Teak (*Tectona grandis*) Plantation: Factors Influencing to Teak Plantation Area Changes of Smallholders during the Year of 2010-2020 in Luang Prabang, Lao PDR. (Case study in Kok Ngiew, Sen Khalok and Thin Some villages)

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Abstract

The study on factors influencing teak plantation area changes during 2010 to 2020 in Luang Prabang province was to identify the factors that affect shifting of smallholder's teak growth to other land uses. This research employed the mixed research method for research design with the specific sample for teak plantation holding from 2010 to 2020 in three communities such as Kok Ngiew, Sen Khalok, and Thin Some villages with the total of 88 teak growers, and village landowner individually for 44, 33, and 11, respectively. The research applied the Enter Method of Multi-Linear Regression Model for identifying the factors influencing teak stand area changes, and showed the study results in descriptive and coefficient statistical analysis. Consequently, the result of this study found that the teak stand area decreased more than 50 percent (69.82 percent or 69 hectares) from 2010 to 2020 in 10 years. These areas have changed to other land uses such as crop cultivation land, land for construction, and unused land. Hence, this result especially found that there are three significant factors that affect the teak plantation area changes of p-value <0.05 and 0.001, which are the market demand for wooden teak products, seasonal cultivation instead of teak, and household economy. These factors pushed teak owners to stop all teak stand areas including mature and young teak raise more household income. As a result, this study proposes the result to the government for policy-making decision for achieving the Sustainable Development Goal (SDG) as well as the sustainability of forest management onto National Development Plan in the future. Due to wood area declines amount of tree stand, it will be lacks wood consumption from tree plantation then it causes to alter using wood increasingly from natural resource instead.

Keywords: *Teak Plantation, Factor influencing, Land uses, Smallholders, Luang Prabang*

1. Introduction

Teak (*Tectona grandis* Linn. f) is a main hardwood tree species and is one of the most valuable timber species in the tropics. It covers about 4.346 million hectares of teak forest and represents 75% of high tropical hardwood plantations, 83% of which is in tropical Asia (Mohapatra et al., 2020). Teak naturally distributes growing in Asian countries a part of India, Myanmar, Lao PDR, and Thailand in the past 400-600 years ago (Ball et al., 1999), teak plantation firstly started in 1680 in Sri Langka, in the 1840s started in India and 1865 onward, also found teak plantation using "Taungya" method in Myanmar, Teak plantation afterward was wisely spread in outside Asia (Pandey and Brown, 2000).

Teak in Laos grows in the north area in Xayabouli, Bokeo, and Luang Prabang provinces. The total area is now 40,000 ha (Midgley et al., 2007), and around 15,000 ha of teak is classified in Luang Prabang (Smith et al., 2017). Most farmers cultivate teak under on agriculture practice with mono-crops in the landscape. Especially, the cultivators in Luang Prabang grow upland rice more than a hectare per family in a rotation system with a short and long-term period. A lot of teak has been planted in the rice filed on mountainous hill area and flat land, and the number of Teak plantations is still increasing for a few decades ago because teak is a very valuable wooden tree and support farmers a good extra income but it should run over 20-30 years (Kolmert, 2001).

The government of Lao PDR (GOL) has supported teak planting document for over 40 years, it showed a significant rising of the area of plantation teak. All farmers have a plantation area which are managed by individual and play an important role as a kind of financial insurance system (Anttila, 2016). Recently, according to decree No. 247 of the government of Laos in 2019, it was defined as promoting tree plantations for commercialization. The GOL highlighted promoting to any investors and organizations for investing in tree plantation to wood log contribution to manufacturing wood production in Laos, and also GOL has reduced the tax including land lease, tree species, and products export. In addition, article 8 emphasized the tree growing promotion to landowners who have a capacity for tree planting expansion in their land, GOL then supports technical and regulation for any activities regarding implementation including any individual investor, group, or organization (Lao Government Office, 2019).

