World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:8, No:11, 2014

# Historical Landscape Affects Present Tree Density in Paddy Field

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***Abstract*****—**Ongoing landscape transformation is one of the major causes behind disappearance of traditional landscapes, and lead to species and resource loss. Tree in paddy fields in the northeast of Thailand is one of those traditional landscapes. Using three different historical time layers, we acknowledged the severe deforestation and rapid urbanization happened in the region. Despite the general thinking of decline in tree density as consequences, the heterogeneous trend of changes in total tree density in three studied landscapes denied the hypothesis that number of trees in paddy field depend on the length of land use practice. On the other hand, due to selection of planting new trees on levees, existence of trees in paddy field now relies on their values for human use. Besides, changes in land use and landscape structure had a significant impact on decision of which tree density level is considered as suitable for the landscape.

***Keywords*****—**Aerial photographs, land use change, traditional landscape, tree in paddy fields.

## I. Introduction

TRADITIONAL landscapes of agricultural systems have long been capable of balance the needs of human and those of nature. Whereas conservation of those landscapes remains one of the main issues in current landscape ecology [1], the fact that those landscapes are disappearing due to urbanization, agricultural modernization and abandonment has reached an alarming level. Beside resources loss, it is common knowledge that ongoing landscape transformation threatens species diversity and caused consequences for the ecosystems. But to understand specifically the mechanism of how landscape transformation affects the ecosystem as well as the corresponding species is very important in pursuance of conserving those traditional ones.

Paddy fields with many standing trees located either in paddy floor or on paddy levee is the typical landscape of rural areas in Northeast Thailand. Unlike other irrigated rice fields, the tree-rice system traditionally in rain-fed paddy contains diverse and abundant natural resources. Due to the presence of various tree species, which are the habitat for fungi, insects, birds and other small animals, the resources gain much more benefit than usual. Famers there have been gathering various biological resources from the ecosystem for daily uses and also as goods for market, which have been helping to save their livelihood, especially in rain-fed rice growing areas, due to the low productivity and unfavorable situation for rice production [2]–[4]. So far, studies on trees in this landscape have showed a wide range of variation in density of trees, locally and regionally. Also, period of land use was often discussed in previous researches as a factor that influences tree density: the older the paddy land, the fewer the numbers of tree; without showing any specific evidences. In recent years, trees in paddy fields have been reducing rapidly by land consolidation caused by modernization of rice cultivation, without any development strategies and management measures [5]. Meanwhile, severe deforestation in the region causes a decline of forest products such as charcoal or firewood, pressure more on using trees in paddy fields. Thus, it has become an urgent subject to learn from the past of the landscape, in order to plan strategies for sustainable conservation of the future one.

Our study was conducted to find out precisely how the chronological factor and land use changes impact the density and structure of tree distribution in paddy field. We hypothesize that:

1. Landscape transformation has affected spatial structure of tree distribution in paddy field.
2. Trend of changes in tree density depended on the length of land use practice for rice cultivation.

To test these hypotheses, data of land use changes together with density of tree in paddy were collected in a time series, using aerial photographs (1975, 1991) and satellite image (2000s) in three landscapes of three villages: Phon Than, Lao Nokchum and Si Chompu, all located in the northeast of Thailand. Field surveys were also conducted in 2012 for obtaining of main village features and collected information about the present tree species composition.

## II. Study Sites and Methods

### A. Study Sites

Often known as “Isan” (means “northeast” in the Thai language), the northeastern region of Thailand located on the Korat Plateau, from the latitude 14º7’ N to 18º26’ N and longitude 100º54’ E to 105º37’ E. Bordered by the Mekong River to the north and east (also is the border between Thailand and Laos), and by Cambodia to the southeast, Isan is separated from Central Thailand by the Phetchabun mountain range to the west.

