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Original Article

Impacts from tourism development and agriculture on forest degradation in Thap Lan National Park and adjacent areas

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A R T I C L E I N F O

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A B S T R A C T

The overlapping area between Thap Lan National Park and Thai Samakkhi subdistrict is a popular tourist destination in Nakorn Ratchasima province, Thailand and in recent decades, this area has been extensively developed for both tourism and agriculture. However, such changes have violated Thai national law since most of the developed areas are within Thap Lan National Park. Therefore, the effect of these developments on the natural forest community was studied. A sample size of 111 temporary plots was set up for collecting data on native tree species and exotic plant species of all life-forms. The findings revealed that the vegetation cover could be categorized into two main groups: 1) natural plant communities, consisting of dry evergreen forests, mixed deciduous forests and secondary forests; and 2) plant communities resulting from anthropogenic disturbances, consisting of forest plantations, field crops, orchards, resort parcels, and temple vicinities. The study also found that tree sapling and tree seedling densities and the percentage ground cover were significantly lower in areas developed for tourism and agriculture than in areas of natural plant communities. This reflected the inability of native species to regenerate and disperse naturally in this modified landscape. In addition, in the human-developed areas, several introduced, invasive, alien plants and weeds in field crop, orchard and resort plant communities were found. The development of tourism activities and agriculture were the major factors which substantially threatened the sustainability of the natural ecosystem of the tropical forests in this region.

Introduction

The overlapping area between Thap Lan National Park (TLNP) and Thai Samakkhi subdistrict (TSS), Wang Nam Khiao district, Nakorn Ratchasima province is a famous natural, agricultural and cultural tourist attraction in Thailand and because of the cool weather and a variety of tourist attractions, a great number of tourists enjoy visiting and holidaying in this subdistrict (Thap Lan National Park, 2014). As a consequence of this popularity, many types of development have taken place in recent decades to accommodate and facilitate the number of visitors, such as resorts and homestays (Phumsathan et al., 2015). Moreover, the local administrative organization has continuously encouraged local tourism by publicizing tourism and developing new kinds of natural tourist activities and hospitality services (Thai-Samakkhi Subdistrict Administrative Organization, 2013) in order to create more career opportunities for the purpose of economic growth. However, such development has violated the Thai National Park Act, B.E. 2504 (1961) (Royal Thai Government, 1961) and has caused many problems, particularly through the degradation of the natural environment and biological diversity.

According to existing aerial photos, the overlapping area between TSS and TLNP was primary forest until the road was developed in 1953. Most of the TSS areas overlap with the area of TLNP. The National Park is a major part of the Dong Phayayen-Khao Yai Forest Complex, which was designated as one of the two World Natural Heritage Sites in Thailand in 2005. This forest complex is considered to be a significant habitat for wildlife, especially for large vertebrates, and for important local plant species because it represents natural ecosystems of the southeastern region of Thailand (Department of National Parks, Wildlife and Plant Conservation, 2006). The area of TSS overlapping with the National Park was also considered a natural ecological corridor connecting TLNP and Khao Yai National Park (Yodyoy et al., 2015). However, it was found that in the past two decades, the land in the area of overlap has been developed for agriculture and tourism,

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including farmland and resorts. At present, TSS areas are being rapidly altered from a natural forest into agricultural areas and some parts have been intensively used for tourism. For this reason, the natural resources of the National Park have deteriorated, impacting the condition of the tropical forest ecosystem. Thai Government agencies, especially the Department of National Parks, Wildlife and Plant Conservation (DNP) is now keen to know the impact on the condition of natural plant communities caused by the development of agriculture and tourism in TSS (Ministry of Natural Resources and Environment, 2016). However, no published research relating to this issue in the area was found. Consequently, there is no information available for planning and managing the area of overlap. The current study focused on changes in the structure and composition of plant communities resulting from the development of tourism and agriculture. Information on the current vegetation communities derived from this study will help DNP to make informed decisions and initiate an effective management program for the area of overlap between TSS and TLNP. This will increase the sustainability of the Natural World Heritage Site as a whole.

Materials and methods

Study site

This research was conducted in TSS, located in the west of Nakorn Ratchasima province. The study focused on the area of overlap between TSS and TLNP which is approximately 52.40 km^2 (Phumsathan et al., 2015) and surrounding areas (Fig. 1). The altitude of this area is in the range 400–700 m above mean sea level (amsl) and the topography is mostly flat to undulating (Land Development Department, 2009).

TSS was the famous tourism destination of the country being widely known as “Cool-climate town”. In recent decades, tourism development in TSS has substantially increased as a result of government policy promoting tourism and infrastructure was constructed to support tourism development (Thai-Samakkhi Subdistrict Administrative Organization, 2013; Phumsathan et al., 2015). Additionally, more than 150 resorts were illegally constructed in the study area mostly by outside investors (Thap Lan National Park, 2014). Phumsathan et al. (2015) reported that there are more than 30 tourism sites in the villages and mostly agriculture-related sites, such as fruit orchards, mushroom farms, and flower farms and the majority of visitors are of the holiday-mass popular individual type who are highly focused on popular destinations and pay little regard to local communities.

