Constraints, mitigations, and opportunities for sustainable development of rice-based system in Laos

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Abstract— *Rice production in Xieng Ngeun District (XND), Lao People's Democratic Republic (PDR) faces several challenges that have resulted in a decline in rice production and a, therefore, food insecurity in the country. Smallholder farmers in XND, Luang Prabang in the Northern part of Lao are the most affected resulting in poor households and economies. Therefore, this study aims first to identify the key constraints affecting rice production systems; secondly to review the opportunities that exist in the rice production systems and lastly, to discuss opportunities that exist if the constraints are mitigated that can boost sustainable development of rice-based systems (SDRBS). A structured questionnaire was administered to village headmen, community members, and farmers in the nine selected villages with a total sample size of 374 farmers. Farmers' strength for rice is that they have agricultural land, on average 3 hectares per family. Apart from rice production, the majority of farmers have diversified into maize, Job's tears, vegetable cultivation and livestock keeping. The key strength of the respondent was the availability of land as most of them had more than 3ha of agricultural land. The diversification into the production of other crops is an important constraint to rice production. Labour was also an important constraint to rice production as most families have more than six children; thus, one member has to stay behind to take care of the children. The opportunities to improve rice production is mainly in the adoption of modern farming approaches using improved rice varieties, fertilizer application, use of herbicides for weed control and pesticides for insects and disease control. The farmers do not use pesticides to control insect pest and disease, and thus perennially faced challenges in rice production due to pest and diseases outbreaks. Moreover, there was a low rice productivity since majority of the the farmers did not use fertilizers in their fields, with a paltry 0.8% of the farmers recording positive response to fertilizer use. Despite this, most of the farmers (78.3%) indicated that they do not use herbicides for weed control. Market accessibility was a major concern to the farmers due to poor road infrastructure, hence resulting in delayed farm operations and produce spoilage. The farmers should be encouraged to adopt modern farming practices such use of pesticides to insect and disease management, weed control using herbicides for weed control, and fertilizer applications for improved soil fertility and yield. Moreover, there exist additional opportunities to improve rice productivity through adoption of improved rice cultivars, farm mechanizations, provision of extension services and improved market accessibility.*

Keywords— Rice production, Constraints, opportunities, Social-Economic, Luang Prabang, Laos.

I. INTRODUCTION

Rice is one of the most important food crops in the world after wheat [1] and a staple food for an estimated 3.5 billion people worldwide, especially in many developing countries [2]. Rice is currently grown in over a hundred countries that produce more than 715 million tons of paddy rice annually equivalent to 480 million tons of milled rice [3]. About four-fifths of global milled rice is produced by small-scale farmers in developing countries with almost a billion households in these regions depending on rice systems for their primary source of employment and livelihood [2].

The Per capita daily rice consumption in most Asian countries is the higher compared to other continents. Bangladesh, Cambodia, Indonesia, Myanmar, the Lao People's Democratic Republic (Lao PDR), Vietnam, Thailand, and the Philippines boasts of highest per capita daily rice consumption with reported intakes of over 300g per capita annually [3]. Rice is the staple food in Laos being grown on more than 49% of the cultivated land with annual production of about 3.27 Million tons of paddy mainly for subsistence consumption [4]. With a per capita consumption of milled rice per annum of 171 kilograms that constitute almost 70% of calorie and protein intake [4](Maclean *et al.*, 2002), rice production plays an integral part socio-economic lives of Lao's smallholders.

The three major rice production systems in Lao are paddy rice (season rice), irrigated rice and upland rice. More than 84% of production happens in the wet season under rainfed conditions [5]. While irrigated rice is cultivated along the Mekong River in the dry season. The lowland rainfed rice accounts for more than 70% of rice cultivated and produced in Laos with less than of 13% of total rice production occurring under irrigation conditions. Upland rice, on the other hand, is produced on steep slopes at higher altitudes above sea level up to as high as 1500 m [6], and is characterized by shifting cultivation and low productivity. No current data on extend to which upland rice is produced in Laos PDR is available, but Chazee (1994), estimated that about 2.1 million ha was used for rice production on a rotational basis under the 'slash-and-burn' cultivation system. More recently [7], estimated that area under upland rice cultivation had reduced to about 1.2 hectares in 2012 with a production of about 2.2 million tons.

The northern parts of Laos PDR is characterized by a large number of smallholder and resource-poor farmers that produce upland rice in sloping, unbounded fields under slash-and-burn systems without fertilizer under rainfed conditions for subsistence consumption[8][9]. This traditional upland rice cropping system accounts for more than 50% of the total rice produced in this region. With annual consumption of about 220 kg /person, the produced rice is sufficient for only 6-7 months. Despite effort and achievements of the Laos PDR government to ensure self-sufficiency of rice at the national level, various studies have reported that about 30% of the population has insufficient food for more than six months of the year [10][6].

1.1 Statement of the Problem

Annual rice production is unstable since most production is under rain-fed conditions accounting for over 10% of the annual variability in rice production. According to IRRI 1999, 87% of the rice produced in Laos in 1998, was rainfed and only 13% was produced under irrigation. There is need to sustainably reduce the area of rainfed upland rice and increase that of irrigated rice. There is still a significant yield gap in irrigated rice production that can be bridged without further investment in land and water development and increase rice production substantially

Almost all rice in Laos is transplanted by hand and harvested by no mechanized methods which hamper rapid and massive increase in yield. This system is labour intensive and hence increases the cost of farm inputs. More so hand transplantation is slow, and the cultivated rice most often is not uniform when the area under cultivation is large causing staggered harvest. Technological, productivity and climatic constraints such, unavailability or high cost of labor, unavailability of quality seed in time, unavailability of sufficient farmyard manure limit production of rice. Economic factors like price fluctuation and existing gap between rice grain and parboiled rice adversely affect rice production. The scarcity of land and water resources, environmental degradation, and loss of biodiversity had significantly limited the expansion of rice production in both developed and developing countries.

As the population and income of people are rising, the demand for food is increasing and meeting the food requirements of the growing population for global food security poses a considerable challenge. Growing prosperity is accompanied by human diets that will claim more natural resources per capita. This reality, combined with growing populations, may raise the global demand for food crops two- to four-folds within two generations. Deccline in land and water resources, environmental degradation, and loss of biodiversity limits development of sustainable food production in both developed and developing countries.