The average temperature range is from 19.6ºC to 30.2ºC. There are three seasons: the rainy season from May to October with average annual precipitation varies from 1270mm to 2000mm; the cool season from October to February and the hot season from February to May with the peak temperature may

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This work was supported by a Grant-in-Aid for Scientific Research (No.23255008).

reach 43.9ºC in April [6]. Unlike other regions, most of the Northeastern people belong to the Thai-Lao ethnic group. Agriculture is the main economic activity. However, production here lags behind the rest of the country due to the socio-economic conditions and the exceptionally hot, dry climate. The northeast remains Thailand's poorest region.

TABLE I
MAIN FEATURES OF THREE STUDY VILLAGES

| Village name | Elevation (m) | Landform | Period of land use (years) | No. of Household (2012) | Population (2012) | Satellite images year |
|---|---|---|---|---|---|---|
| Phon Than | 128 | Low terrace | 1000 | 192 | 457 | 2007 |
| Lao Nokchum | 153 | Flood plain | 300 | 193 | 700 | 2002 |
| Si Chompu | 205 | Low terrace | 100 | 110 | 1000 | 2010 |

Dry and saline soil conditions of the northeast make this region face difficulty in suiting upland crops other than sugarcane or cassava [7]. When the deforestation became the most severe in the region compared to others, the National Forest Policy adopted in 1985 in an effort of reforestation has expanded the area of eucalypt (*Eucalyptus camaldulensis*) plantation, which is said to be the only introduced species that can endure the critical soil and weather conditions of the region [8].

Although located in the same northeast region, the three target villages have dissimilar features. Phon Than and Si Chompu are both classified as low terrace region with easily access to water resources (about 300-900m apart from central village). Because of consisting of mostly denudation surface, and with a long history of land use (about 1000 years), Phon Than has apparently lower elevation than Si Chompu. On the other hand, Lao Nokchum located right next to the meander of Chi river, one in two main rivers in the northeast, and rice fields here are often partly flooded in peak time of rainy season from May to October. All three villages have a long period of rice cultivation, from the oldest 1000-year Phon Than to the 300-year Lao Nokchum and the newest Si Chompu with also more than 100 years of history (Table I). Through interview the village headman, we acknowledged that in all three villages, there has been the history of growing eucalypt, and in recent decades, a project of integrated growing eucalypt on paddy levee has been implemented.

### B. Methods

The landscape surrounding each target village was analyzed using Geographical Information Systems (Quantum GIS 1.6.0 and ArcView GIS 10). For each village, three maps representing different time layers were analyzed. Aerial photographs taken in 1975 and 1991, and satellite images (Landsat TM) in 2000s (the actual taken years of satellite images are different in each landscape due to available of good quality images, and are listed in Table I), were used for measuring the tree distribution patterns and the area of respective land-use types (paddy fields, other crop fields, open water, forest patches and village settlement areas). At each target village, the landscape was analyzed at 1 km spatial scale by 1-km radius circle, chosen to include the whole settlement of the target village and the surrounding paddy fields but not to overlap with other village settlements (Fig. 1). For measuring level of the urbanization, geographic information of well-constructed main roads was also recorded.

Paddy field was recognized from other crop fields in the images by the netlike appearance of levees, which is man-made earthen ridges used as footpath, property boundary, or space for planting trees [9]. The length of paddy levee was also measured using the Calculate Geometry of ArcView GIS 10. From satellite image and aerial photographs, it is difficult to identified exactly numbers of each individual tree. Thus, each canopy of tree was considered one tree-unit on behalf of tree-individual density. Density of two components of tree distribution: in field floor and on paddy levee was then calculated when dividing counted numbers of tree either in paddy floor or in paddy levee for total area of paddy field respectively.

Annual rates of change were calculated for each type of land use as the percentage of change, divided by the number of years disconnecting the pairs of time layers being compared. Beside proportions change, the changes in landscape structure were followed over the three decades for each layer by computing three landscape metrics, which describe particular features of the landscape [10]: the Number of Patches (NP), the Mean patch size (MPS) and the Shannon's Diversity index (SHDI).