Land use classification based on Land Development Department (2009) showed that most of the land in the area of overlap was used for agriculture (61.63%), with the rest being forested areas (14.54%), forest plantations (6.34%), community areas, in the vicinity of temples and resorts (8.42%) and water bodies and other areas (9.07%).

Plant community data collection

1) The geographical characteristics of the surrounding natural forest areas were intentionally selected to be similar to those of TSS to make sure all the sample plots were similar in geographical condition and altitude. This study was conducted in 2014 by setting up 111 temporary sample plots randomly scattered over the study site to investigate current plant communities (Fig. 1). Plots represented the major land use types consisting of dry evergreen forest, mixed deciduous forests, secondary forests, forest plantations, field crops, orchards, resorts, and temples. Since the local human community and resort owners have taken over most of the TSS area, there are current conflicts between TLNP and illegal possessors of land parcels. Consequently, the study researchers had serious problems in

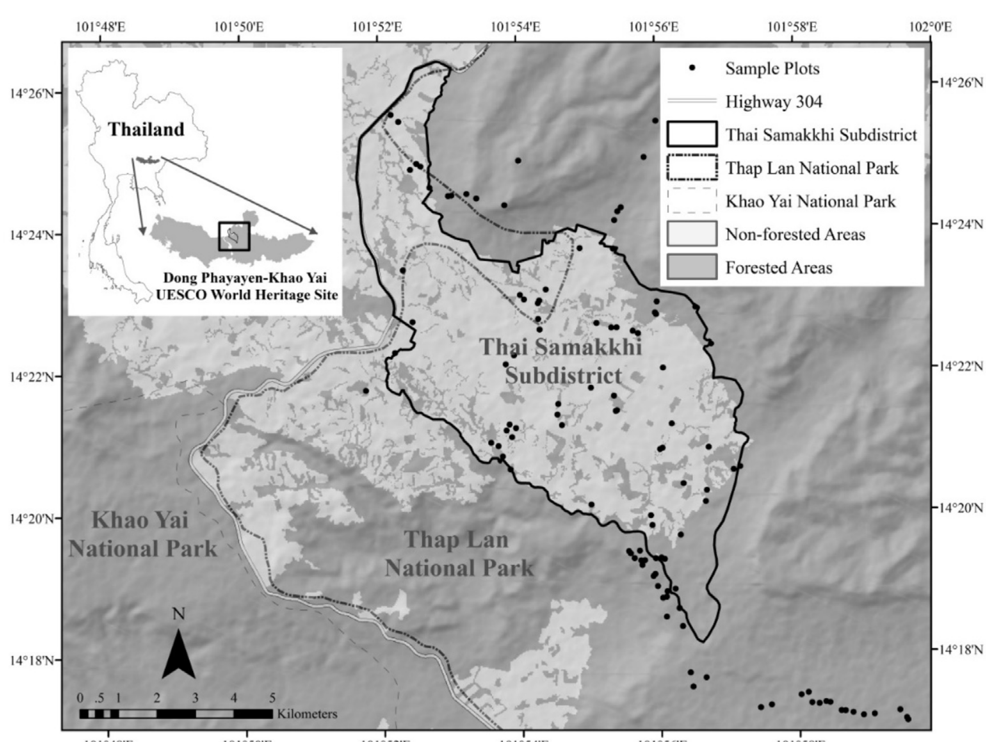

Fig. 1. Location of Thai-Samakkhi subdistrict, Wang Nam Khiao district, Nakhon Ratchasima province and the sample plots located in the study area.

getting permission to gather the data relating to plant communities in particular areas for this study. Therefore, some temporary plots, especially those located in the resort and agricultural areas were selected based on limited access in order to obtain proper vegetation data.

2) Temporary plots 0.09 ha in area (30 m × 30 m) were used to study the plant communities representing the major land use types existing in the study area. Each plot was divided into nine smaller subplots (10 m × 10 m). If the habitat of a plant community was long and narrow such as for ones located near a stream or along a roadside, 10 m × 90 m temporary plots were used, with each of these plots divided into subplots (10 m × 10 m).
3) In each of the subplots, the existing woody plants with a diameter at breast height (DBH) ≥ 4.5 cm were identified to the species level and the DBH was recorded for all trees. At the corner of each subplot, a smaller plot (4 m × 4 m) was set up to mark the existence of saplings (woody plants with height ≥ 1.3 m, but DBH < 4.5 cm). At the corner of each of the smaller plots, a quadrat (1 m × 1 m) was set up to assess seedlings (woody plants with height < 1.3 m).
4) Surveys of exotic and invasive species were carried out. The surveys were conducted along local roads in TSS and the surrounding areas. A list of exotic and invasive species was made with reference to the information provided by the Office of Natural Resources and Environmental Policy and Planning (2013), Department of National Parks, Wildlife and Plant Conservation (2010) and Poopath et al. (2013).