Biotic and abiotic constraints at farm level most significantly droughts and floods, poor soil fertility, pests and diseases and off-farm constraints such as high production costs, fluctuating market prices, and uncertain trade policy limit farmers' production beyond household self-sufficiency [5]. More so, increased intensity of cropping rice leading to low nitrogen and phosphorus in the soil coupled with inherent low water retention capacity of soils in this region against a background of irregular rainfall only serve to exacerbate the problem [9]. To ensure enough supply for the year, additional rice has to be procured from neighboring provinces. However poor road network coupled with the fact that poor smallholder farmers lack funds to frequently buy rice make this avenue unfeasible.

Sudden changes in rice policies in Laos are frequent and cause significant losses to both millers and farmers. For instance, Lao government policy in 2010 to liberalize the rice industry and allow farmers to export rice outside the country resulted in unexpected rapid exhaustion of rice stock forcing the government to import rice at very high prices [11]. Shifting cultivation has been associated with a decline in land and water resources, environmental degradation, and loss of biodiversity that

consequently limits the development of sustainable food production in both developed and developing countries. Constraints such as a dietary preference for rice and the inability to introduce tillage technology on sloping lands in Luang Prabang, however, make it hard to modify livelihood strategies and land-use [12].

Currently, no sustainable rice production systems that are easy to adopt which will help smallholder farmers exist in Xieng Nguen District (XND) and hence farmers are unable to produce enough rice for consumption and commercial purposes. The need to develop modern rice farming systems for resource-poor farmers of Xieng Nguen District is therefore apparent.

This study aims to identify critical constraints affecting rice production systems and review opportunities that exist in the rice production systems in XND, Lao PDR. The study also aims at designing complementary initiatives such as micro-insurance geared towards providing security to farmers in the face of unforeseen weather events. The findings of this study will help in establishing new systems that are sustainable, environmentally friendly, flexible and resilient to climate change.

II. MATERIAL AND METHOD

2.1 Study site location and description

The study was conducted in the uplands of northern Laos in Xieng Ngeun District (XND); about 25 kilometers to the south of the capital of Luang Prabang Province, on the Nam Khan River and Route 13, the main road to Vientiane (Figure 1). The study site was selected for this research based on the recommendation of the District Agriculture and Forestry Office (DAFO), and because it captured the fundamental research question that underpins this study.

Xieng Ngeun District has 49 villages, 6,600 households, and a population of 33,395 people. The villages included in the survey sample (Table 1) indicate the broad distribution of villages and the location of survey villages in this study. The key informants in this study were headmen, community members, and farmers from the nine (9) selected villages. Questionnaires were administered and the interviews conducted with the current farmers in the study area. A questionnaire, open-ended questions, was floated and same questions asked to individual respondents during the interviews.

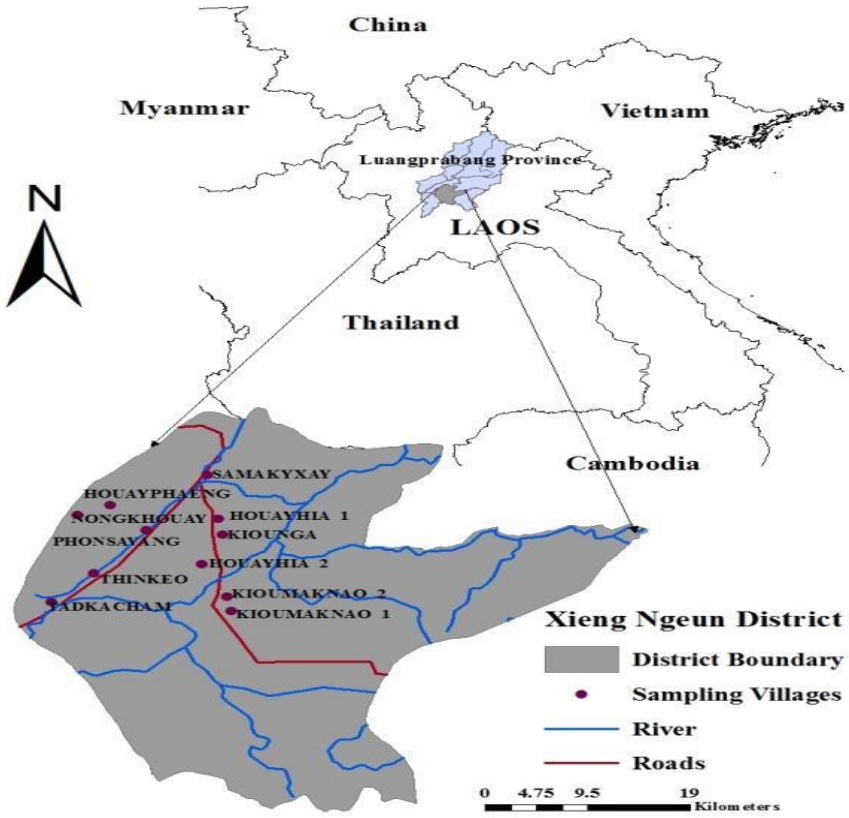

FIGURE 1: location of the study site and the villages sampled for the study. Source: Drawn by researcher, 2017

TABLE 1
LIST OF THE VILLAGES SAMPLED FOR SURVEY IN XND, LPB, IN LAO PDR IN 2017

Village Name	No. of households	Population per Village	NHH selected	Date of survey
Kioumaknao	150	843	57	9/2/2017
Kiouya	127	734	33	10/2/2017
Houy hear	124	721	43	11/2/2017
Houypheng	49	251	22	11/2/2017
Nongkuay	48	385	25	12/2/2017
Tadkacham	223	1,379	51	14/2/2017
Thinkeo	170	966	53	15/2/2017
Phonsavang	144	785	35	18/2/2017
Samackhyxay	655	3,419	55	20/2/2017
Total	**1,690**	**9,483**	**374**	

Source: by researcher (2017); NHH = Numbers of Households

Primary data were collected by interviewing individual farmers, groups of farmers, and government officials at the district and village levels. Structured and semi-structured interviewing techniques were adopted. Secondary data were gathered from a review of documents from several sources such as the Province Agriculture and Forestry Office (PAFO) and District Agriculture and Forestry Office (DAFO).

2.2 Rice Production Systems in the study area

The general information of rice cultivation in the nine study area villages in XND are shown below (Table 2). Rice production was the most common and significant economic, agricultural activity among the residents of the study area. Due to the mountainous nature of the study area, most of the households (74.4%) were engaged in upland rice production compared to paddy rice production. Upland rice production was significantly predominant in Kiouya village where all the household had an area of land set aside for rice production (Table 2). For smallholders who rely on a specific crop such as rice for their livelihood, it is, therefore, important to determine constraints affecting rice production systems to improve rice yield in the future. This calls for the involvement of key stakeholders to improve the farmer's livelihoods and improved food security.

