Again, it was due to price fluctuations year to year after enter production. Intercropping of rubber with cash crops will provide alternative sources of income and protect farmers from price instability. This qualitative research using household rubber growers interviews, crop and soil measurement was carried out to investigate growth of rubber and cash crops, as well as farmer's income from cash crops at Nongnangvong village, Khon Kaen province where farmers practiced intercropping of young rubber with banana and cassava, and at Poopankham village, Nongbualampoo province, as well as Nongsaengsoi village, Udorn-Thani province where farmers practiced intercropping of mature rubber with coffee. The results indicated that intercropping of young rubber with banana and cassava successively at the same area for 4 years gave similar growth rates (girth increments) of rubber as compared with none of these crops. Young rubber trees intercropped with banana combination with caeruleum (*Calopogonium caeruleum*) cover legume tend to give maximum girth increments. Soil moisture content was observed higher in plot with intercropped banana than those of plot without intercropped plants. Mature rubber trees (7-9 years old) intercropped with coffee have no retarding effect on the main crop. In some case, intercropping of rubber with coffee tends to improve growth of rubber trees as compared to mono rubber plantation. Coffee performed better growth under shading by rubber than those of under normal light. The shading reduced amount of light transmission into the intercropped plants was 4, 15 and 18 times of normal light (measured by light meter), depending on rubber canopy covered the land. SPAD chlorophyll meter reading (SCMR) were recorded on each leaflet of coffee presented at three levels; upper, middle and lower of canopy. SCMR exhibited greater values under shading than those of normal light. In this study, yield and farmer's income from intercropped plants will be also discussed.

Keywords: *Rubber, Intercropping, banana, cassava, coffee*

Description of Agroforestry System

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This study aimed to determine the definition of Agroforestry System (AS) and the functions of AS that could be modified to strengthen agrarian communities. The methodology of this study consisted of literature review, field survey and data analysis by content analysis technique. The results indicated that the definition of agroforestry system could be shown in easy formula: Agriculture + Forestry = Agroforestry or building forests through agriculture. By cultivating crops in a condition similar to nature, it is possible to bring diversity back to fields and achieve sustainable production of crops that were previously mono cultural. There were three functions of AS: 1) economic functions, composed of the four sub-functions of various, even and resilient incomes, production efficiency, expenditure reduction and economic immunity; 2) environmental functions, composed of the eight sub-functions of land conservation, sedimentary reduction, flood relief, droughty relief, storm resistant, air purification, carbon sequestration and biodiversity; 3) social security functions, composed of the five sub-functions of product charity, good health, knowledge sources, traditional descent and social grouping. The functions of AS might help strengthen the agrarian communities in many aspects of capacity building, self-esteem, quality of life, traditional descent, social and ecological harmony, and sufficient economy. However levels of the strength of the communities depended on some accelerators. In the future, AS extension can be one of the measures to support the routine socio-economic and environmental programs of central and local governments in many agrarian communities.

Keywords*: Agroforestry, sustainable production, economic, environment, social security, agrarian communities*

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Characterization of rubber agroforestry systems in mature rubber plantations in Phatthalung province

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Rubber based agroforestry systems could be characterized by the type of associated trees and crops to rubber trees. Several typologies of rubber based agroforestry systems have been proposed[1-4]. The present study objective is to identify the types of rubber agroforestry system existing in Phatthalung province and to describe these systems. We focused on mature rubber plantations. First, we used the "focus group" methodology with rubber smallholders that implement rubber agroforestry systems with 5 groups and 56 households in Sribanpon, Srinakarin, Tamod and Pabon districts. This led to the main agroforestry systems identification. Then, 31 farmers were surveyed with a complete interview and for some farmers, we also conducted field survey. In Phatthalung province, both simple and complex agroforestry systems were found. The simple rubber agroforestry system has one to three kinds of crops and systematic spacing pattern while the complex system has more than two species and non-systematic spacing pattern. The associated plants in rubber plots were mostly fruit trees (21 species), timber trees (15 species) and perennial vegetables (6 species). The systematic spacing pattern is based on associated plants regularly planted in between rubber rows with low level of species diversification. The non-systematic spacing pattern is based on a fully randomized associated plants with rubber. Various types of association were founded with temporal differences. Associated plants and trees are combined to both fulfil income improvement and food self-consumption.