Plant community data analysis

The plant community data gathered from the sample plots were analyzed to compare stand structure and tree species composition within given plant communities by estimating the dominance in density (D), frequency (F) and basal area (BA) of all species. These three values (D, F, BA) were standardized to relative values (0–100) in order to compare the relative density, relative frequency and relative dominance in basal areas of each tree species in each 0.09 ha sample plot. These three relative values were summed to represent the importance value (IV) indices of the plant species (sum in the range 0–300). If a plant species has a higher IV, this value reflects a higher dominance in density, frequency or tree basal area or a combination compared to other plant species with a lower IV in a given sample plot (Skeen, 1973; Mueller-Dombois and Ellenberg, 1974). The biological diversity of woody plant communities existing in the sample plots was estimated using Shannon's diversity index (Ludwig and Reynolds, 1988; Kent and Coker, 1994; Spellerberg and Fedor, 2003).

The plant community data gained from the temporary sample plots were then analyzed using cluster analysis to study the degree of similarity among the species growing in the sample plots. The index of similarity (calculated based on the Euclidean distance method) was used to group the clusters in terms of species composition and IV. Later, Ward's linkage (Kent and Coker, 1994; Jongman et al., 1995; Sadia et al., 2016; Oksanen et al., 2018) was used to differentiate the clusters by minimizing the variance within the cluster while maximizing the variance among the clusters. Analysis of variance was applied to analyze differences in stand characteristics among the eight ground cover communities. Tukey's honest significant difference (HSD) method was used to perform a pairwise comparison among the means of each pair of ground cover types using a confidence interval of 95%. All statistical analyses were done using the “vegan” package version 2.5–2 (Oksanen et al., 2018) in the R platform Version 3.2.4 (R Core Team, 2016).

Results and discussion

Plant community classification

The surveys in TSS and surrounding areas resulted in a total of 371 species of trees with DBH ≥ 4.5 cm. Dry evergreen forests had 278 species, mixed deciduous forests 112 species, secondary forests 110 species, forest plantations 67 species and there were 55 species in the vicinity of temples, with 83 species in resort parcels, 17 species in orchards and 19 species in field crops. In analyzing the similarity of these plant communities, the cluster analysis technique took into consideration only those tree species having the highest 10 IV values from each of the 101 sample plots (only the plots with the similar altitudes to TSS). The cluster analysis showed that the vegetation could be classified into two main types: 1) natural forest communities; and 2) plant communities impacted by human land development activities. These two main vegetation types could be further sub-divided by determining the similarity of the sample plots at 20% into eight sub-community types including mixed deciduous forests, dry evergreen forests, secondary forests, orchards, field crops, and resort surroundings. The result of this classification revealed that the vegetation could be clearly classified according to the impact of human land development, especially those sample plots representing the developed land cover types which were completely different from those influenced by natural processes. On the developed land, plant species were selected and managed according to various objectives of land use such as growing trees for timber production, for agriculture and for the ornamentation of resorts. Therefore, existing plant species and their abundances were completely different among the different vegetation types. The classification of the plant communities resulting from the cluster analysis corresponded with the present condition of land use. However, the cluster analysis was not able to distinguish between dry evergreen forest communities and plant communities found in the temple neighborhoods because both plant communities had similar dominant species in the canopy and subcanopy layers (Fig. 2).

Plant communities in the vegetation cover classification

The conditions of the plant communities identified in the vegetation cover classification were as follows.

Natural plant communities

1) In total, 237 tree species were found in 18 plots in the dry evergreen forest. The average basal area of these trees was 30.67 m^2/ha and the average tree density was 1086.42 trees/ha DBH ≥4.5 cm) (Table 1). Almost all sample plots in this forest type were outside TSS, on the sandstone plateau at an elevation of approximately 514 m amsl. The dominant canopy tree species were evergreen, particularly belonging to the family Dipterocarpaceae such as *Shorea henryana* Pierre, *Dipterocarpus turbinatus* C.F. Gaertn. and *Dipterocarpus alatus* Roxb. ex G. Don. Average tree height was 20 m and the canopy could be divided into three layers. (Fig. 2A).
2) In the 19 plots of mixed deciduous forest, there were 112 tree species, with an average basal area of 12.36 m^2/ha, and an average tree density of 568.42 trees/ha (Table 1). This forest type was intermixed with dry evergreen forests at a mid-elevation of approximately 460 m amsl. The dominant species were deciduous, including *Pterocarpus macrocarpus* Kurz, *Xylia xylocarpa* (Rxob.) Taub, *Afzelia xylocarpa* (Kurz) Craib and species of the family Lagerstroemia. Average tree height was 20 m and the canopy could be divided into three layers with a fairly open upper canopy (Fig. 2B).