For that reason, Luang Prabang province has a teak plantation area of more than 10,000 hectares by smallholder teak growers that increase rapidly expansion since 1988 and another larger teak area booming in 1996. Afterward, it was decreased planting of teak for many reasons such as a policy of land use, and the result of smallholder survey demonstrated to improve teak management with thinning and pruning (Newby et al., 2010). On the other hand, high market demand from wooden teak has recently been rising to smallholders, they need immediate cash for home daily expenditure and motorcycles, electric goods, jewelry, livestock, and others, its high market demand affects teak plantation area decline, whilst it was the low price from middlemen (Ling et al., 2012).

Additionally, over the last few decades, forest land cover has declined and will continue to decline as a result of deforestation. High dependence on forest products utilization and high market demand from globalization that compress farmers to cut down of the tree to market suppliers. In addition, farmers need to earn cash immediately. Hence, 70 percent of forest harvest trees to meet household wood energy demand (Yusuph, 2016).

Almost all farmers have owned teak plantations today that sold their teak trees stand to investors of furniture factories, and use of cleared land to support agriculture practices with rice and vegetables (Kolmert, 2001). Moreover, about 20 percentage of teak

plantation area is of mixed size classes and geographically distributes close to road and rivers, which are the easily accessible location of plantation, high-risk replacement teak area to infrastructure building (Smith et al, 2017).

Significantly, this study conducted the survey and data collection about teak plantation area changes of two periods from 2010-2014 and 2015-2020 in three villages, all smallholders of teak growers have harvested the logging of teak to the domestic market as furniture factories in Luang Prabang and other provinces, and some logs from villages that were verified from SFC pilot project has sent to specific factory in Vientiane capital. However, all growers of teak need to earn cash immediately from their plantation. Then the objective of this study is the identify the factors influencing teak plantation change during the year 2010-2020. As a result, this study is to address the lack of teak stock information for the log provision that decline gradually, its information can significantly be supported the government policy making-decision on land use planning and urban development.

2. Material and Methodology

2.1 Research Location

Luang Prabang province was selected as the study area (Fig. 1). It is located in the central area in the north of Laos and shares a border with seven provinces as Oudomxay, Phongsaly, Huaphanh, Xiengkhuang, Xaysomboun, Vientiane, and Xayabouly provinces. Luang Prabang province has a total of 431,900 people, 753 villages, and 77,700 families. They live in 12 districts as Luang Prabang, Xiengngeun, Nan, Pak Ou, Nambak, Ngoi, Pakxeng, Phonexay, Chomphet, Viengkham, Phoukhoun, and Phonethong.

This study particularly conducted the survey and data collection in three villages (Ban) as Kok Ngiew, Sang Khalok and ThinSome, Luang Prabang district, Luang Prabang province, Lao PDR. Ban Kok Ngiew has located in the southeast of Luang Prabang city about 15 km, and Ban ThinSome and Sen Kha Lok are located in the southwest of Luang Prabang city, which is far about 16 km and 38 km, respectively.

