

Impacts of Disturbance on Floristic and Soil Properties in Deciduous Forest, Nam Wa Sub-watershed, Northern Thailand

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ABSTRACT: Up to about 15 years ago a deciduous forest in the Nam Wa sub-watershed was increasingly encroached for agricultural purposes. Then, about 15 years ago, the local people and the local authority in Lai Nan District cooperated to conserve this forest area through natural succession. This study was carried on the quantitative floristic characteristics, soil organic matter and soil nutrients with the aim of identifying the impact of the disturbance. The trees' database in the area and land use history were used to classify the area into five degrees of disturbance as follows; i) very high (orchard); ii) high (abandoned crop field with 15 years of natural succession); iii) medium (most trees were logged 15 years or more ago and then left to succession), iv) low (some trees were logged 15 years or ago and then left to succession); and iv) very low (small number of trees were logged). The results indicate that the density and basal area is the lowest in the very high disturbance area and the highest in the low disturbance area. Indeed the measured characteristics of the soil differ significantly among the disturbance areas (ANOVA: $P < 0.05$), and therefore, that the quantitative characteristics of this disturbed forest have not completely recovered after 15 years of natural succession. The soil chemistry at two soil depths: 0 - 20 cm and 20 - 40 cm does not vary for most soil chemical properties measured. The pH, organic matter, total nitrogen, available phosphorus and exchangeable potassium show no statistically significant difference between each of the sites with different degrees of disturbance nor between the two soil depths at each site. It is therefore possible that soil organic matter and some soil nutrients are recovered after 15 years of forest succession.

Key words: Floristic diversity, soil quality, disturbance, natural succession, deciduous forest

INTRODUCTION

Disturbances can cause significant changes in ecological processes⁽¹⁾ and can be classified into three main types, based upon their intensity, duration and size, as large, medium and small.⁽²⁾ There are many studies on the impact of disturbance upon natural resources or natural phenomena, such as storms, fire, etc., but also human activities which create severe and continuous impacts.

Forests are one of the renewable resources that are disturbed by humans. There are many

changes in disturbed forests, such as species diversity and composition,⁽³⁻⁷⁾ and soil properties and organic matter, which are ecologically sensitive in tropical forest ecosystems.^(8,9) Agricultural activities are well known to not only reduce the biodiversity but also to diminish the soil quality and lead to the permanent degradation of land productivity, especially after prolonged practice in any given area.⁽¹⁰⁾

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Disturbed forest, in fact, can recover in structure and function through natural succession. The recovery rate depends on many factors, such as the integrity and resilience of the previous area,⁽¹¹⁾ nutrients and water availability, and the frequency of, and the time since, the last disturbance.⁽¹²⁾ Forest recovery through the natural succession usually takes a longtime, and so hardly limits forest degradation. However, forests can be stimulated by reforestation if ecological knowledge and so a suitable action plan are clearly understood. The assessment of soil properties assessment upon the conversion of natural forest for varying agricultural purpose and succession time are important to determine the changes in soil quality and are useful for management planning and action.⁽¹⁰⁾

In Thailand, especially in the northern region, deforestation is one of the major problems due to the increase of human population and agricultural area. The average rate of national deforestation is around 160 ha/day.⁽¹³⁾ The satellite image classification showed both the degraded forest and abandoned area that need to be restored to be around 4,800,000 ha.⁽¹⁴⁾ According to this rapid degradation, top-down policies for forest management, such as reforestation, agro-forestry, and economic tree plantation, have been implemented.

The deciduous forest at Nam Wa sub-watershed, Nan province, has been deforested for orchard and annual crop cultivation since 1979 until it was announced as a conserved area in 1989 by the cooperation between Lainan people and the Lainan Tambon Administrative Organization (TAO). At the present, however, there is no specific management plan for this area. Therefore, the floristic characters and soil properties upon the converted forest represent the transition from diverse agricultural activities to regenerating secondary forest at different stages of succession. It is important to characterize these stages in order to determine the changes in the ecosystem and apply the results for decision-making on management planning.

In this study, we report on the assessment of the impacts of different degrees of disturbance on the floristic diversity, vegetation structure and soil properties of a lowland secondary deciduous forest in northern Thailand. We compare the results with

other studies that have been conducted in Thailand. Our present study was undertaken to provide the background knowledge to aid future forest ecosystem recovery monitoring and strategies, and to encourage the sustainable management plans in this area.