Keyword*: Intercropping, associate plants, timber trees, fruit trees, vegetables*

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Nutrient cycling in tropical planted forests: example of eucalypt plantations

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The ecological impact of eucalypt plantations has been widely discussed around the world. The sustainability of fast-growing tropical Eucalyptus plantations is of concern in a context of rising fertilizer costs, since large amounts of nutrients are removed with biomass every 6–7 years from highly weathered soils. A better understanding of the dynamics of tree requirements is required to match fertilization regimes to the availability of each nutrient in the soil. The nutrition of *Eucalyptus* plantations has been intensively investigated from empirical field trials and many studies have been carried out to quantify specific fluxes in the biogeochemical cycles of nutrients (in particular litterfall). However, studies dealing with complete cycles are scarce. The objectives of this talk are: 1) to give an overview of nutrient cycling in commercial eucalypt plantations, and 2) to show the main consequences of improving our understanding of the biogeochemical cycles for the management of tree plantations on deep soils.

The main features of nutrient cycling were similar for *Eucalyptus* plantations in Congo and Brazil, despite contrasting productivies, management practices, climates, and soil properties. Most nutrient fluxes were driven by crown establishment the two first years after planting and total biomass production thereafter. These plantations were characterized by huge nutrient requirements: 155, 10, 52, 55 and 23 kg ha^{-1} of N, P, K, Ca and Mg the first year after planting at the Brazilian study site, respectively. High growth rates the first months after planting were essential to take advantage of the large amounts of nutrients released into the soil solutions by organic matter mineralization after harvesting. The biological and biochemical cycles play a predominant role over the geochemical cycle of nutrients in tropical *Eucalyptus* plantations, which highlights and the prime importance of carefully managing organic matter in these soils. Nutrient losses through deep drainage after clear-cutting are very low, even in sandy soils. *Eucalyptus* trees are remarkably efficient in keeping limited nutrient pools within the ecosystem, even after major disturbances. Nutrient input–output budgets suggest that *Eucalyptus* plantations take advantage of soil fertility inherited from previous land uses and that long-term sustainability will require an increase in the inputs of certain nutrients.

The recent improvement of our understanding of nutrient cycling changed fertilization regimes over million hectares of *Eucalyptus* plantations in Brazil. Fertilizers are now applied only once (or 2 times) over the entire rotation of 6 years. The consequences of harvest residue management on the availability of nutrients for next stand also changed harvest methods and soil preparation. The "minimum cultivation" practice is now widely used in tropical planted forests (Gonçalves et al., 2013).

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Fertilization of rubber plantation a new approach

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Unlike in most other crops, the product harvested from rubber trees is not directly linked to biomass production. Natural rubber (NR) obtained from the latex of the trees is a secondary metabolite made mainly of a specific polymer, the cis-polyisoprene. As latex does not naturally exudes from the trees, only tapped trees have to regenerate latex, through a tapping-induced metabolism. Moreover, the amount of exported dry matter is rather low as compared to the tree biomass (4-5 kg/tree/year) and it contains very low amounts of mineral nutrients.

This may explain why few published experimental data show clear positive effects of fertilization on rubber yield. Most the productivity gains in recent cropping systems have been obtained through improvements of the tapping methodologies, rather than through management of fertilization. However, in Thailand the fertilization recommendations from R&D institutions are high and farmers actually use high level of NPK fertilizers in tapped plantations. Socio-economic survey showed that farmers believe such practices are beneficial. Such contradictions may arise from non-direct effects of NPK fertilization on the latex yield through the improvement of the whole tree nutrient status, resulting in long-term benefits.