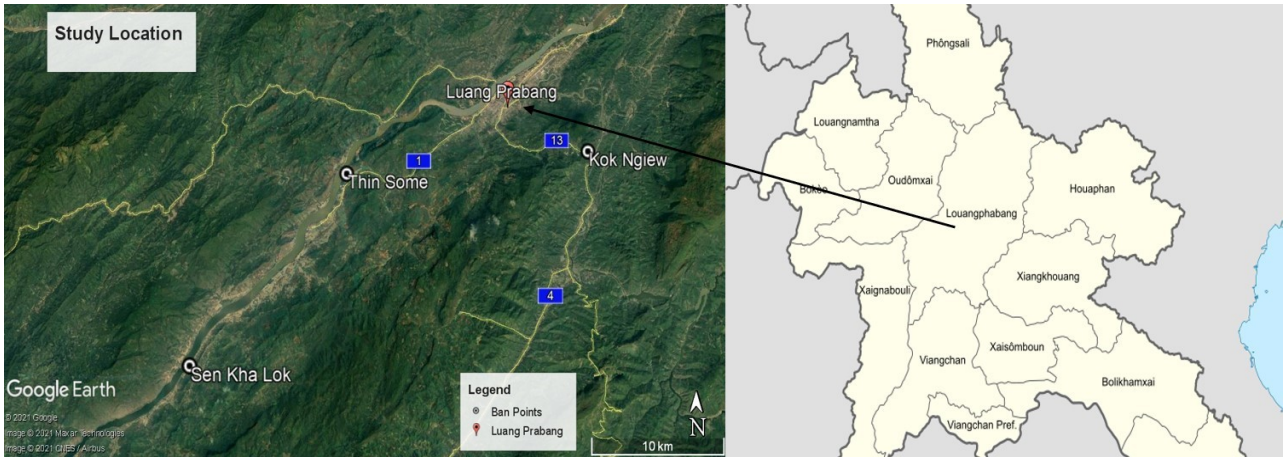

Figure 1. Location of Study Area.

The total population of three villages has 438 families, there are only 88 families who grow the wooden teak tree in their landowner, and its teak plantation area is a total of 89.09 hectares. Separately, the teak plantation area of Kok Ngiew, Sen Khalok, and ThinSome is about 44; 33 and 11 families growing teak, respectively.

2.2 Research Material

This research has employed the guideline of socio-economics livelihood survey that combined with landscape data approach by the geographic information system (GIS). GIS is a tool for landscape data analysis with spatial information. Hence, the research was interviewed by focus group and individual, and

used satellite imagery for land use classification by ArcGIS application.

2.3 Methodology

2.3.1 Sample selection

This research has selected a sample by selecting only teak plantation owners of three communities at Ban Kok Ngiew (KN), Sen Khalok (SK), and ThinSome (TS), which is about 44; 33, and 11 owners, respectively. These numbers of the sample were interviewed for socio-economics, factors influencing plantation area changes, and area of teak plantation.

2.3.2 Data collection

The study was applied the mixed research method for data collection, which means that used the questionnaire with quantitative and qualitative design for data collection of this research, this was employed the tools of socio-economics livelihood, land tenure, and right survey for use in collaborative ecosystem-based land use planning (Liswanti et al., 2012). Moreover, this research did focus group discussion and interview smallholders individually with socio-economics, factors influencing plantation area changes, and many teaks area plots (Table 1). This research was created questionnaire by structure with an open, closed and multiple-choice question. On the other hand, the area changes of the plantation were collected by both procedures as group and individual discussion and checking point of the all-plots teak area by GPS and marked into the note.

Table 1: Determinants of Teak plantation area change during 2010 to 2020 (N=88).

Factors	Variables	Responses	Remark
Socio-economics	Sample (N)	KN=44, SL=33, ST=11	
	Gender	Male=76; Female=12	Dummy (1; 2)
	Age	Range=35-71	
	Education	Five level (non-edu=4, Primary=42, Middle=33, Second=7, High=2)	
	Occupation	Four jobs (Gov.=1, Staff private=1, Retailer=9, Farmer=77)	
Teak Growing and Utilization	Market demand	Yes=81, No=7	Dummy (1; 2)
	Knowledge of Planting	Yes=42, No=46	Dummy (1; 2)
	Income from Teak growing	Yes=48, No=40	Dummy (1; 2)
	A teak movement to other plant cultivation	Yes=19, No=69	Dummy (1; 2)
	Wooden use in a home	Yes=13, No=75	Dummy (1; 2)
	Wooden sell to a market	Yes=13, No=75	Dummy (1; 2)
	Government project	Yes=9, No=79	Dummy (1; 2)
Teak area Change	Quantity of area (ha)	Change from 0.01 - 4.05 ha (total 69 ha)	

Note *Dummy representative of 1 (Yes); 2(No); source of data: interview.*

2.3.4 Data analysis

There are two parts of data analysis, (1) analyzing of factors influencing teak plantation changes during 2010 - 2020, this duration has separated into two periods for 2010-2014, and 2015-2020, the result of research has tried to understand the situation of teak plantation area to be changed by since 2010 to 2020, which have shown the descriptive statistical analysis; (2) this research classified the land use of teak plantation changes of two periods using ArcGIS

application with satellite imagery from Google Earth for finding out proof of land-use change.