TABLE 2
THE DISTRIBUTION OF THE FARMERS THAT ARE ENGAGED IN RICE PRODUCTION WITHIN THE SELECTED NINE VILLAGES, IN XND, IN LAO PDR IN 2017

Village name	NH	SpS	PP	NF	FUR	FUR (%)	FPR	FPR (%)
Kioumaknao	150	57	843	443	80	53.33	-	0
Kiouya	127	33	734	368	127	100.00	-	0
Houayhia	124	43	721	365	114	91.94	-	0
Houayphaeng	49	22	251	119	44	89.80	11	4.38
Nongkouay	48	25	385	184	46	95.83	3	0.78
Tadkacham	223	51	1,379	695	163	73.09	33	2.39
Tinkeo	170	53	966	454	64	37.65	49	5.07
Phonsavang	144	35	785	324	52	36.11	32	4.08
Samakeyxay	655	55	3,419	1,604	601	9		
Total	**1690**	**374**	**9483**	**4556**	**1291**	**74.39**	**128**	**1.86**

Source: A survey in 2017 by the researcher. Mark: NH=Number of Households; SpS = Sampling Site; NF = Number of Females; PP = Population, FUR = Families with Upland rice; FPR = Families with Paddy rice.

2.3 Climatic/weather pattern of Luang Prabang area

Luang Prabang is located in the mountainous area of Lao PDR. The area is characterized by high humidity and relatively high rainfall amounts. The rainfall is well distributed throughout the year, although with intermittent pockets of dry periods. The average annual temperatures range between 25°C and 26°C. Theoretically, these climatic characteristics are favourable for crop production throughout the year. Thus the study area is well suited for agricultural activities, including rice production among other agricultural activities. However, the study revealed that these favourable conditions are also suitable for weed growth and pest and disease infestations. Therefore, despite the favourable weather conditions for crop production, a slow increase in rice production has been recorded in the study area.

TABLE 3
THE CLIMATIC CONDITIONS OF LUANG PRABANG PROVINCE, LAO PDR BETWEEN THE YEAR 2010 AND 2015

Item/Year	2010	2011	2012	2013	2014	2015
Rainfall	1368.6	2233.5	1259.4	1747.6	1468.5	1525.1
Temperature	27.1	25.8	27.0	26.3	26.5	26.6
Humidity	72.0	75.0	74.5	79.5	71.5	60.5
Sunshine	2,277.5	1,920.3	1,923.8	1,880.9	2,013.6	1,957.1

Mark: The units are annual amounts in; Rainfall (mm), Temperature (°C), Relative Humidity (g/m³)

2.4 Analysis of Qualitative and Quantitative Data

The sample size of 374 respondents, comprising of headmen, farmers, groups of farmers, and government officials was selected for the study. This sample size allowed for statistical analysis with confidence. Descriptive statistics were used to analyze quantitative data with social science statistical software (SPSS). Descriptive statistics provided a method to describe trends and draw generalisations and conclusions about the farmers using statistically significant results. An exploratory factor analysis was conducted on the frequency statements as many significant correlations were found within the data. Both quantitative data and qualitative are reflections of the process that provided the findings. Identification of constraints and opportunities for the sustainable development of rice production systems in XND was based on observations of the study area by interviewers, and collection of secondary data from any source on important agricultural factors such as environmental temperature, amount of rainfall and distribution, occurrences and frequencies of floods and natural disasters, incidences of insect pests and diseases, and general social-economic status of the respondents.

III. FINDINGS DATA ANALYSIS AND RESULTS

3.1 Characterization of the Socioeconomic Status of the Respondents

The age of the respondents ranged from 18 years to 90 years, with majority of the respondents, both males and females ranging between 28-37 years of age. Interestingly, the youngest farm owners ranged between 18 – 27 years of age. This finding observes that a good proportion of the younger generations are venturing into agricultural farming. It brings decisive significance as they can adopt new and necessary innovations in the farming fields. Most of the respondents (55.6%) were male compared to the 44.6% female respondents. Majority of the respondents (87.7%) were from Kummou ethnic group. The number of women ranged from zero to 11, and with a maximum of eight (80 children per household. Generally, the study area was characterized with large size of household member, the maximum being seventeen (17) members and a minimum of 2.

TABLE 4
SOCIOECONOMIC CHARACTERIZATION OF THE RESPONDENTS

Variable	Mean ± S.E	Std. Deviation	Minimum	Maximum
Age	42.0 ± 0.69	13.25	18	90
Number of Children	1.54 ± 0.081	1.53	0	8
Number of Women	3.00 ± 0.08	1.60	0	11
HH member	6.14 ± 0.12	2.36	2	17
Bicycle	0.26 ± 0.029	0.56	0	3
Motor bike	1.25 ± 0.050	0.96	0	6
Car/ Truck	0.06 ± 0.01	0.25	0	2
Hand tractor	0.04 ± 0.01	0.20	0	1
TV	0.87 ± 0.02	0.43	0	3
Radio	0.17 ± 0.02	0.39	0	2
Rice Mill	0.26 ± 0.02	0.44	0	1
Refrigerators	0.51 ± 0.03	0.53	0	2
Cell phone	2.69 ± 0.09	1.64	0	13
Bank Account	1.71 ± 0.02	0.38	1	2

Source: Survey by researcher, 2017

The mean age of the respondents was 42.0±0.69 years with a standard deviation of 13.25 and was statistically significant as the t-value was smaller than the difference freedom (*df = 373*). Again, the standard deviation indicated a small deviation

from the main population means resulting in a good representation of the mean. The descriptive analysis showed that the respondents' households had more children than women. Majority of the respondents owned either bicycles or motorbikes that they used as transportation to the farms or the markets for their daily activities (Table 4). Again, most of the respondent farmers had hand tractors for their ploughing. Most of the respondents also owned devices such as cell phones, radios and television sets, either for communication or entertainment purposes respectively. Nonetheless, there was a greater number of televisions, refrigerators and cell phones.

These findings illustrate that the respondents had more access to information on various agricultural techniques and equipment. Also, the mean for the number of bank accounts by the farmers was high indicating a statistical significance and a t-value lower than the difference freedom. The respondents also had a great number of speakers and DVDs that could be used for entertainments. All the descriptive socioeconomic variables were significant at 95% confidence level. It could be supported by the *sig. 0.000*** that indicates that the values fall under 0.0005, *(0.0005< p>0.05)*. Again, large households are proxy of labor endowment that would enable them to accomplish various farm tasks on a timely basis. In essence, it could increase the farm rice productivity.