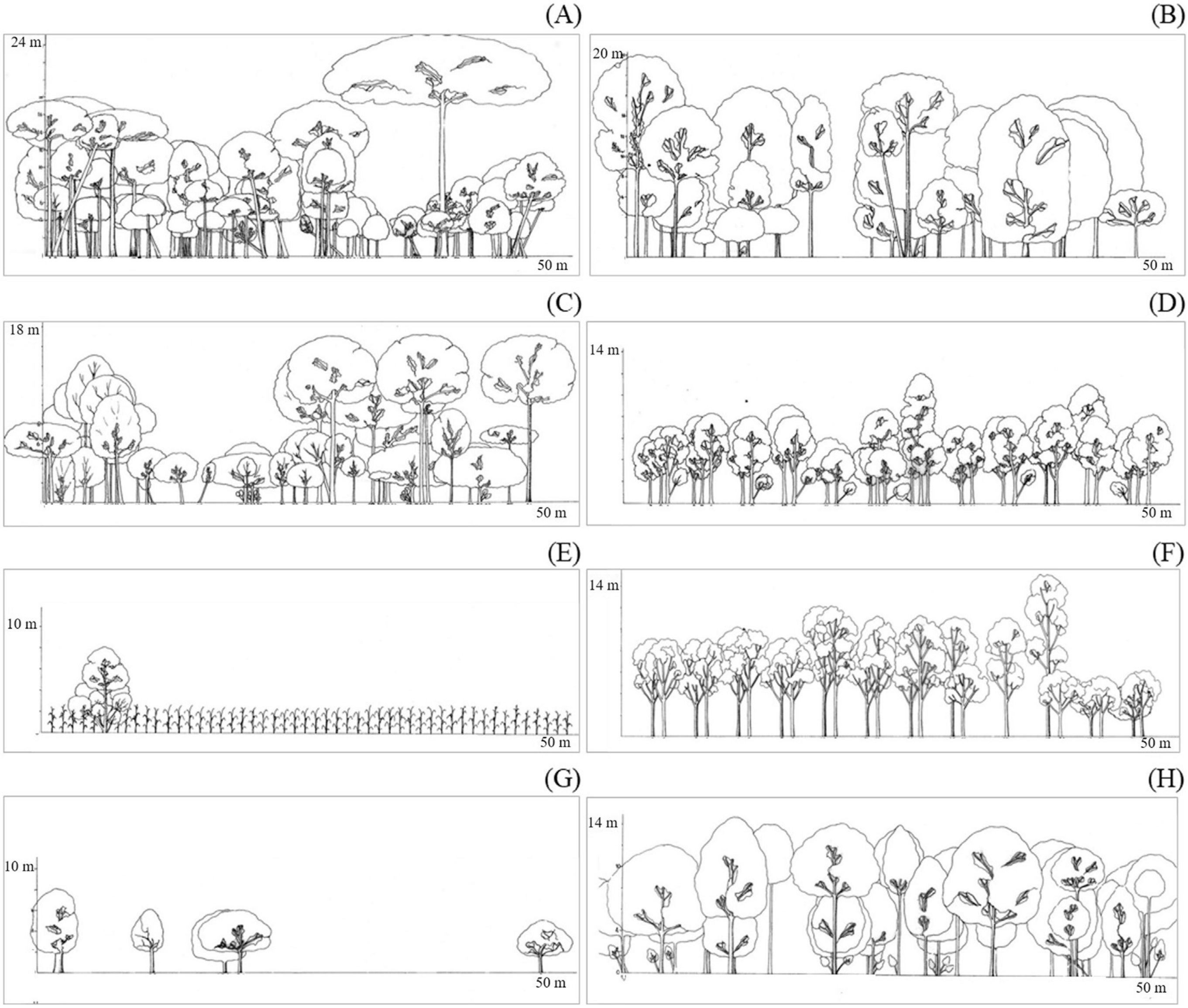

Fig. 2. Profile diagrams showing vertical structure of different vegetation types found in Thai Samakkhi subdistrict: (A) dry evergreen forest; (B) mixed deciduous forest; (C) secondary forest; (D) forest plantation; (E) field crop; (F) agriculture; (G) resort; (H) temple.

Table 1
General vegetation characteristics in each land cover type in Thai Samakkhi subdistrict and surrounding areas.

Land cover types	Total number of species	Average canopy cover (%)	Average number of tree species	Average tree basal area (m^2/ha)	Average tree density (per ha)	Shannon's diversity index (H′)
Dry evergreen forest (n = 18)	237	87.56 (1.44)^{b}	37.33 (2.70)^{a}	30.67 (0.02)^{a}	1086.42 (68.49)^{a}	4.73 (0.63)^{d}
Mixed deciduous forest (n = 19)	112	77.14 (3.07)^{d}	13.95 (1.57)^{b}	12.36 (0.01)^{bc}	568.42 (76.63)^{bc}	3.21 (1.14)^{c}
Secondary forest (n = 16)	110	60.96 (6.67)^{c}	13.63 (1.94)^{b}	12.62 (0.01)^{bc}	635.42 (79.11)^{b}	2.95 (0.98)^{c}
Forest plantation (n = 15)	67	81.95 (2.30)^{d}	7.80 (1.45)^{bcd}	17.32 (0.02)^{b}	697.78 (89.19)^{b}	1.99 (1.13)^{b}
Field Crop (n = 12)	19	30.47 (10.63)^{a}	1.92 (1.14)^{d}	3.50 (0.01)^{c}	95.37 (67.73)^{d}	0.000 (0.89)^{a}
Horticulture crop (n = 11)	18	58.05 (7.90)^{c}	2.45 (0.47)^{cd}	9.77 (0.02)^{bc}	307.07 (41.47)^{cd}	0.50 (0.81)^{a}
Resort (n = 15)	83	40.69 (7.24)^{ac}	8.13 (1.03)^{bcd}	9.52 (0.02)^{bc}	317.78 (46.59)^{cd}	2.52 (0.967)^{bc}
Temple (n = 5)	55	83.13 (5.72)^{bcd}	13.60 (2.71)^{bc}	16.83 (0.03)^{b}	520.00 (77.25)^{bcd}	3.00 (0.85)^{c}

Figures within parentheses indicate standard error of the mean. Different superscript letters indicate significant differences among means ($p < 0.05$).