Identification of the factors influencing the land of teak plantation changes was estimated by the multi-regression model because it needs to understand the situation of factors affecting teak area change from the year 2010 to 2020. Thus, the factors are the determinants of independent and dependent variables for input to the multi-linear regression model. Additionally, the independent variable includes socio-economics, teak growing, and the dependent variable is the area of teak plantation change from 2010 to 2020 (Table 1). As a result, multilinear regression illustrates the equation as follows:

Multilinear regression Model

$$yí = \beta_0 + \beta_1 \chi_{i1} + \beta_2 \chi í_2 + ... + \beta_n \chi í_n + \varepsilon í \qquad (1)$$

where yí represents the $í_{1-n}$ value of the response variable y, a part of χ_{i1}, $\chi í_2$, to $\chi í_n$ represent the values of the predictor variables for the $í^{th}$ unit, β_0, β_1, β_2, to β_n represent the coefficients, and εí represents the error in the approximation of yí.

To analyze the factors influencing the teak plantation area change by smallholders growing teak, linear regression was defined independent variables as dummy and ordinary data with gender, age, education, job, market demand, knowledge of planting, income from teak, teak area removal to other plants, wooden use in the home, wooden sell to the market, and government project. In terms of the dependent variable is data of scale as teak plantation area changed. Eventually, this model analysis was launched with the Enter Method for a reasonable quantify of various influences on the single dependent variable. Thus, it shows the equation of multilinear regression as below:

$$y = \beta_0 + \beta_1 \chi_1 + \beta_2 \chi_2 + \beta_3 \chi_3 + \beta_4 \chi_4 + \beta_5 \chi_5 + \beta_6 \chi_6 + \beta_7 \chi_7 + \beta_8 \chi_8 + \beta_9 \chi_9 + \beta_{10} \chi_{10} + \beta_{11} \chi_{11} + \varepsilon \qquad (2)$$

Independent variables: χ_{1-11} (Gender, age, education, job, market demand, knowledge of planting, income from teak, teak area removal to other plants, wooden use in the home, wooden sell to the market, and government project, respectively), where y is dependent variable as teak plantation area changed in hectare from 2010 to 2020.

Land use analysis

The teak plantation area estimation of changes was conducted by field survey for teak area situation currently accompanying smallholders' group discussion for checking the number of plots and area individually of land use types including rice field, cropland, urban, unused land, teak plantation, forestland, new road, and railway in hectare by following two phases as the year of 2010-2014, and 2015-2020 (Table 2). In addition, all land uses and teak plantation area change were analyzed the land-use change by Google Earth imagery interpretation of satellite image classification with spectral pattern during the year 2010-2014, and 2015-2020. Nonetheless, the land uses especially have the mapping of land-use change with all land use types including rice field, crop field, land for construction, un-used land, teak plantation, and forest area.

Table 2: Land uses and teak plantation area in 2010-2014 and 2015-2020 (N=88).

Land use types	Land Area in 2010-2014 (ha)			Land area in 2015-2020 (ha)		
	KN (44)	SL (33)	TS (11)	KN (44)	SL (33)	TS (11)
Rice Field	140.84	486.1	81.98	131.63	479.23	78.32
Crop land	161.35	231	20.79	176.53	263.80	25.33
Urban/Land for Construction	8.78	4.05	5.77	14.28	7.53	7.80
Unused land	4.64	4.9	1.75	8.79	7.8	5.61
Teak plantation	69.55	23.21	6.06	20.09	9.31	0.42
Forestland	1041.19	1788	560.98	1026.19	1765	556.93
New Road	5.59	0	0	5.59	0	0
Railway	0	0	0	36.2	0	0

Remark: KN (B. Kok Ngiew), SK (B. Sen Khalok), TS (B. Thin Some); Land area (ha) number estimated by Google Earth Satellite image and Interview.

3. Result

3.1 Smallholder's teak plantation during 2010-2020

The smallholders' teak plantation grows 88 households in three communities of Ban Kok Ngiew, Sen Khalok, and Thin Some, Luang Prabang province, Lao PDR. This study found that they have grown around 128.64 ha. Individually, by the sum of areas are about 98.82 hectares and average 1.123 hectares per family in the year of 2010-2014, and decrease largely about 19.82 hectares (Table 3), it has down more than 50 percent in 2015-2020.