3.2 Landholding per farmer (How many hectares)

All the respondents interviewed during the survey managed a piece (s) of land where they practiced various agricultural activities (Table 5). The sizes of land varied significantly from 1 hectare to 16 hectares. The possibility of managing land did not necessarily translate to land ownership. Majority of the farmers did not have their pieces of land, but instead either leased from other farmers or households. Thus there was a strong correlation between the land ownership to the types of crops or livestock the responded kept in the farm. There was a mixed aspect to land utilization from one village to another and from individual farms to another. In a simple frequency analysis, most (78%) farmers observed that the available land parcels are further subdivided into smaller units that can contain intercropping and livestock rearing. It is a challenge as large farms of rice would lead to higher yields of product.

TABLE 5
LAND SUBDIVISION CHARACTERIZATION WITHIN THE STUDY AREAS IN XND, LPB, LAO PDR IN 2017

Land area (hectare)	Mean ± S.E	Std. Deviation	Minimum	Maximum
Total number of parcels managed	4.564 ± 0.128	2.482	1.0	16.0
Land Area (hectare)	4.330 ± 0.185	3.577	0	33
Number of parcels for Agriculture	3.265 ± 0.108	2.088	0	11.0
Agricultural Land (Hectare)	3.601 ± 0.155	2.995	1.0	2.0

Source: Survey by research, 2017

The characteristic values for the land size and partitioning amongst the respondent farmers are illustrated above (Table 5). Most of the farmers managed between 3 and 4 pieces of land. It was observable that some of the respondents (10.4%) also had no pieces of land to maintain. The highest number of managed parcels was 16. The overall mean for the land management was statistically significant with a standard deviation of 2.482. On the other hand, the land area representation had a mean of 4.33 ± 0.19 and a variable deviation of 3.58. The significant level was statistically correct as the p-value was less than the recommended threshold. Most of the respondents had between 0.1- 3 hectares of agricultural land. It illustrated that most of the respondents are small-scale farmers with just a few (2.7%) being large-scale farmers. The findings indicated that most of the land pieces engaged in agricultural activities.

TABLE 6
CROP DIVERSIFICATION IN TERMS OF TOTAL LAND AREA AND CORRESPONDING YIELD PER HECTARE PER CROP AMONG THE INTERVIEWED FARMERS IN XND, LPB IN 2017.

Type of crop	Area (hectare) *	Yield (tons) *	Rice yield (tons)	
			Minimum	Maximum
Upland rice	0.687±0.034	1.248±0.064	0.0	5.2
Paddy rice	0.090±0.014	0.317±0.051	0.0	7.5
Maize	0.176±0.018	0.670±0.071	0.0	6.0
Job's tears	0.225±023	0.793±0.083	0.0	10.0
Banana area	0.026±0.008	0.012±0.007	0.0	2.0
Fallow	1.662±0.090	-	-	-

****The values within the columns marked with an asterisk (*) represent the mean ± the standard error of the mean (S.E) for the individual category. The minimum value represents the minimum amount/Quantity of the product per respondent.***

Majority of the respondents (79%) had rice plantations, with the majority of the responded cultivating upland rice type compared to paddy rice. A chi-square indicated a statistical significance between the two groups of rice types. The findings also showed that the upland rice productivity was higher and significant at 10% confidence level. Due to the mountainous nature of the study area, upland rice production is the most feasible of the two rice production systems. Moreover, the environmental characteristics of the study area favours upland rice production compares to paddy rice.

Maize production was higher than paddy rice production as the mean of maize production in tons was higher than the paddy rice production mean, (0.670±0.071 > 0.317±0.051). Other land crop partitioning included the cultivation of bananas and fallow land. A more significant chunk of land parcels was not ploughed in the study area. Again, the findings observed that Job's tears was the second highly cultivated crop in the study area. It contained a statistical mean of 1.82. In cumulative, rice formed the highest produced crop within the study area justifying the significance of researching the constraints affecting its production.

3.3 Agricultural land in the study area

Most residents of Luang Prabang province practice rotational farming system. This is characterized by farming in one parcel of land for 3-5 years, followed by relocation to a new piece of land. This system is apparently evident and is represented by the data that reflects constant changes in the total area under rice production. Generally, the area under rice production has been on the increase, with few instances of decline in total area under production. The increase punctuated with a few cases of a decrease in total area of land did not result in a significant change in the total rice production within the province.

TABLE 7
TOTAL LAND AREA (HA) UNDER RICE PRODUCTION IN LPB BETWEEN 2010 AND 2015

Rice Type/Year	2010	2011	2012	2013	2014	2015
Season Rice	627,865	598,358	706,028	683,125	739,932	769,193
Irrigated Rice	108,410	112,210	107,967	92,340	102,504	99,019
Upland Rice	118,839	106,682	119,772	115,725	115,400	116,720
Total	**855,114**	**817,250**	**933,767**	**891,190**	**957,836**	**984,932**

There has been a general increase in rice production in Luang Prabang province. This is exemplified by a steady increase in the total quantity (tons) of the rice produced from the year 2013 to 2015. It is also interesting to note that there were years when there was a nonsignificant decline in total rice productivity. The season rice/wet season rice is the leading source of rice in Lao. The season has been contributing to a significant amount of rice from the year 2006 to the time of the study. There has been a significant contribution in the total rice production from upland rice production system. This can be explained by the opening up of new agricultural lands in the formerly fallow upland regions. Moreover, the development of new rice cultivars specifically bred for upland production systems could have contributed to the increased contribution in total production from upland rice.

TABLE 8
GENERAL TREND IN RICE PRODUCTION (TON) PER UNIT AREA IN LPB BETWEEN 2010 AND 2015

Rice type/Year	2010	2011	2012	2013	2014	2015
Season Rice	2,331,330	2,323,195	2,763,150	2,734,970	3,211,584	3,357,640
Irrigated Rice	512,430	540,315	509,920	439,150	555,086	520,000
Upland Rice	226,880	202,250	216,140	240,440	235,755	224,360
Total	**3,070,640**	**3,065,760**	**3,489,210**	**3,414,560**	**4,002,425**	**4,102,000**

The study reveals the existence of a positive correlation between the total rice production (tons) and the total area under rice production. There was a general increase in rice production with the corresponding increase in total area under rice production. This is an expected phenomenon especially when all other factors of production are kept ceteris Paribas. However, the increase in rice production was not unit by unit proportional to the increase in total area under rice production.