3) The secondary forest was represented by 16 plots and consisted of 110 tree species in total. The average tree basal area was 12.62 m^2/ha, and the average tree density 635.42 trees/ha (Table 1). Secondary forests were found on the plains in the foothills and in the valleys and on the plateaus of sandstone at mid-altitudes (approximately 442 m amsl). Most secondary forests were rehabilitated abandoned farmlands, logged forests and previous village areas. Forest fire was common to these

forest stands due to regular burning by the local people. Forest rehabilitation and fire have introduced a variety of plant species to the forest stands, including pioneer species from the neighboring dry evergreen and mixed deciduous forests. The pioneer tree species included *Markhamia pierrei* Dop, *Trema orientalis* (L.) Blume and *Peltophorum dasyrachis* (Miq.) Kurz. The average tree height was 18 m. The canopy could be divided into three layers. The top canopy was open with a height of 15–23 m (Fig. 2C).

4) For forest plantations, 67 tree species were found in 15 sample plots. The average tree basal area was 17.32 m^2/ha with an average tree density of 697.78 trees/ha (Table 1). The average altitude of the plantation stands was approximately 442 m amsl. The forest plantations were monocultures or a mixture of commercial tree species, such as *Tectona grandis* L. f., *Pterocarpus macrocarpus Kurz* and *Xylia xylocarpa* (Rxob.) Taub. The average height of these trees was 18 m and the canopy could be divided into three layers. The top canopy was fairly open (Fig. 2D).

Plant communities caused by anthropogenic disturbance

1) In total, 19 tree species were found in 12 plots representing field crops existing in the area. The average basal area of native trees was 3.50 m^2/ha and the average tree density was 95.37 trees/ha (Table 1). These agricultural fields could be found at mid elevations (approximately 461 m amsl). Most of them were located within TSS. The crops which were grown intensively in these areas were tapioca, maize, sugar cane, and rice. Relict tree species were scattered in these agricultural areas, including *Shorea henryana* Pierre; *Dipterocarpus turbinatus* C. F. Gaertin and *Dipterocarpus alatus* Roxb. Ex G. Don. The average native tree height was 18 m. The upper canopy was highly discontinuous as it was surrounded by field crops (Fig. 2E).
2) Orchard stands were represented by 11 plots distributed at an average altitude of approximately 422 m amsl. There were 17 species of non-native (9 species) and native trees (8 species) in these plots. The average basal area of tree species was 12.26 m^2/ha with the average tree density being 306.06 trees/ha. The horticultural plants common in this area included *Hevea brasiliensis* (Wild. ex A. Juss) Muell. Arg., *Mangifera indica* L., and *Dimocarpus longanum* Camb. The average height of the native trees was 18 m. The canopy could be divided into one or two layers with the upper canopy being scattered at long distances (Fig. 2F).
3) In the resort areas, 83 tree species were found in 15 plots (average altitude of approximately 440 m AMSL). The average tree basal area was 9.52 m^2/ha and the average density was 317.78 trees/ha. Most of these trees (native or alien species) were introduced species and some trees had been translocated from other places for ornamental purposes, such as *Millingtonia horthensis* L.f., *Albizia saman* (Jacq) Merr. and *Mimusops eleggi* L. as well as a few native species. The average height of these trees was 15 m. The canopy comprised three layers. The upper canopy ranged from 12 m to 18 m and was not connected (Fig. 2G).
4) Five plots represented vegetation in temple surroundings at an average altitude of approximately 443 m amsl. These plots contained 55 tree species, with an average basal area of 16.83 m^2/ha and the tree density averaged 520 trees/ha. It was noted that some temples had conserved some native tree species and also introduced some other species. Consequently, the plant communities in the vicinity of the temples were composed of both native and introduced species, such as *Dalbergia cochinchinenis* Pierre, *Pterocarpus macrocarpus* Kurz, and *Azadirachta indica* A. Juss. The average tree height was 15 m and the canopy was could be into three layers. The trees in the upper canopy were not quite connected to one another, contrasting with the dry evergreen forest (Fig. 2H).

Tests of vegetation characteristics among different vegetation cover types using Tukey's HSD test showed that mean tree basal area, mean tree density, and mean percent canopy cover in the natural vegetation communities (particularly in dry evergreen forest and field crops) were significantly different whereas in the other areas were not different. These results imply that the official permission, issued by the Thai Cabinet Resolution on 11 June 1998, to temporarily allow local people utilizing the land in the national park for cultivation over recent decades has caused major harm to the forest ecosystem. Such developments within the National Park inevitably affected natural conditions of the forest ecosystem resulting in decreased plant diversity and altered species composition and stand structure.