METHODS

Study site

Nam Wa is one of the sub-watersheds of the Nan watershed, northern Thailand. The study site is located between N2051960 - 2054260 and E0688400 - 0693060 in UTM zone 47Q and covers an area of 297.30 ha. The climate is tropical savanna,⁽¹⁵⁾ with a mean annual temperature, rainfall and relative humidity, over the 10 year period of 1993 - 2002, of 25.9°C, 1,334.5 mm and 78%, respectively.⁽¹⁶⁾ The altitude ranges from 200 to 260 m above the mean sea level (msl). The forest type is lowland deciduous with overlapping deciduous dipterocarp and mixed deciduous communities. The economic trees, such as *Tectona grandis*, *Azela xylocarpa*, *Pterocarpus macrocarpus*, *Dalbergia oliveri* and *Lagerstroemia* spp., have small stem size as the coppices resulting from the selective logging activities.⁽¹⁷⁾

Disturbance classification

The diameter at breast height (diameter at 130 cm above ground: DBH) of trees with a DBH $\geq$ 5.0 cm, in the GIS database of this area and land use history,⁽¹⁷⁾ were used to classify the degree of disturbance into five categories; very high (VH), high (H), medium (M), low (L) and very low (VL), as described below:

1) VH is the area that has been converted to orchard farming since 1979. There are two orchard species, mango (*Magifera indica* L.) and tamarind (*Tamarindus indica* L.). The land was prepared by using a large tractor car to plough and disturb the soil surface down to 30 - 40 cm depth. The villager's applied fertilizer as well as do tillage every year for almost 25 years. There are three sites of VH area. The tamarind plot was not well maintained and so some native species have established within the orchard. The other two plots, both mango orchards, were well maintained and so have no native trees in these plots.

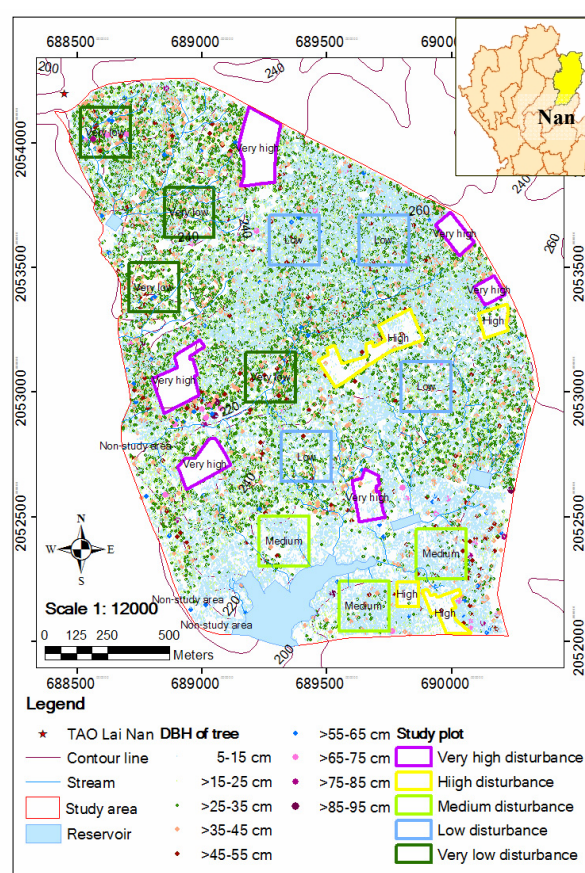


Figure 1. Study area and location of study plots of 5 different degrees of disturbance.

2) *H* (three sites) covers the area that was converted to annual crops, comprised of two crop species (maize and soybean). For the planting pattern, maize is planted from May to July and after harvesting, a small ploughing machine was used to clear the maize stems. Thereafter, soybean was planted for the period of 3 - 4 months. After the soybeans were harvested, the land was abandoned until the following May. This cycle of agricultural practices was carried out for 10 years and then this area was left to natural succession for almost 15 years. During this time the area was invaded by pioneer species.

3) *M* (three sites) is defined as where 80% of the area was clear cut for timber purposes. As a result, many stems of a small diameter size were regenerating from each stump.

4) *L* (four sites) is the area that was deforested with a lower degree of disturbance and leaving a higher proportion of big trees than that in *M*.

5) VL (four sites) is the area that had the least degree of disturbance with more big tree available in this area. The character of this area is similar to primary forest. There are 4 sites of VL area.

The ecological indicators in each degree of disturbance were calculated in order to investigate the

dominant species in each disturbed area. The equations are indicated as follows:⁽¹⁰⁾

$$\text{Basal area (BA)} = (22/7) * (\text{DBH}/2)^2$$

Tree density = number of tree/ha

Stem density* = number of stem/ha

$$\text{Relative density} = \frac{\text{density of one species} \times 100}{\text{Sum of density of all species}}$$

$$\text{Relative frequency} = \frac{\text{frequency of one species} \times 100}{\text{Sum of frequency of all species}}$$

$$\text{Relative dominance} = \frac{\text{basal area of one species} \times 100}{\text{Sum of BA of all species}}$$

$$\text{Importance value index} = \text{Relative density} + \text{Relative frequency} + \text{Relative dominance}$$

* Note: In disturbed area by cutting, one tree can regenerate by producing small stems from existing stump.