In addition, this research has also shown that almost all farmers grow teak tree range from 0.1 to 2 ha of area distribution in 2010-2014, but teak areas are distributing from 0.01 to 1 ha in 2015-2020 (figure 2). Therefore, the farmers have changed their teak area to other land uses for selling out, removing a teak tree to cultivate other plants, and generating income.

3.2 Land Uses and Teak Plantation Changes from 2010-2014 to 2015-2020

These communities are based on agriculture and forest resources to improve their livelihood, most farmers use land with rice and crops cultivation, a clear teak area to build a house, and being still holders of their teak plantation. Table 2 describes land uses including rice field, cropland, teak plantation, forestland, new road, and railway in three communities, especially teak plantation areas are growing of three villages as KN, SL, and TS during 2010-2014 that are about 69.55, 23.21, and 6.06 ha, respectively. However, smallholders of teak growth are still holding their teak area about 20.09, 9.31, and 0.42 ha during 2015-2020, respectively.

Moreover, the teak plantation has related to other land uses in these communities. Hence, there are six land use types which have changed from teak plantation area to cropland, land for construction, unused land and be removed by government project as railway and a new road. Nevertheless, only rice field does not change from the teak plantation, it changes to urban, cropland, and government project (Table 4).

Consequently, this research found that the big large of changing is teak plantation about -69 ha or 69.82 percent of changing, meaning that the teak area has declined deeply to other land uses (Table 4) because almost smallholders' teak plantation has changed to cropland, un-use, urban and railway. Conversely, the big large area changes of teak plantation occurred in Ban Kok Ngiew and Sen Khalok where cleared their teak trees to unuse land, land for construction, cropland of 96.63, 59.19, and 12.71 percent, respectively. Accordingly, these percentages largely increase the area from the teak plantation, rice field, and forestland, respectively.

3.3 Factors Influencing Teak Plantation Area Changes

Smallholder's teak plantation recently has changed their teak trees with various factors related land of teak changes. Thus, the factors that affect the teak plantation changes to other land uses, which was predicted the land-use change by the Enter Method of the multilinear regression model. Therefore, the model has input eleven factors including two parts as socio-economic, and teak growing and utilization (Table 1), the socio-economic includes gender, age, education, and occupation; and teak growing and utilization are market demand, knowledge of plantation, income from the teak plantation, teak movement to other plants cultivation, wooden use in the home, wooden sell to the market, and project development.

The result of this model highlights to identify the factors that affect land-use changes of the teak plantation, mean that farmers change their teak plantation to other activities of land uses such as changing teak growing to cropland, urban, railway, and road, unused land. Because, they use cropland for pineapple and other plants cultivation, clear teak area for construction building, and remove teak trees out for transferring land tenure, some farmers sell or transfer land either include and exclude trees to other buyers. Accordingly, this research found that market demand, teak movement to grow other plants, and wooden teak selling to the market, these factors are significantly changing teak area changes (Table 4). The market demand was positively related to teak area changes, which means that market demand increases, farmers will increase teak cutting by market price and high demand from customers in the domestic and overseas. However, this research found that two factors were negatively related significant to teak plantation changes, by the farmers removed teak trees for growing other plants imply that farmers grow plants rise, it still decreases the area of teak. Also, farmers cut teak trees for wood consumption and commercial, imply that they earned income from the teak area but its area was down.

4. Discussion

Teak tree is a popular world for wooden utilization and commercialization, and it is an important resource to increase household economy, which is an effect to land-use changes. Then the main research objective is to identify the factors influencing teak plantation changes and other land uses by smallholders' plantations in Luang Prabang, Lao PDR. This research finds out the land uses in the three communities since 2010-2020 by classifying them into the eight categories of land use activities, namely: rice field, cropland, land for construction, unused land, teak plantation, forestland, railway, and the new road.