## III. RESULTS

### A. Land Use Change Detection

The annual rate of land use change and main road change over each period is described in Table II, separately in each landscapes and in average of three landscapes. In average, forest areas have been reducing continuously at rate of -3.63% and -1.16% per year, respectively in both two period of time series. Whereas village settlement and main road showed a gradually increasing rate of 1.70% and 2.86% in the first period, then 1.82% and 0.87% in the second period, respectively. Paddy areas increased in the former period: 1975 to 1991 at rate of 0.26% per year but then declined in the later one: 1991 to 2000s at rate of -0.28% per year. The constantly decline of the levee length per paddy area (-0.95% and -1.26%) showed the ongoing land readjustment for expanding field plot areas by removing levees (Table II).

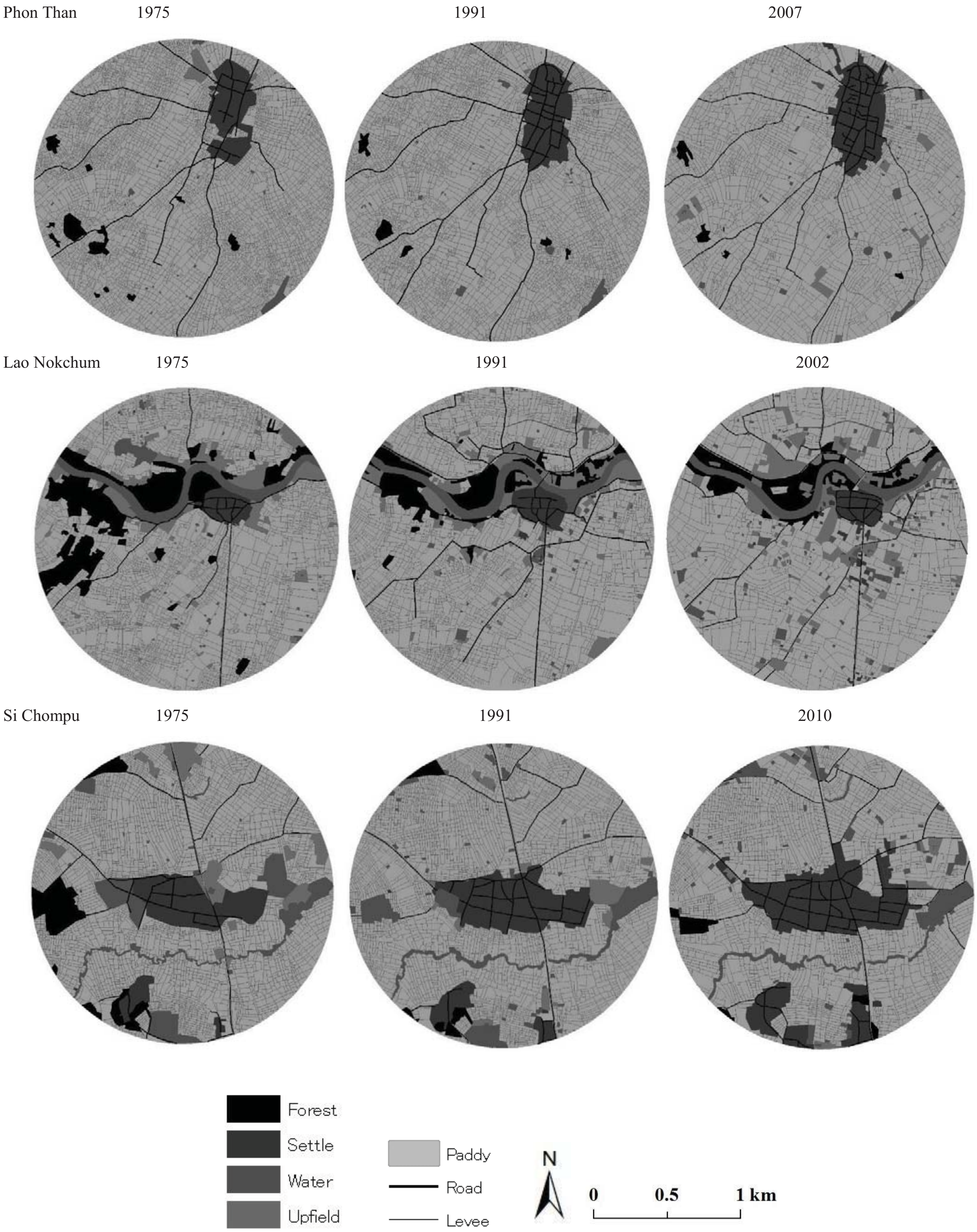


Fig. 1 Land use and land cover changes between 1975 and 2000s in three selected landscapes. Each circle has a radius of 1km