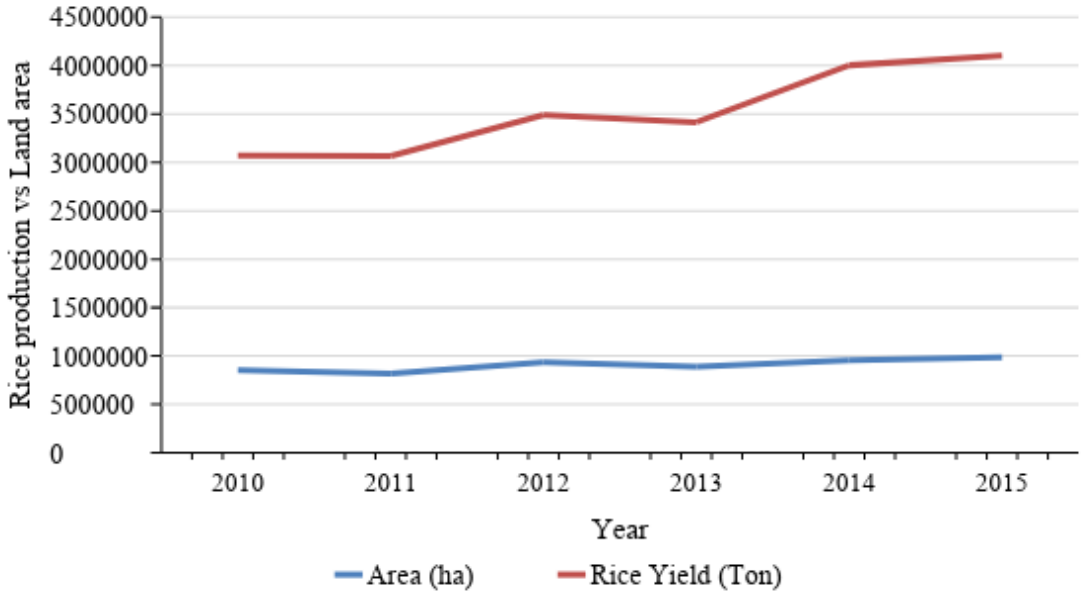

FIGURE 2. Comparative between rice production increasing with area increasing, in 2010 to 2015

Despite there being a steady increase in the total area under rice production, the increase was not statistically significant. As a result, there were seasons that the total increase in rice production was not proportional to an increase or decline in the total area under rice production. Rice production also varied from one study village to another. This mostly depended on whether the village produced upland or paddy rice. The upland rice was mainly produced in the higher mountainous regions of the study area. Thus, paddy rice production was not recorded in the mountainous villages such as Kioumaknao, Kiouya, Houayhia and Samakeyxay.

TABLE 9

RICE PRODUCTION STATISTIC IN THE SELECTED STUDY VILLAGES

Village Name	Upr (Ha)	Upr (Ton)	Pdr (Ha)	Pdr (Ton)
Kioumaknao	97.00	135.80	-	-
Kiouya	138.00	193.20	-	-
Houayhia	120.00	168.00	-	-
Houayphaeng	54.00	75.60	7.70	23.10
Nongkouay	45.70	63.89	1.60	5.50
Tadkacham	180.47	252.66	27.70	171.30
Tinkeo	64.62	129.24	28.55	164.40
Phonsavang	52.50	125.00	16.80	58.80
Samakeyxay	590.50	885.00	-	-

Mark: Upr = Upland rice; Pdr = Paddy rice

TABLE 10

PROPORTION OF THE RESPONDENTS THAT PRACTICE CROP PROTECTION AND FERTILIZER USE AMONG THE RESPONDENTS IN XND, LPB, LAO PDR IN 2017.

Parameter	Proportion (%)	Quantity (litres or kg) (AQY(L)	Minimum (L/kg)	Maximum (L/Kg)
Herbicide use for weed control (HWC)	21.7	1.51 ± 0.21	0.0	40.0
Pesticide use for pest control (DPC)	0.00	0.0	0.0	0.0
Fertilizer application (DFC)	0.80	0.508 ± 0.31	0.0	90.0

***Source: Survey 2017. Mark: HWC = Herbicides use for weed control (1 No; 2 Yes); AQY = Approx. Quantity of use per year (L); DPC = did you use Pesticides for crop (1 No; 2 Yes); DFC =* did you use fertilizers for crop (1 No; 2 Yes)**

Table 10 illustrates the crop protection and management mechanisms within the study area. It focused on the substances such as herbicides, fertilizers, and pesticides. The findings observed that the respondents preferred none of the elements. Most of the respondents (78.3%) indicated that they do not use herbicides to control weeds in their rice farms. On the other hand, only 21.7% had used herbicides for weed control in rice fields. Among the respondents who used the herbicides, majority used between 5 -10 liters. On the fertilizer, only 0.8% of the respondents acknowledged using fertilizer with the most substantial number of farmer respondents not using pesticides summing up to 99.2 %. Among the respondents who used fertilizer, they preferred 90kgs annually. Finally, no respondent had used pesticides in their rice farms. There were more farmers using herbicides compared to fertilizers and pesticides. Therefore, it is observable from the findings that one of the problems that could be affecting rice production in XND was lack of fertilizer application and pest management.

TABLE 11
THE PROPORTION OF RESPONDENTS THAT WERE ENGAGED IN LIVESTOCK REARING IN XND, LPB, LAO PDR IN 2017.

Variables	Proportion (%)	Mean ± S.E	Minimum	Maximum
Buffalo	5.10	0.184 ± 0.052	0.0	10.0
Cows	27.00	1.757 ± 0.294	0.0	61.0
Pigs	63.60	3.267 ± 0.239	0.0	38.0
Goats	24.10	1.525 ± 0.194	0.0	25.0
Chicken	73.30	18.957 ± 1.621	0.0	300.0
Duck	29.10	2.511 ± 0.318	0.0	50.0

Source: Survey by researcher, 2017

Among the respondents, 88.2% engaged in livestock production leaving 11.8% as having no livestock. A more significant number, 94.9% had no buffalos with the modal number being 1 – 3 buffalos. However, the number of buffalos was statistically correlated to the number of the farmers who had more than six pieces of land to manage. It is, therefore, observable that Buffalo rearing was practiced purposely for ploughing the land, as the large number and size of the lands would not be easily ploughed using hand tools. It was also found that most of the farmers had no cows, representing 73% of the total respondents. Nonetheless, the majority of the respondents (63.6%) engaged in pig production. Very few percentage was slotted for goat rearing with the individuals not having goats represented by 75.9%. Interestingly, 73.3% of the respondents had chickens in their households. Not many (29.1%) engaged in duck production. It is observable that the respondents do not participate in mixed farming and the preferred kind of animal was a pig. The variables contained a small variation margin from the means indicating the compactness of the variable distribution. Again, the variables were statistically significant at 95% confidence level.