Another possible explanation is that the potential gain from fertilization may be actually reached only through an intensification of tapping practices. As the later determines the demand for latex regeneration, it is not surprising that no effect of fertilization is demonstrated if we keep the same tapping systems in fertilized and unfertilized plots.

We therefore set up a detailed experiment to re-assess the possible effects of fertilizers on latex yield, and the overall functioning of the trees. The objectives of the study were to test the impact of different levels of NPK application on rubber yield; to assess their effect on the physiological status of the trees, particularly latex physiology, to assess the interactions between fertilization and stimulation of latex yield by ethylene application and to assess the impact on net primary production and the long term effects on rubber yield. In addition, effects of fertilization on rubber properties were also tested.

The preliminary results showed that yield was high in the first year of tapping with an average yield of 5.4 kg/t/year. Latex yield was significantly higher ($p<0.05$) with stimulation and also with fertilization (+11% as compared to control). Latex diagnosis parameters were significantly affected by stimulation ($p>0.05$), but not by fertilization despite a trend showing an increase of all parameters with application of fertilizers. As expected, the overall growth of untapped trees was much higher than that of tapped trees, but surprisingly, the later grew faster during the wintering period. These preliminary results are promising to establish links between fertilization, tree functions and rubber yield.

Keywords: *Fertilization, rubber yield, tree functioning, stimulation*

Alternative tapping system to cope the labor shortage in rubber field

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The two major issues for rubber production were identified as kilogram per hectare and tapper productivity. This matter of concern is addressing to land productivity and labor productivity. Skill farmers will be involved to face the challenges as sustainable practices to consider high yielding clones, well-tailored tapping systems to clones and the use of diverse technics of ethylene stimulation. The main issue is to focus on the reduction of the cost of production for the farmers and providing them a better income from their rubber fields.

Latex harvesting is a dynamic process. It can now be modeled, allowing the prediction of the response to the new tapping systems, considering tapping frequency (d2, d3, d4, d5 and d6) and tapping panel position, tapping direction (downward tapping, upward tapping, tapping cut length S/2, S/4). Alternative systems will help planters optimize latex production according to their land productivity and labor productivity addresses.

Keywords: *rubber production, cost of production, farmer income, model, alternative tapping systems*

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Growth and Hydraulic (GRHYD) project
Ecophysiological traits for genetic improvement of rubber tree performance under water constraints (2014-2017)

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Scenarii of climatic change predict increase of extreme events as waterlogging in rainy season and droughts (soil and atmospheric) in dry season in ASE[1] (Masaki et al. 2011). Such events threaten the sustainability of the rubber tree cultivation, and particularly in Thailand, the current first world latex producer, where the same genetic material and the same agricultural and exploitation practices are applied whatever the large variability of pedoclimatic conditions.

The overall objective of the project is to evaluate interest and drawbacks of several ecophysiological traits related to water and carbon economies for the improvement of genetic material performance on immature growth under water constraints. 20 clones, including the reference one (RRIM 600), are compared within a field trial at the NongKhai Rubber Research Center in upper NR Thailand. This cooperative project has three steps. The first is to evaluate the existing clonal variability on immature growth and on ecophysiological traits related to water status, hydraulic, water use, carbon gain and water use efficiency at leaf and whole-tree scales. The second step is to analyze statistical relationships between ecophysiological traits and growth. The third was to test the hypothesis that water use behavior (as indicated by traits) significantly determines difference in clonal growth under water constraints.

The analysis of pedoclimatic conditions confirmed the likely occurrence of the different types of water constraints within a year in NRRC: soil waterlogging, soil drying and high evaporative demand. The results of the first year of study (2014), 2 years after planting, showed a significant clonal variability on radial growth, leaf water status and leaf $\delta^{13}C$ (an assumed proxy of the leaf water use efficiency).

A subsample of 5 contrasted clones were selected to be thoroughly studied in order to better analyze relationship between traits, leaf and tree scales and responses to seasonal water constraints. In May 2015, trees and plots within 4 blocks were equipped with sapflowmeters, microdendrometers, access tubes for soil water measurement, scaffoldings for leaf gas exchange measurement. This presentation shows how the intensive study was set up and the first results.