TABLE II
ANNUAL RATES OF CHANGES IN LAND USE AND MAIN ROAD FROM 1975 TO 2000S IN PERCENTAGE

| Village | Period | Forest patch | Settlement | Open water | Other fields | Paddy field | Road | Levee length/paddy area |
|---|---|---|---|---|---|---|---|---|
| Phon Than | 1975-1991 | -3.39 | 1.20 | 1.37 | -5.78 | 0.04 | 1.73 | -0.60 |
| | 1991-2007 | -1.82 | 1.70 | 3.19 | 206.33 | -0.29 | 0.61 | -2.20 |
| Lao Nokchum | 1975-1991 | -2.88 | 1.80 | 0.38 | 0.88 | 0.39 | 6.05 | -2.03 |
| | 1991-2002 | -1.95 | 1.05 | 1.99 | 1.96 | -0.25 | 0.27 | -0.84 |
| Si Chompu | 1975-1991 | -4.62 | 2.09 | -0.82 | -2.97 | 0.34 | 0.79 | -0.23 |
| | 1991-2010 | 0.30 | 2.71 | -1.15 | -1.48 | -0.29 | 1.72 | -0.74 |
| Average | 1975-1991 | -3.63 | 1.70 | 0.31 | -2.62 | 0.26 | 2.86 | -0.95 |
| | 1991-2000s | -1.16 | 1.82 | 1.35 | 68.94 | -0.28 | 0.87 | -1.26 |

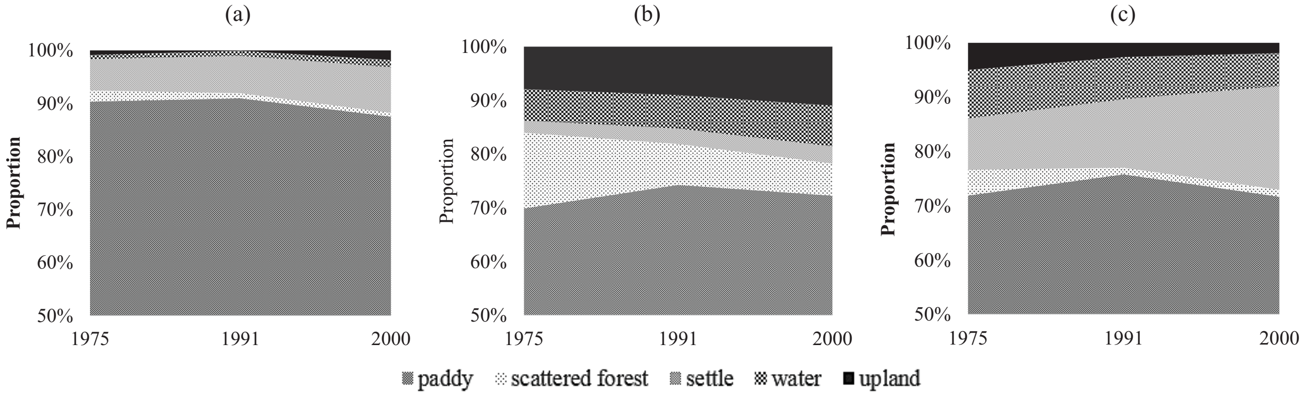


Fig. 2 Land use proportions change from 1975-2000s in three villages: (a) Phon Than, (b) Lao Nokchum, and (c) Si Chompu.