TABLE 12A
DISTRIBUTION OF FARMERS' SOURCES OF INCOME (US$) IN XND, LPB, LAO PDR IN 2017

Income category	Mean ± S.E	Std. Deviation	Minimum	Maximum
Total Household Income	2698.16 ± 135.79	2626.00	55.00	16500.00
Government or Public service (US$)	484.06 ± 70.99	1370.98	0.00	11250.00
Wages, Temporary employment	814.97 ± 81.19	1570.23	0.00	15125.00
Trade incl. small shops or business (US$)	212.60 ± 44.39	858.43	0.00	6875.00

Source: Survey by researcher, 2017

The findings indicated that most of the respondents enjoyed a house income in the range of 55 – 2000. Few respondents, 2.4% had a household income higher than 10,000. The finding depicts that most of the respondents are either small-scale farmers or work on various farms owned by others. They were purely farmers with no other occupation. Averagely, the earnings from either the public or government were statistically significant and displayed a small deviation from its mean. It was observed that 43.6% of the income earned was as a result of temporary employment. Therefore, the majority of the respondents who had other jobs apart from farming were temporarily employed. It was distributed to the right with a skewness of 1.76. The majority, 90.6% did not engage in trade either in small shops or large businesses.

TABLE 12B
PROPORTION OF FARMERS' INCOME (US$) DISTRIBUTION FROM SALE OF AGRICULTURAL COMMODITIES AND OTHER ACTIVITIES IN XND, LPB IN LAO PDR IN THE YEAR 2017

Income Activity	Mean ± S.E	Std. Deviation	Minimum	Maximum
Sale of Rice	66.93 ± 8.85	171.11	0.00	1162.5
Sale of other agricultural crops	517.75 ± 46.95	907.94	0.00	12375.0
Sale of non-timber forest products	103.06 ± 11.78	227.76	0.00	2500.0
Sale of livestock	369.93 ± 45.37	877.51	0.00	9375.0
Sale of Fish	0.836 ± **0**.69	13.32	0.00	250.0
Sale of handicrafts	16.862 ± 4.27	82.52	0.00	875.0
Money sent home, remittance	120.06 ± 23.34	451.46	0.00	6250.0

Source: Survey by researcher, 2017

Farmers received more revenues from the sale of other agricultural products as compared to the sale of rice. About 81.8% did not participate in rice sales, indicating that most of the farmers produce rice for their domestic consumptions leaving 18.2% for trading. However, other crops such as bananas sold heavily in the markets. It displayed a 71.1% positivity in sales revenue, and only 26.7% of the farmers never received revenues from the other crops. Again, few farmers (36.4%) engaged in the sale of non-timber forest products. A more considerable portion of the livestock sale was significant. Regarding the market share, both the sale of livestock and other agricultural products had the highest demands displayed from their level of revenue turnover. Few or no farmers (99.5%) engaged in fish production sales within the villages where the study was conducted. A few farmers (6.7%) also engaged in the sale of handicrafts as an alternative earning projects. About 17.1% participated in remittances after sales with a higher number of the respondents not being able to send money back home. However, amongst those who attended in payments, the greater number lied between the range of 1 – 1000 (US$).

TABLE 13
TEST FOR MULTICOLLINEARITY FOR HOUSEHOLD CHARACTERISTICS AND SOCIO-ECONOMIC STATUS OF THE RESPONDENTS IN 2017

Model	Collinearity Statistics	VIF
	Tolerance	
(Constant)		
Age	.875	1.143
Sex	.885	1.131
Ethnic	.768	1.302
Number of women	.701	1.427
Number of Children	.673	1.486
Have you always lived in this village	.830	1.204
Bicycle	.906	1.104
Moto bike	.777	1.287
Car/truck	.893	1.119
Hand tractor	.856	1.169
TV	.792	1.262
Radio	.862	1.160
Rice mill	.730	1.370
Refrigerator	.600	1.667
Cell phone	.720	1.390
Bank account (1 No; 2 Yes)	.824	1.214
VCD/DVD	.822	1.216
Speakers	.770	1.299
Total number of pieces of land managed per respondent	.755	1.325

Source: Survey by researcher, 2017

Variance Inflation Factor (VIF) and Pearson correlation matrix test methods were employed to test for the multicollinearity among the explanatory variables. VIF test was carried out by determining 'artificial' Ordinary Least Squares regressions where every independent variable was regressed against the rest of the explanatory variables. The results show that VIF of all the independent variables were below 2.00 (Table 13). As a rule of thumb, if the VIF is greater than 5, then the variable is said to be highly collinear [13]. Pearson's correlation matrix test also indicated that all the correlations between the

independent variables were below 40 percent, reaffirming non-existence of multicollinearity in the data. Following [13], explanatory variables with correlations less than 75 percent are considered to have autocorrelation.

IV. DISCUSSIONS

This study focused on the constraints and opportunities for sustainable development of rice production system in XND, Luang Prabang province in Laos. The study sought to identify the challenges and provides potential mitigation of the problems to enable sustainable rice production in the said area. Over the past year, rice production in Lao has increased a lot, as the country has achieved self-sufficiency of food. Despite the high rice productions in the country, this agricultural sector has had its equal share of opportunities and challenges.

The poor road infrastructure within the study area was a great hindrance to the transportation of agricultural commodities to the market. The poor road conditions also affected rice production activities as the farmers would take longer time to access their farms on foot. This means that the good part of the time is spent on walking to the farms rather than engaging in productive agricultural activities, especially rice production. There is a likelihood of a substantial amount of loss of agricultural produce through post-harvest losses and handling of the produce. This can also be associated with the poor road infrastructure that results in either delayed delivery of the produce to the storage facilities or spillage of the produce on transit. The poor road network could, however, be explained by the hilly, rugged and rough terrain characteristic of the study area and a larger part of Lao PDR.