Tree species diversity index

Tree species diversity estimated using Shannon's diversity index (H′) for the 111 sample plots in TSS and surrounding areas revealed that the lowest H′ found in the 17 sample plots was 0.00. No native tree species existed in these sample plots. The vegetation comprised field crops (8 plots), orchards (5 plots), monoculture forest plantations (3 plots) and resort areas (1 plot). Tukey's HSD test (Table 1) indicated that the dry evergreen forest plots had the highest mean diversity (H′) being significantly higher than other vegetation cover types. The vegetation type with the second highest diversity was a mixed deciduous forest. The tests revealed that mixed deciduous forests were not significantly different in diversity from secondary forests, temples, and resorts. Such results could be explained by the increase in tree species introduced by humans for resorts. In temple areas, some tree species in the dry evergreen forest had disappeared due to landscape modification in the monastery surrounding. The field crop areas had the lowest H′ diversity because these areas focused mostly on growing commercial plants, resulting in a low diversity value. In some disturbed areas, native tree species were scattered across the landscape. In areas that had been converted to agriculture, the population of native plants seemed to have declined substantially which was clearly caused by the replacement of the natural plant communities with invasive alien species to the ecosystem of the National Park. These findings were consistent with research conducted by Polsen (1997) and Raman et al. (1998) which showed that in land development areas, the diversity of plant species declined.

Natural regeneration

The 4 m × 4 m and 1 m × 1 m subplots were established to survey saplings and seedlings, respectively, and to compare natural tree regeneration between the various vegetation types to identify the influence of tourism and agricultural development. It was found that the various development activities differentially influenced sapling and seedling density among vegetation types. The mean sapling density (Table 2) in the dry evergreen forests was the highest (42,673.61 saplings/ha) and in the secondary forests second highest (32,421.88 saplings/ha), whereas that of the resort areas was the lowest (291.67 saplings/ha). The vegetation types showing the highest seedling recruitment were the secondary forest (368,750 seedlings/ha), the dry evergreen forest (248,333.33 seedlings/ha) and the resort areas had the lowest recruitment (1333.33 seedlings/ha) as shown in Table 2. Tukey's HSD test

Table 2
General conditions of tree seedlings and saplings in each land cover type in Thai Samakkhi subdistrict and surrounding areas.

Land cover types	Average number of sapling species	Average sapling density (per ha)	Average number of seedling species	Average seedling density (per ha)
Dry evergreen forest (n = 18)	28.89 (2.32)[a]	42673.61 (414.73)[a]	12.06 (0.90)[a]	248333.33 (3281.18)[ab]
Mixed deciduous forest (n = 19)	13.95 (1.76)[b]	17302.63 (270.79)[bc]	9.26 (1.09)[ab]	188947.37 (3175.71)[ab]
Secondary forest (n = 16)	13.13 (2.05)[b]	32421.88 (1145.90)[ab]	6.44 (1.10)[bc]	368750.00 (1.58)[a]
Forest plantation (n = 15)	10.73 (2.75)[b]	22416.67 (805.39)[abc]	3.20 (1.31)[cd]	36666.67 (1908.139)[b]
Field Crop (n = 12)	1.42 (1.25)[c]	1666.67 (156.30)[c]	0.58 (0.31)[d]	7500.00 (495.49)[b]
Horticulture crop (n = 11)	1.45 (0.72)[c]	1534.09 (84.981)[c]	1.00 (0.48)[d]	13636.36 (707.07)[b]
Resort (n = 15)	0.40 (0.40)[c]	291.67 (32.41)[c]	0.07 (0.07)[d]	1333.33 (148.15)[b]
Temple (n = 5)	5.00 (1.92)[bc]	6625.00 (275.69)[bc]	3.00 (1.55)[cd]	126000.00 (1.11)[ab]

Figures within parentheses indicate standard error of the mean. Different lowercase superscript letters indicate significant differences among means using Tukey's honest significant difference test ($p < 0.05$).

indicated that the mean number of sapling and seedling species in the agricultural and tourism areas were significantly lower than those in natural forests. In general, natural regeneration of seedlings and saplings of native trees in the TSS areas, where lands were used for agriculture and tourism purposes, were significantly lower in species richness than those in the natural forest areas. In particular, the resort areas where natural native plants could hardly be found, the mean numbers of sapling and seedling species were the lowest. These results demonstrated that the dynamics of plant communities had changed and that it was not possible to rely only on natural succession to restore these vegetation types back to their original forest ecosystems.