### B. Change of Land Use Proportions

Land cover proportions were estimated from the analysis of the homogeneous time series starting from 1975 (Fig. 2). In all three landscapes, forest patch had a negative rate of change. In contrast, village settlement was expanded gradually over the period. Up to 1991, area of paddy field all increased but after that, all decreased. Open water and other fields showed different trends in three landscapes. In flood plain Lao Nokchum, both had positively increased. In low terrace Si Chompu and Phon Than, area of open water both had negatively decreased. Other fields in Si Chompu decreased over time but in Phon Than, it first decreased from 1975 to 1991 then increased in the later period.

The increase in number of patches and the decrease in mean patch size imply that the landscape has become more fragmented (Figs. 3 (a), (b)). Thus it is obvious that Lao Nokchum landscape is significantly more fragmented than the other two villages. In general, the land use diversity in the landscape has been decreasing between 1975 and 1991, but since 1991, it had managed to recover slightly (Fig. 3 (c)). However, the landscape diversity index is clearly lower in Phon Than (Fig. 3 (c)), indicated the unequal in proportion of land use types here, with highly dominant of paddy field as seen in Fig. 2.

### C. Changes in Tree Density

In the recorded time series, trend of changes in tree density differed between three studied villages, as well as among different types of tree density within each village (Fig. 4). In general, tree density in floor was minor and decreased over two periods, except its slightly increasing from 1991 to 2000s in Phon Than. Tree density on levee was major and showed signs of risen from 1975 to 1991 in Lao Nokchum and from 1991 to 2000s in Si Chompu (Fig. 4). However, only in Si Chompu that finally total density had a positive of change in 2000s, compared with that in 1975 (Fig. 4).

## IV. DISCUSSION

The continuously reducing of forest areas reflected the fact of severe deforestation happening in the region whereas expansion of village settlement and well-constructed road were corresponded with the rapid development of the economic and urbanization. Those human activities caused consequences to the landscape changes, which then affected tree density in paddy fields.

When forest was converted to paddy field, some trees were left standing for used in various ways [2]. Trees in floor then reduce over time universally due to natural death when flooding field or cutting for used, which was proved by our results (Fig. 4). At the same time, trees survived or were newly planted on levees [2], resulting in higher proportion of tree density on levee compare with that of tree density in floor (Fig. 4).

To examine further the relationship of tree density of tree on levee with changes of land use, we based on the following equation:

$$levee\ density = \frac{no.of\ tree}{paddy\ area} = \frac{no.of\ tree}{levee\ length} \text{ x } \frac{levee\ length}{paddy\ area}$$

Therein, levee density (unit/ha) was found to be in high correlation with no. of tree per levee length (unit/m) (r = 0.928, p<0.01), rather than with levee length per paddy area (m/ha).