Land fragmentation has been blamed for a decline in agricultural productivity and potential food insecurity in many developing countries [14]. Most of the respondents had several pieces of land that they either individually owned or leased from other households. A good number of this mentioned parcel of land were lying fallow for several seasons, either to regain their reduced fertility or due to the inability of the farmer to cultivate it. This resulted in a significant number of the agricultural land area being recorded but without a corresponding increase in yield. The quantity of the returns from the small parcels is not comparable to the amounts that would be achieved from the large parcels of land. Increasing the size of the farming parcels results in a positive productivity coefficient. Moreover, the relationship between land size and rice production can be as a consequence of returns to scale. However, several studies have suggested that the return to scale is merely a constant. Again, since the shadow prices of factors of production change with changes in the size of land holding, farmers are forced to apply more of the elements to which they access quickly and the ones that command lower shadow prices. Therefore, it is expected that the above explanation can be applied in the case of XND region and that the marginal productivity analysis is at constant levels. Finally, the principal differences in size of land parcels, as well as land management practices, might lead to the differences in the economic life of the rice farmers within the same locality.

4.1 Household sizes and lack of labour as a challenge

Lack of or inadequate labour supply/availability impacts negatively on agricultural productivity especially in non-mechanised farming systems. The analysis of the responses from the farmers indicated that they lacked enough farm labor despite the relatively large households. The large household sizes did not necessarily translate to the availability of farm labour. The large households were due to a higher number of children per family that were not within the legal working age limit. As a result, in most of these households, one of the adult members was tasked with the duty of taking care of the children, thus cutting further on the available labour force in the family. In addition, the lure of better employment opportunities also confounded the inadequate labour problem within the study region. Rural to urban migration has been a significant challenge in the availability of labour in many parts of the world [15][16], and continue to threaten food production and consequently food insecurity in many developing countries.

4.2 Irrigation system challenges

Continued reliance on rainfed farming activities has been pointed out as the potential source of decline in agricultural productivity and is seen as a threat to food security in many parts of the world. Rice production, especially paddy rice, requires an adequate water supply and for most of the growth period, flooding of the land. Smallholder farmers in Lao PDR consistently rely on rainfall for farming activities and rice production. In the cases of unpredicted droughts, massive crops failures had been reported in most parts of the country. In such instances, most farmers, especially those with parcels of land that border rivers/streams, had to resort to irrigation. The irrigation system is poorly developed and comes as an expensive last resort for most farmers. The farmers were grappling with unreliable rainfall and periods of dry spells in some of the areas. This was noted as a challenge among many farmers who did not have irrigation systems in place.

4.3 Diversification and income from sale of farm commodities

The uncertainties that exist in agricultural activities has driven many farmers into diversifying crop and animal production. The findings of the study highlight the high level of crop diversification among the respondents. This could be attributed to need to cushion themselves from uncertainties that could arise from one crop failure. Also, having an alternative source of income is a common characteristic of many smallholders. [17] Suggested that diversification of farming systems, land tenure and human capital formation by the government and multilateral development agencies would successfully enhance livelihood in Luang Prabang. This is in line with numerous past research studies that observed that needs of rural communities in the province are highly differentiated and require locally adapted self-sufficient, diverse, economically viable and small-scale agro-ecosystem based strategies.[18][19][20].

4.4 Sources of household income and remittances

Farmers received more revenues from the sale of other agricultural products as compared to the sale of rice. The income from the sale of rice among the respondents was low compared to other sources of income. This could be attributed to low rice productivity within the region. The smallholders characteristically practice subsistence farming and only sell the surplus produce, if any [21]. Among the residents of XND, only a small proportion of the population recorded income from government or public services. This could be an indication of lack of employment opportunities in the public sector. The lack of formal employment coupled with non-engagement in agricultural activities explains the low household income among the respondents. As a result, there was a small remittance after sales with a higher number of the respondents not being able to send money back home. This is an indication of the poor economic status of the respondent and that the little that they earned was only enough to sustain their families. The study was however not able to unravel where the bulk of the potential labour force is utilized.

4.5 Biotic and abiotic challenges to rice production

Insect pests and diseases have resulted in a decline in both quality and quantity of agricultural produce in many countries [22][23]. Biotic and abiotic constraints at farm level most significantly droughts and floods, poor soil fertility, pests and diseases and off-farm limitations such as high production costs, fluctuating market prices, and uncertain trade policy limit farmers' production beyond household self-sufficiency [5]. Several insects pests and diseases continuously attack rice in the field, during harversting period and/or in storage. The respondent pointed out that they were struggling with insect pests and diseases management on their farms. Astonishingly, most of the farmers did not practice use of pesticides to avert challenges due to these biotic stresses. This could be attributed to the poor economic status of the farmers and thus their inability to afford the chemicals. Therefore, despite the continued efforts put in rice production, there is a substantial amount that is lost due to pest and disease damage. Lack of pest control mechanisms among the respondents was a significant challenge to the rice farmers. From the descriptive analysis, most of the farmers if not all had not used any of the pesticides in to protect their crops. In most cases, herbicides and pesticides are used in controlling weeds rice insect pests, respectively

Continuous cultivation of one crop, or crops in the similar family, on the same piece of land results in a decline in soil fertility. Most cereal crops are heavy miners of nutrients and minerals from the soil. There is always a need to apply organic or inorganic fertilizers to maintain or improve the fertility status of land for continued productivity. Most farmers in Lao do not use fertilizers for crop production due to the perceived high fertility of the land. However, the decline in fertility in these lands has made most farmers resort to shifting cultivation, with slash-and-burn systems being prevalent. The practiced shifting cultivation does not allow for sufficient rest period for the land to regain natural fertility. In addition, the slash-and-burn system has been blamed for degradation in soil fertility and destruction of beneficial microorganisms in the soil [24] [25][26]. More so, increased intensity of cropping rice leading to low nitrogen and phosphorus in the soil coupled with inherent low water retention capacity of soils in this region against a background of irregular rainfall only serve to exacerbate the problem [9].

4.6 Access to agricultural information and extension services

Farmers across the globe are faced with farming uncertainties as a result of lack of agricultural information. Such information relates to farming inputs, pest and disease control, ploughing periods, as well as harvesting techniques. Differences in accessing various agricultural farming information are the reasons that have resulted in different crop productivity yields. However, the lack of response when the farmers were asked whether they get help from the government could be interpreted as lack of extension services, either because of the poor accessibility of the areas or for other reason (s) that was/were not captured during the study.