The land uses in these communities are based on household economy, it is the teak growing and utilization of wood especially. Almost farmers growing teak from their land tenure on a mountain hill, and grow over 15 years. Due to Lao policy for promoting of tree plantation on swidden shifting cultivation land, which converses to tree plantation, and programing of land and forest allocation aimed to raise land using effectiveness, at that time the tree growth was booming and expand increasing of teak plantation area in the north of Laos especially after among the 1990s (Hansen et al., 1997). This research found that Ban Kok Ngiew has grown teak tree to 69.55 ha of 44 farmers, followed by Ban Sen Khalok and Thin Some has grown teak tree to 23.21 and 6.06 ha of 33 and 11 farmers surrounded by 2010-2015, respectively. On the other hand, some farmers of a growing teak tree had removed some plots area of the teak tree standing for their reason privately, it has affected to teak area reduction to 20.09, 9.31, and 0.42 ha from 2010-2020, separately. This change is the opposite direction in the year of 1990s, because of few factors have pushed up to farmers changing their livelihood activities. Likewise, the farmers can be controlled with any permission from government regulation since all trees are grown

in their land with their land tenure.

Land uses have many activities of farmers for generating households' economy. In these communities, almost all farmers have had a teak plantation from the beginning of its growth a few decades ago, because there are many reasons for planting expansion such as short and long-term investment, hope to gain capital from the teak tree, and add value in mono-crops on mountain hill (Kolmert, 2001). In contrast, this research, found that teak plantation land has directly related to other land uses activities with crops cultivation, teak log sale, and house construction. As a result, the land of teak plots from some smallholders have changed to pineapple cultivation because of its price is fluctuation and able to manage cash flow every year as long as 4 years rotation of pineapple cultivation (Newby et al., 2014), and offering all logs to a middleman for earning income to buy convenient properties consumption such as smartphone, motorbike, and fund of education, etc. Eventually, this study has shown that the teak plantation area has rapidly decreased hectare more than 50 percent amongst 10 years ago, and no found any farmers regrow it and explant of teak area.

Significantly, this research revealed the factors influencing to farmers changes their teak area during 2010-2020. The research was applied the Enter method of multilinear regression model to identify the factor that relates to land-use changes, this model found that only three of all model elements in land-use change analysis such as market demand, crops cultivation, and log sale. As a result, the market demand is a positive sign to teak area change because of having a high market demand that pushes to be changed by customers in the domestic and other provinces as well as export teak wood oversee. According to Kollert and Kleine (2017) reported that the price of teak was attractive in South East Asia, where is China, Thailand, and Vietnam, also they mentioned in the Luang Prabang particularly, teak has been a cycle age of log cutting down and sale, the price of teak relies on the year, stand height, and diameter at breath by ranging from small to larger logs.

In terms of crops cultivation onto teak plantation area movement was negatively significant of land-use change, mean that the teak area and volume stand were down in the same direction, farmers have changed their teak land to grow mono-crop as pineapple and other plants in short term, because they mentioned that they can generate income depending on seasonal. Also, the contributors of household income were from teak about 11.6 percent but it was a higher income source as food crops and livestock about 24.9 percent, and the rest was other sources (Kollert and Kleine, 2017), and the research of Keonakhone (2005) found that the diversified groups of changing land relation with the teak area, the poor group was a much of rice field but the teak area was holding a smaller than wealth and middle groups.

Moreover, this research has shown that the income also is a major critical issue of farmers for giving up a medium and mature teak tree to market, somewhat the trees were mature growth and ready to sell with cycle ages, but some plantations have not reached the age of cutting because of a lot of household's expenditures in daily activities, and growing any crops, building a house and transfer landholding, then farmers have to cut their all logs selling out by estimated price. It was negatively significant for land-use change, imply that farmers sold out of teak but regrowing teak in the same area. According to Kolmert (2001), found out that the farmers who have still sold almost all teak trees because they changed their land to cultivate rice and vegetables, however, the government of Laos has still promoted individual landholding and investors for expanding plantations in the land degradation.