Keywords: *Climate change, rubber ecophysiology, breeding, tree performances, water constraints, rubber clones*

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Carbon stocks and dynamics in rubber dominated watershed in Xishuangbanna, China

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The rapid expansion of rubber in the Greater Mekong Subregion (China, Cambodia, Laos, Myanmar, Thailand, and Vietnam) has been accompanied with the conversion of over 2 million ha of other land use types to rubber since 2000[1] (Li Z et al, 2012). These trends in land use change in the region has greatly altered ecosystem based carbon (C) stocks with potential impacts on climate change mitigation and future C trading opportunities. Therefore, reliable estimations of carbon sequestration and emission at landscape level after land cover transition from forest, swidden agriculture and other land use types are needed.

We completed a multidisciplinary study in Naban River Watershed National Nature Reserve (NRWNNR) in Xishuangbanna, China aiming the estimation of carbon stocks and ecosystem carbon fluxes such as gaseous C emissions and C losses with water erosion at landscape level. Rapid Carbon Stock Appraisal approach was applied to evaluate time-averaged carbon stock of dominate land use types including forest, rubber plantation, bush and grassland, and agricultural crops. Soil losses with runoff were estimated with Gerlach troughs for rubber plantation of different age at plot level and corresponding measurements of C export with water by continuous monitoring for watershed level. CO_2 emissons and CH_4 exchange at soil surface were estimated during two seasons. Gathered experimental data were used both for upscaling the relevant processes to landscape level and for validation of LUCIA – Land Use Change Impact Assessment modeling tool. Model simulations were completed for testing the alternative land management scenarios and sensitivity of ecosystem C balance to climatic factors.

We found that i) C stock in aboveground rubber biomass strongly depends on plantation age and location, e.g. altitude a s.l., and this trend was successfully predicted using model validated by own data; ii) C sequestration or emission during land conversion to rubber depended on original land cover type: forest to rubber conversion always led to C losses; iii) rubber plantations were more erosion prone as compare to forest, but the improved weed management with less herbicide application could help in soil C loss mitigation; iv) rubber planting changed both CO_2 and CH_4 fluxes from soil due to modification of soil properties, contributing thus in total C balance.

Integrated approach supported by modeling helped us to get a balanced view on ESS and specifically C balance change caused by land conversion to rubber.

Keywords: *carbon stock, ecosystem carbon flux, water erosion, LUCIA modeling tool, land conversion*

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Fine root production and turnover in a mature rubber tree link to soil depth and implication for soil carbon stocks in North East Thailand

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Most studies on root dynamics are based on shallow soil layers, but most trees develop deep roots which play a significant role in water uptake[1] (Lobet G et al, 2013) and can contribute to carbon storage[2](Maeght et al, 2013). However, it remains a major challenge to observe and analyze roots in a non destructive way, within the soil matrix[3](Stone EL, 1999). We present the results experiment conducted in plantation of rubber tree (*Hevea brasiliensis* Mull. Arg.) in north east Thailand. This work documents the functional role of rubber tree fine roots and inform about the carbon stock provided by the root system as environmental services.

Fine root growth of 18-year old rubber trees was monitored at monthly intervals over 3 years. Observations were made using root windows installed at 50 cm depth increments, to a depth of 4.5 m [2]. Environmental conditions and physiological status were monitored along this period. Destructive samples were used to quantify fine root-related carbon stocks.

Rubber trees have demonstrated drought adaptation capacities on long term or short term periods with impact on shoot and root phenology. Root dynamics is linked to transient changes in water availability. It also showed that, at specific increments, root dynamics was likely driven by internal tree carbon allocation.

This work shows that deep fine roots are organs of foremost functional importance and we demonstrate their instrumental role during critical dry periods. The presence of significant amounts of deep roots in the soil profile further indicates that they should be taken into account when quantifying long-term carbon storage.

Keywords*: Fine root system, environmental services, root growth monitoring, carbon stock, tree carbon allocation*

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