V. CONCLUSION

There are no sustainable rice production systems that are easy to adopt which will help smallholder farmers existing in XND, PLB, Lao PDR and hence farmers are unable to produce enough rice for consumption and commercial purposes. Smallholders in Lao PDR face several challenges in farming, especially in rice production. The major obstacles to rice production were lack of agricultural inputs, poor road infrastructure, lack of access to extension services, period drought and crop damages due to insect pests and diseases. To improve upland rice productivity, the irrigation systems must be implemented to assist the rice farmers. The farmers also need to be sensitized on the negative impacts of slash-and-burn systems on the soil fertility. Moreover, emphasis should be placed on the use of fertilizers and pesticides to improve soil fertility and to control rice pests and diseases respectively, in their farms. This call for the improvement of extension services to the farmers through the concerned government departments and ministries. To enhance this, the government need to invest in development of the road infrastructure. This will not only boost access to the villages but will also enable the farmers to transport farms inputs and produce to and from the farm respectively.

ACKNOWLEDGEMENTS

This study was funded by the Chinese Scholarship Council (CSC) through a Ph.D. scholarship at Nanjing Agricultural University. We would like to express our sincere gratitude to all the people that contributed to the completion of this paper. Great appreciation to the staff of DAFO, Xieng Nguen District Mr. Savath Veulicheu, Mr. Khamla Lattanamixay, and Ms. Sila Thammasan for excellent guidance during field research and data collection. Special acknowledgment to Ms. Maiseng Xiong, Miss. Bangphone and Miss Hua Xiong, Students from Department of Politics and Public Administration, Faculty of Social Science, National University of Laos.

REFERENCES

[1] Jones, Monty P. *The rice plant and its environment*. WARDA Training Guide 2. WARDA, Bouaké, 1995, p. 27-30.

[2] International Rice Research Institute. 2013. World Rice Statistics 2013. Los Banos, the Philippines: IRRI. June 29, 2013. *http://irri.org/index.php?option comk2& view= item&id=9081&Itemid=100481&lang=en. IRRI (2014). http://irri.org/news/hot-topics/rice-and-climate-change.*

[3] Food and Agricultural Organisation. 2013. FAOSTAT Database. Rome: Food and Agricultural Organization.

[4] MAF, 2012. Lao Census of Agriculture2010/11 Highlights.

[5] Schiller, J.M., Linquist, B., Douangsila, K., Inthapanya, P., Douang Boupha, B., Inthavong, S. and Sengxua, P. Constraints to Rice Production in Laos, 2001.

[6] ADB. 2001. Participatory Poverty Assessment in the Lao PDR. Manila.

[7] Khamko, T., Gang Hua, L.I., Edzesi, W. M. (2016). Constraints and Opportunities for the Sustainable Development of Rice Production Systems in Laos. International Journal of Business, Economics and Management Works. Kambohwell Publisher Enterprises ISSN: 2410-3500. Vol. 3, Issue 5, PP. 66-74, May 2016.

[8] Linquist, B.A., Trosch, K., Pandey, S., Phouynyavong, K., Guenat, D. Montane paddy rice: its development and effects on food security and livelihood activities of highland Lao farmers. Mountain Res. Dev. 27, 2007, p.40–47.

[9] Roder, W. Slash-and-Burn Rice Systems in the Hills of Northern Laos PDR: Description, Challenges and Opportunities. International Rice Research Institute, Los Baños, Philippines, 2001, p. 201

[10] United Nations' World Food Programme (UNWFP). (2005). World Hunger Laos. Available: http://www.wfp.org/country_brief/indexcountry.asp?country=418

[11] NURiFaR, 2012. Rice marker assessment in NURiFaR target provinces

[12] Roder, W. Slash-and-burn rice systems in transition: challenges for agricultural development in the hills of northern Laos. Mountain Research and Development, 1997, p.1–10.

[13] Gujarati, D.N. 2003. Basic Econometrics. New York: McGraw Hill Book Co. p328.

[14] Alemu, G. T., Ayele, Z.B. and Berhanu, A.A. (2017). Effects of Land Fragmentation on Productivity in Northwestern Ethiopia. *Advances in Agriculture*, vol. 2017, Article ID 4509605, 9 pages, 2017. doi:10.1155/2017/4509605

[15] Angba, A.O. (2003). Effect of rural-urban migration of youths on agricultural labour supply in Umuahia North Local

[16] Mbah, E.N., Ezeano, C.I. and Agada, M.O. (2016). Effects of rural-urban youth migration on farm families in Benue state, Nigeria. *Int. J. Agril. Res. Innov. & Tech*. 6 (1): 14-20.

[17] Bravo-Ureta, B., Solı´s, D., Cocchi, H. and Quiroga, R., 'The impact of soil conservation and output diversification on farm income in Central American hillside farming', *Agricultural Economics*, Vol. 35, (2006) pp. 267–276.

[18] Akram Lodhi AH. 2008.(Re)imagining agrarian relation. The World Development Report 2008: Agriculture for development *development and change* 39(6): 1145-1161.

[19] Thongmanivong S, Fujita Y. 2006. Recent land use and livelihood transitions in Northern Laos. *Mountain Research and Development* 26(3): 237-244.

[20] Wale, E. and Yalew, A. 2007. Farmers' Variety Attribute Preferences: Implication for Breeding Priority Settings and Agricultural Extension Policy in Ethiopia. African Development Bank, 379-396.

[21] Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijohn, R. H., MacKinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. Philosophical Transactions of the Royal Society B: Biological Sciences, 369(1639), 20130089.

[22] http://doi.org/10.1098/rstb.2013.0089.

[23] Kihoro, J., Bosco, N. J., Murage, H., Ateka, E., & Makihara, D. (2013). Investigating the impact of rice blast disease on the livelihood of the local farmers in greater Mwea region of Kenya. SpringerPlus, 2, 308.

[24] http://doi.org/10.1186/2193-1801-2-308.

[25] Cerda, R., Avelino, J., Gary, C., Tixier, P., Lechevallier, E., et al. (2017). Primary and Secondary Yield Losses Caused by Pests and Diseases: Assessment and Modeling in Coffee. PLOS ONE 12(1): e0169133.

[26] Adeniyi, S. A. (2010) . Effects of slash and burning on soil microbial diversity and abundance in the tropical rainforest ecosystem, Ondo State, Nigeria. *African Journal of Plant Science*, 4(9) 322 – 329.

[27] Beliveau, A., Davidson, R., Lucotte, M., Lopes, O.C., Paquet, S. and Vasseur, C. (2015). Early effects of slash-and-burn cultivation on soil physiochemical properties os small-scale farms in the Tapajos region, Brazilian Amazon. The Journal of Agricultural Science, 153(2) 205 – 221.

[28] Giardina, C. P., Sanford, R.L., Døckersmith, I.C. and Jaramillo, V.J. (2000). The effects of slash burning on ecosystem nutrient during the land preparation phase of shifting cultivation. *Plant and Soil*, 220: 247 – 260.