5. Conclusion

This research was on the teak plantation area changes during 2010-2020 by identifying the factors influencing to teak area transition in

Luang Prabang province, Lao PDR for the case study in three communities as Kok Ngiew, Sen Kalok, and Thin Some villages with 88 households (called landowners). This research revealed the land use activities including rice field, crops land, urban, unused land, teak plantation, forestland, new road, and railway, also Teak plantation related to other land uses because farmers changed teak area to crops land, urban and unused land, then affected to decreased teak stand area more than 50 percent of total teak area plantation since 2010 to 2020. Moreover, this research applied the multilinear regression model to identify the factors that affect teak stand area changed, this found that there are three determinants significantly to influence transition land-use changes of teak stand area changed, namely, market demand of wooden teak, teak stand movement for other land use activities, and taking a teak log for income. As the result, this research discloses the factors of teak plantation changes every year and this result can support to local government for policy-making decisions to promotion the increase teak stand area.

6. Conflict of Interest

I certify that there is no conflict of interest with any financial organization and person regarding the research process discussed in the manuscript.

7. Reference

Anttila P. (2016). Implications of middlemen in smallholder teak production systems in Northern Lao People's Democratic Republic (Lao PDR).

Ball J.B., Pandey D., and Hirai S. (1999). Global Overview of Teak Plantations. Paper presented to the Regional Seminar. Site, Technology and Productivity of Teak Plantations, Chiang Mai, Thailand 26-29 January 1999.

Hansen P.K., Sodarak H., and Savathvong S. (1997). Teak production by shifting cultivators in Northern Lao P.D.R. Paper prepared for the workshop on Indigenous Strategies for Intensification of Shifting Cultivation in Southeast Asia. 23-27 June 1997, Bogor, Indonesia. Cornell University and International Centre for Research in Agroforestry.

Keonakhone T. (2005). A holistic assessment of the use of teak at a landscape level in Luang Prabang, Lao PDR [MSc thesis]. Uppsala: Department of Soil Sciences, Swedish University of Agricultural Sciences.

Kollert W., and Kleine M. (2017). The Global Teak Study. Analysis, Evaluation and Future Potential of Teak Resources. IUFRO World Series Volume 36. Vienna. 108 p.

Kolmert A. (2001). Teak in northern Laos. Swedish University of Agricultural Sciences: Minor Field Studies No. 175.

Lao Government Office (2019). Decree of Tree Plantation Promotion for commercialization. Online at http://www.laogov.gov.la/legaldoc/pages/document.aspx?LoaiID=4

Liswanti N., Shantiko B., Fripp E., Mwangi E., and Laumonier Y. (2012) Practical guide for socio-economic livelihood, land tenure and rights surveys for use in collaborative ecosystem-based land use planning. CIFOR, Bogor, Indonesia.

Ling S., Smith H., Xayvongsa L., and Laity R. (2012). The evolution of certified teak grower groups in Luang Prabang, Lao PDR: An action research approach. The evolution of certified teak grower groups in Luang Prabang, Lao PDR, Final Version

Midgley S., Blyth M., Mounlamai, K., Midgley D. and Brown, A. (2007). Towards improving profitability of teak in integrated smallholder farming systems in northern Laos. ACIAR Technical Reports No. 64.

Mohapatra A., Nayak H., and Das O. (2020). Factors influencing establishment of teak

(*Tectona grandis* Linn. f) plantation: A review. e-planet 18 (1): 85-94.

Newby J., Cramb R.A., and McNamara S. (2010). Smallholder Teak and Agrarian Change in Northern Laos. Paper presented to International Conference on "Revisiting Agrarian Transformations in Southeast Asia: Empirical, Theoretical and Applied Perspectives" Research Centre for Sustainable Development, Chiang Mai University.

Newby J., Cramb R., and Sakanphet S. (2014). Forest Transitions and Rural Livelihoods: Multiple Pathways of Smallholder Teak Expansion in Northern Laos

Pandey D., and Brown C. (2000). Teak: a global overview; An overview of global teak resources and issues affecting their future outlook. FAO: Unasylva 201, Vol. 51, 2000.

Smith H. F., Ling S. and Boer K. (2017). Teak plantation smallholders in Lao PDR: what influences compliance with plantation regulations? Australian Forestry, 80:3, 178-187, DOI: 10.1080/00049158.2017.1321520

Yusuph J. K. (2016). Key factors that influence households' tree planting behavior. Natural Resources Forum 40 (2016) 37–50. DOI: 10.1111/1477-8947.12088.

Table 3: Teak Plantation Area during 2010-2014 and 2015-2020.