The result from this study in secondary forest supported Panichsuay (2012) in that the restored forests tended to resemble the dry evergreen forests in terms of species composition and stand structure. The introduction of pioneer tree species helped to enhance environmental conditions to enable regeneration and the establishment of later successional native trees. Panichsuay (2012) also showed that forest restoration with selected fast-growing trees species better enabled native tree species to regenerate and shortened the time needed to restore disturbed areas to natural forest. However, in these restoration processes, introduced plants had to be carefully selected to avoid invasive alien species. Otherwise, the native tree species would decline in numbers and finally disappear (Parrotta et al., 1977) due to their inability to compete with invasive species. Forest restoration and rehabilitation of areas disturbed by agriculture and tourism activities should be carefully managed, especially by selecting plant species for restoration programs to achieve the goals of preserving the forest ecosystems of the region.

Native plant communities in Thai Samakkhi subdistrict

The survey of native tree species in TSS found a total of 256 trees with DBH > 100 cm. Most of them were randomly distributed throughout the area as relict trees. These 256 native trees consisted of 48 species in 25 families, with 195 trees being evergreen species which were the common species found in the dry evergreen forest of this region. The most abundant species of large trees was *Irvingia oliveri* Pierre (68 trees). Large trees belonging to the family Dipterocarpaceae, the indicator tree family of evergreen forest in Southeast Asia, were found in the valleys along streams and included 35 *Dipterocarpus turbinatus* C. F. Gaertn, 6 *Shorea henryana* Pierre and 5 *Dipterocarpus alatus* Roxb. Ex G.Don. On the upper slopes, deciduous tree species, which are indicator tree species for deciduous forests, were also found, including *Pterocarpus macrocarpus* Kurz (33 trees), *Lagerstroemia calyculata* Kurz (19) and *Afzelia xylocarpa* (Kurz Craib) (6). The persistence of these old trees showed that the original forest types before human encroachment were dry evergreen forests and mixed deciduous forests.

Alien invasive plants

Based on the official list of registered invasive alien species in Thailand (Office of Natural Resources and Environmental Policy and Planning, 2013), the 31 species of exotic plants found in this study were classified as 17 species of Category I invasive alien species, such as *Hyptis suaveolens* (L.) Poit, *Mimosa diplotricha* C. Wright ex Sauv Allen, *Mimosa pigra* L. and *Leucaena leucocephala* (Lam.) de Wit; 5 species of Category II alien species with potential for invasion, including *Amaranthus spinosus* L., *Sphagneticola trilobata* (L.) *Pruski, Rivina* humilis L., *Peninsetum purpureum* Schumach. and *Eryngium foetidum* L.; 4 species of Category III alien species which have become invasive in other countries but to date are not invasive in Thailand, consisting of *Spathodea campanulata* P. Beauv., *Thalia geniculata* L., *Citharexylum spinosum* L., *Psidium guajava* L. and *Echinodorus cordifolius* (L.) Griseb.; and 1 species of Category IV invasive alien species which have not been introduced into Thailand, including *Typha angustifolia* L. However, according to Office of Natural Resources and Environmental Policy and Planning (2013), Department of National Parks, Wildlife and Plant Conservation (2010) and Poopath et al. (2013) the current study found 289 alien plant species, classified into 88 families. Among these, 43 families belonged to the family Leguminosae. Most of the exotic species (213 species) were introduced as ornamental plants, and landowners might not know that those plants were either alien or invasive. Furthermore, this study categorized the exotic plant species into two groups as invasive alien species, Category I or II (Office of Natural Resources and Environmental Policy and Planning, 2013) or with an invasion score of 1, 2 or 3 (Poopath et al., 2013) and as non-invasive alien species otherwise. The total number of non-native plant species could be categorized into 189 non-invasive alien species in 72 families and 100 invasive alien species in 38 families. In the natural forests adjacent to TSS, a total of 75 non-invasive alien species and 25 invasive alien species were found (Fig. 3). The non-invasive and invasive alien plants in resorts and agricultural areas significantly outnumbered those in the natural forests. This indicated that the alien species had begun to spread out from the human-developed lands to the natural forest and to the protected areas which were connected to the edge of TSS. It was also observed that invasive alien trees already existed in primary dry evergreen forests, mixed deciduous forests, secondary forests, and forest plantations. This result agreed with Lugo (2004) in that the lands developed for agriculture and tourism tended to have more alien species than the natural forest areas. This study demonstrated that land development for agriculture and particularly for tourism caused native plant species to decline and enabled invasive alien species to establish. The latter had spread widely and had invaded the natural forests directly impacting the establishment of native tree seedlings and saplings in the natural forests. This was apparently due to the inability of native species to