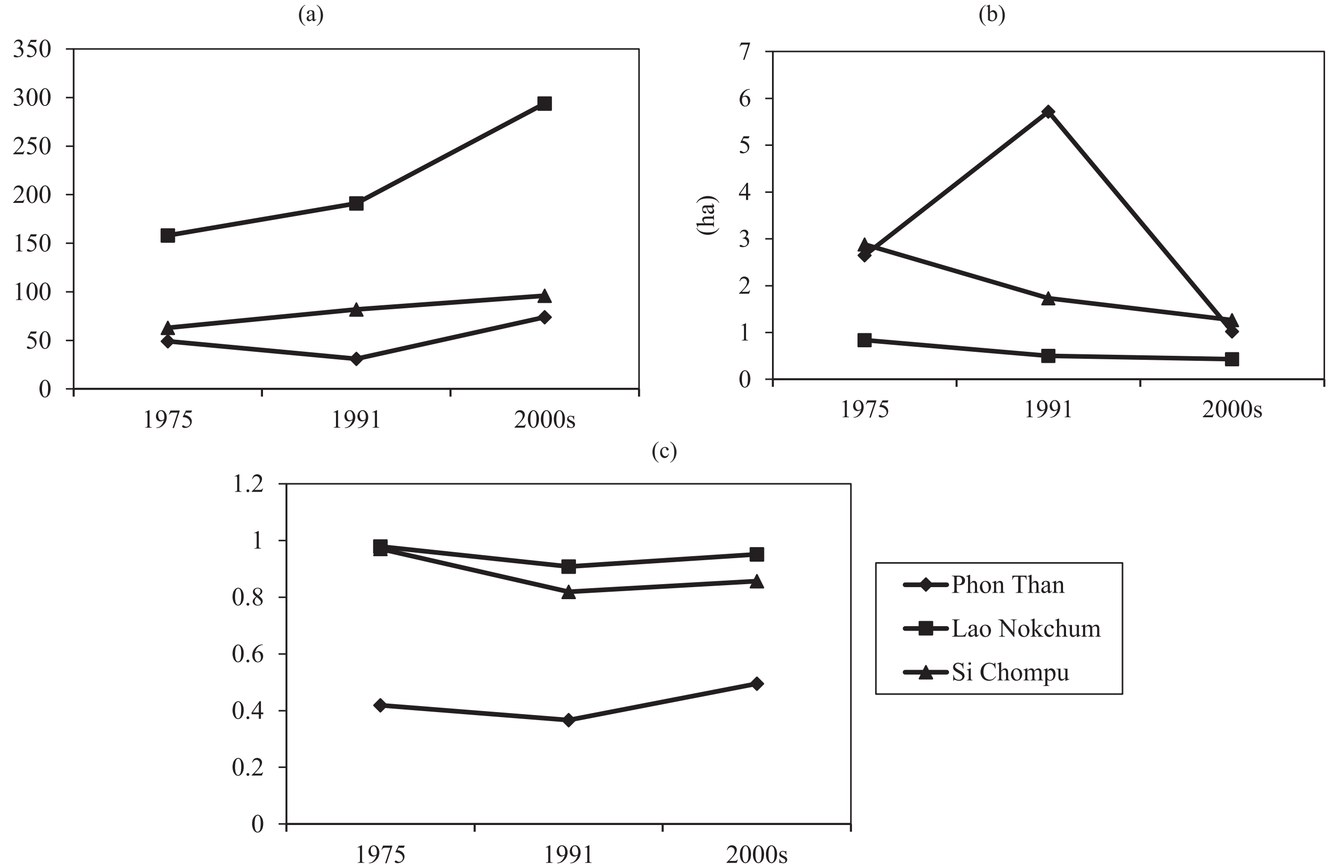


Fig. 3 Changes in landscape structure measured by three landscape indices from the time series in three landscapes (a) Number of patches (NP); (b) Mean patch size (MPS); Shannon's Diversity index (SHDI)

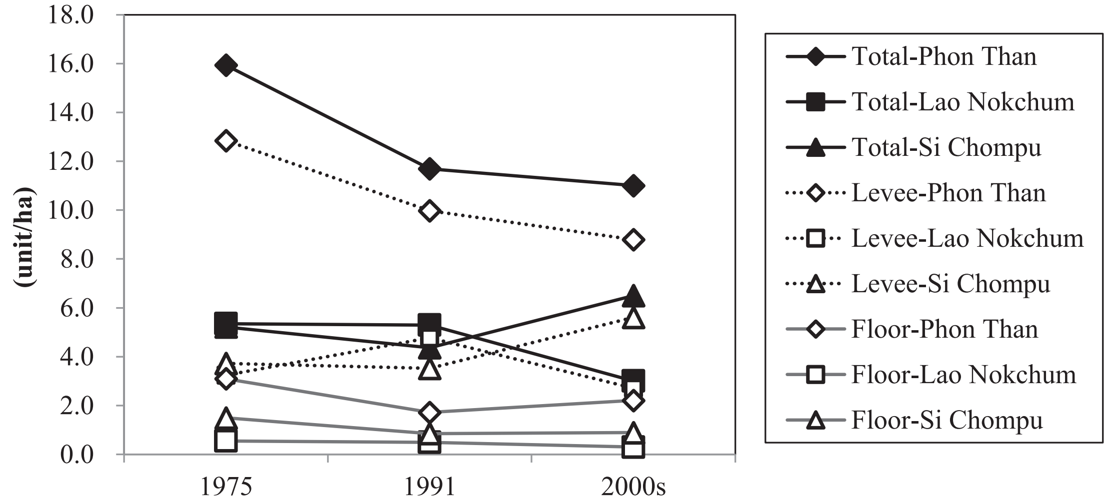


Fig. 4 Changes of total tree density (Total), tree density on paddy levee (Levee) and tree density in paddy floor (Floor) in three landscape through three time layers