Teak area period	N	Mean	Std. Error of Mean	Std. Deviation	Sum (ha)
2010-2014	88	1.123	±0.137	1.290	98.82
2015-2020	88	0.339	±0.08	0.753	29.82
Total	88	1.462			128.64

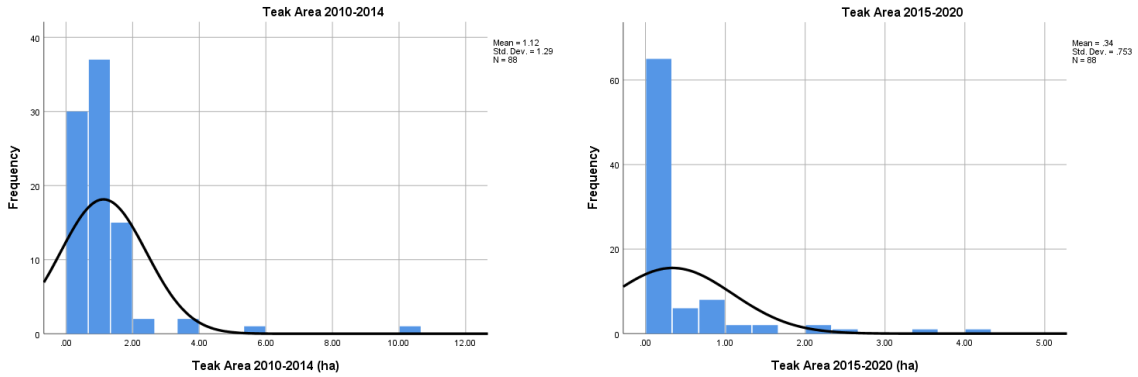

Figure 2: Teak plantation area distribution of 2010-2014 and 2015-2020.

Table 4: Land uses and teak plantation area changes during 2010-2020

Land Use Activities	2010-2014 (ha)	2015-2020 (ha)	Change (ha)	Change (%)	Cause of changes
Rice field	708.92	689.18	-19.74	-2.78	Urban, Railway/road, cropland
Crop land	413.14	465.66	52.52	12.71	From the teak area, forestland
Urban/land for construction	18.6	29.61	11.01	59.19	From forestland, rice field, teak area
Unused land	11.29	22.2	10.91	96.63	From rice field, teak area, cropland
Teak	98.82	29.82	-69	-69.82	Cropland, land for construction,

plantation					unused land, railway/road.
Forestland	3390.17	3348.12	-42.05	-1.24	Cropland, unused land, urban
New Road	5.59	5.59	0	0	Rice field, teak area, cropland
Railway	0	36.2	36.2	100	Rice field, teak area, cropland
Total	4646.53	4626.38	-20.15		

Note: *ha (hectare)*

Table 5: Multi Linear Regression model for prediction of teak plantation changes

Factors	Mean	S. E	S. D	Standardized coefficients (Beta)	t	P-value
Gender	1.136	±0.037	0.345	-0.059	-0.901	0.371
Age	54.989	±0.979	9.180	0.086	1.160	0.250
Education	2.557	±0.085	0.800	-0.031	-0.409	0.684
Occupation	3.852	±0.052	0.492	0.035	0.476	0.635
Market demand	1.080	±0.029	0.272	0.173	2.536	0.013*
Knowledge of Planting	1.523	±0.054	0.502	0.020	0.298	0.766
Income from Teak growing	1.455	±0.053	0.501	-0.040	-0.556	0.580
Teak removement to other crops cultivation	1.784	±0.044	0.414	-0.345	-4.662	0.000**
Wooden use in home	1.477	±0.054	0.502	-0.003	-0.038	0.969
Wooden sell to market	1.852	±0.038	0.357	-0.425	-3.676	0.000**
Project development	1.898	±0.032	0.305	-0.159	-1.417	0.160

Enter method for significant at P-value<0.05, and P-value<0.001**; R 0.834; R Square 0.696 or 69.6%; Adjusted R Square 0.652; F-value 15.843; ANOVA 0.000.*

Map of Lang use change during 2010-2020 in Research location