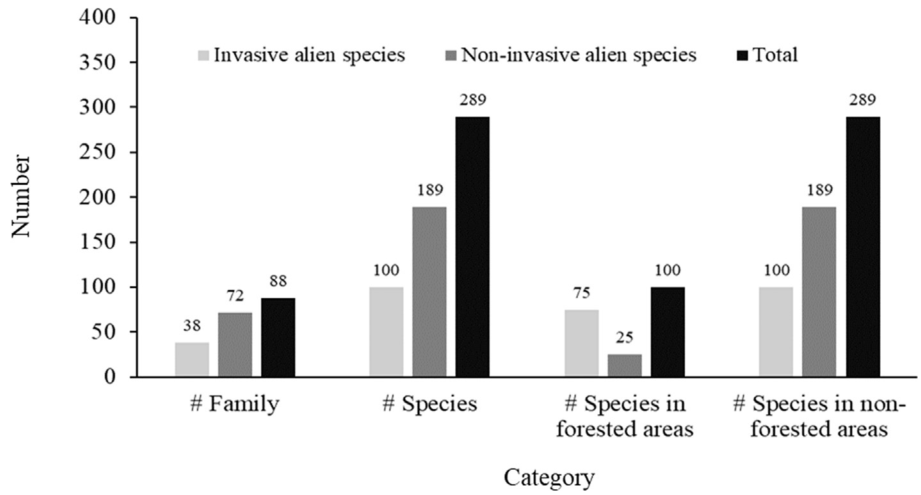

Fig. 3. The number of families and species of exotic and invasive plant species found in Thai Samakkhi subdistrict and its surrounding areas.

compete with the invasive alien species (Ryan and Crowley, 2002). Invasive alien weeds tend to have higher resistance and resilience to severe environments, such as trampling and drought. Daehler (2003) also revealed that invasive species commonly have some advantage characters such as having wide range of growing condition, higher leaf area, lower tissue construction costs and higher phenotypic plasticity. Invasive plants also tend to grow faster, occupy sites even with high soil compaction, and more rapidly establish than native tree species in either disturbed or natural habitats (Hammitt et al., 2015).

Restoration of degraded forest

The deforestation in the overlapping areas was considered as resulting in a large, degraded landscape mostly caused by monoculture and polyculture farming. In the future, when a restoration program is required by Thap Lan National Park, an alternative method of regrowth management could be taken into consideration to restore biodiversity to this degraded forest ecosystem intruded by invasive plant species. The use of forest plantations to catalyze the degraded lands may be an inevitable practice in this situation (Parrotta et al., 1997). Based on previous studies in nearby locations having a somewhat similar forest ecosystem, exotic fast-growing species of *Acacia auriculiformis* and *A. mangium* could serve as catalyzing tree species for forest stands and they have been proved to be non-invasive for the purpose of forest rehabilitation and for accelerating succession processes of native plant communities in this particular region (Kamo et al., 2002; Doi and Ranamukhaarachchi, 2009, 2013). Canopy closure of the fast-growing tree stand will play an important role in eradicating undesired light-demanding understory plants such as vines and herbs (Kamo et al., 2002) as well as potentially suppressing most invasive plant species (Padmanaba and Corlett, 2014). This silvicultural practice will also facilitate soil improvement and allow the seedling establishment of indigenous tree species in the forest plantation. On the other hand, in the later stage of succession, introduced exotic trees such as *A. auriculiformis* and *A. mangium* may need to be eliminated to accelerate succession of native plant species. Lugo (2004) pointed out that native pioneer species will not be able to colonize in the sites where introduced species are dominant as a canopy layer. The shade tolerance native species and their seedlings are potentially be suppressed under the introduced invasive species for several decades (Lugo, 2004; Sharma and Raghubanshi, 2007; Doi and Ranamukhaarachchi, 2009). Instead, Padmanaba and Corlett (2014) encouraged the same silvicultural practice but using a mixed species plantation of natives having light-demanding and fast-growing traits. However, current knowledge on how to practice native tree plantation to suppress invasive plant species in Thailand's degraded tropical forest is still poorly understood and needs to be addressed in the future to provide more options of suitable practices for this particular situation in Thailand's protected areas.

The vegetation survey in TSS and surrounding areas revealed two major groups of plant communities: natural forest communities and plant communities caused by anthropogenic disturbances. Natural forest communities consisted of dry evergreen forests, mixed deciduous forests, secondary forests and forest plantation, while plant communities caused by anthropogenic disturbances consisted of old agricultural fields, orchards, and areas in resort and temple compounds. The study found that agriculture and tourism caused negative impacts on the species composition and canopy structure of native plant communities. Considering the capacity of native tropical trees to regenerate in natural plant communities, this study revealed that in anthropogenic areas, especially the resorts where the development was concentrated, almost all native trees had disappeared and saplings and seedlings were at extremely low densities in these habitats. The changes associated with the expansion of agriculture and tourism most likely facilitated 189 non-invasive alien species and 100 invasive alien species to be introduced into Thap Lan National Park. This study showed the different levels of change in tropical plant communities resulting from human land development activities, especially from agriculture and tourism. The survey of large-sized trees still existing as relict trees within the landscape revealed that in the past before land development took place, the forest types in the TSS area that overlaps with Thap Lan National Park used to be dry evergreen and mixed deciduous forests. If, in the near future, a program for ecosystem restoration in these areas were to be initiated, given the present condition of plant communities, it would seem impossible to restore these areas using only natural succession because of the fact that invasive alien species already occupy the areas. To restore these areas, exotic forest plantations to catalyze the degraded landscape might be applied in the first stage to support the seedling establishment of indigenous trees. In the future, control of the population of exotic species, especially invasive alien species, is essential for the long-term sustainability of these natural forest ecosystems.

Conflict of interest

The author declares that there are no conflicts of interest.

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