This explains why despite the repeatedly reducing of levee length per paddy area, the levee density was not kept reducing. Farmers prefer a paddy field with trees rather than no tree, hence decided to preserve some species that thought to be valuable, and even planted new ones on paddy levees, as we acknowledged through field surveys. However, landscape structure might also play an important part in decision of future tree density. When landscape structure were dominated by paddy fields and originally had high tree density, it would then lead to higher ratio of natural generated saplings and less affected by human interference. This might be the cause behind the increasing trend of tree in floor from 1991 to 2000s in Phon Than (Fig. 4), as this village landscape had the largest paddy areas proportion (Fig. 2). On the contrary, landscapes with initially few tree would then reflected evidently the effect of human activities. Nevertheless, only in low terrace Si Chompu with more suitable conditions for application of trees planting than flood plain Lao Nokchum, had an increasing trend of total tree density up to 2000s (Fig. 4).

Our study was the first to showed real data on changes of tree density over time of land use practice for rice cultivation. Despite the general consensus that trees would gradually reduce as time pass, the dissimilar trend of changes recorded in three landscapes then implied that period of land use was not a determinant to tree density in paddy field. And the results also suggest that tree in paddy field might not disappear in the future landscape.

## Acknowledgment

The authors wish to express profound gratitude to Ms. Ratchaporn Seetho for her contribution. Gratitude is also extended to Prof. Kazuo Funahashi for his valuable advices. This research would never have been completed without the generous hospitality of the local residents at three studied villages.

## References

[1] H. Palang and G. Fry, “Landscape interfaces cultural heritage in changing landscapes” Kluwer, Dordrecht, 2003
[2] S. W. Grandstaff, T. B. Grandstaff, P. Rathakette, D. E. Thomas, J. K. Thomas, “Trees in paddy fields in Northeast Thailand” in: Marten, G.G., Ed. Traditional agriculture in Southeast Asia. Westview Press, Boulder & amp, London, 1986, pp. 273-292
[3] Y. Kosaka, S. Takeda, S. Prixar, S. Sithirajvongsa, K. Xaydala, “Species composition, distribution and management of trees in rice paddy fields in central Lao, PDR” Agroforestry System 67, 2006, pp. 1-17
[4] Y. Natuhara, A. Imanishi, M. Kanzaki, S. Southavong, I. Duangvongsa, “Uses of trees in paddy fields in Champasak Province, southern Lao PDR” Landscape Ecology Engineering 8, 2006, pp. 115-122
[5] P. Vityakon, S. Subhadhira, V. Limpinuntana, S, Srila, V. Trelo-ges, V. Sriboonlue, “From forest to farmfields: Change in land use in undulating terrain of northeast Thailand at different scales during the past century” Southeast Asian Studies 41(4), 2004, pp. 444-472
[6] Thai Meteorological Department, “The climate of Thailand” Climatological Group, Meteorological Development Bureau, Bangkok, 2012
[7] B. Prachaiyo, “Farmer and forests: A changing phase in northeast Thailand” Southeast Asian Studies 38, 2000, pp. 273-446
[8] M. Masaki, “Eucalyptus planting and community development in north east Thailand” in: Reports submitted to the Regional Expert Consultation on Eucalyptus. Vol 2 United Nations Centre for Regional Development, Bangkok, Thailand, 1996
[9] K. Fukamachi, H. Oku and A. Miyake, “The relationships between the structure of paddy levees and the plant species diversity in cultural landscapes on the west side of Lake Biwa, Shiga, Japan” Landscape Ecology Engineering 2005, pp. 191-199
[10] M. G. Turner and R. H. Gardner, “Quantitative Methods in Landscape Ecology” Springer-Verlag, New York, NY, USA, 1991