Floristics and vegetation structure

In addition, the Shannon-Wiener's Index (H'), Species Richness Index ($H_{\max}$), and Pielou's Evenness Index (E) were calculated in order to compare the impact of disturbance on species diversity. The equations are indicated as follows: ⁽¹⁰⁾

$$H' = -\sum_{i=1}^S (P_i)(\ln * P_i)$$

where: i = counter for the species
 S = total number of species present, and
 P_i = proportion of species i in the total number of individuals present : =

$$= n_i / \sum_{i=1}^S n_i$$

where n_i = number of species i present

$$H_{\max} = \ln S$$

where: S = number of species

$$E = H' / H_{\max}$$

Soil sampling and analysis

In the five degrees of disturbance, outlined above and totaling 17 sites, the composite samples of soil were collected using a soil auger. Two depths of soil, 0 - 20 and 20 - 40 cm, were taken at each site. The soil analysis, including the pH (measured as a 1:1 (v/v) ratio of soil: water), organic matter (OM), total nitrogen, available phosphorus, exchangeable potassium, and exchangeable calcium was analyzed at King Mongkut's Institute of Technology Ladkrabang by the standard methods for soil analysis. ⁽¹⁸⁻²⁰⁾

Statistical analysis

One-way analysis of variance (ANOVA) was used to compare the effects of the different degrees of disturbance on forest characteristics and soil properties. Then, the Tukey test procedure inside ANOVA was used to separate the means of the soil properties at $P \leq 0.05$.

RESULTS AND DISCUSSION

Vegetation structure

The diameter class distribution or age-class (Figure 2) reflected the development in the floristic structure of the disturbed forest. The largest tree in the VH area was found in the DBH class >35 - 45 cm, which is the largest size of orchard, while in the VL area the largest tree was found in the DBH class >75 - 85 cm. Moreover, the percentages of trees in the second size class increased in the VL area compared to that in the VH sites. This changing pattern clearly reveals that the disturbance changed the forest structure as has been reported for other disturbed deciduous forests in Thailand. ⁽²¹⁾

Floristic quantitative characteristics

After the forest is disturbed to different degrees, the cumulative numbers of trees and stems, the density of trees and stems, and the basal area all show somewhat similar changes in pattern (Table 1). The lowest value of each character was found in the VH area or orchard. The value then increases from the H area (15 years old abandoned field) to the M area (clear cut land) and reaches its maximum value in the L area before declining a little in the VL area, an area that is similar to a primary forest.

In the VH area, a high proportion of small trees and the lowest value of quantitative characters, except for the ratio of tree number and stem number, is caused by the clear cutting activity. There are a lot of new coppices at the edge of the VH or orchard area because the deciduous species have a high capacity to regenerate from stumps. ⁽¹⁰⁾ The ploughing activity and burning of weeds are two factors that mainly inhibit the regeneration of native species in this area.

The values of the quantitative characters in the H area were higher than those in the VH area but lower than that in the M area because the M area has been abandoned and left to natural succession for 15 years. Seedlings of fast growing species can invade the M area under the low competition and no limitation on light and nutrient resources. In this secondary deciduous area, however, forest fires play the importance role of controlling the succession rate because the fire damages some seedlings and saplings. If the forest fire controls them, the density and basal area will rapidly increase.

In the M and L areas, the quantitative values are high because there are many existing trees in the area as a result of the previous selective logging. Seedlings grow very fast under the different sizes of the light gaps and then they reach a maximum density for that area. The even-age of trees, especially for the same species, will use the same resources leading to inter- and intra-specific competition. Nutrients and light thus become the limiting factors to growth. Therefore, in the late succession stages, some trees or some species will be eliminated through the natural selection process and the tree density becomes lower. ^(22, 23) This is the cause of the decline in the quantitative characters seen in the VL area compared to that in the L area.

BA, which was classified by diameter size, is showed in Figure 3. In all disturbed forest types, the high value of BA is represented by the small trees with a DBH of 5 - 25 cm including the majority of saplings found in the deciduous forest. According to the maximum value of BA in L area (16.51 ± 1.67 sq.m./ha, table 1) and capacity of the small trees to growth and stock carbon dioxide, it is possible to manage the VH, H and M areas for carbon sequestration.

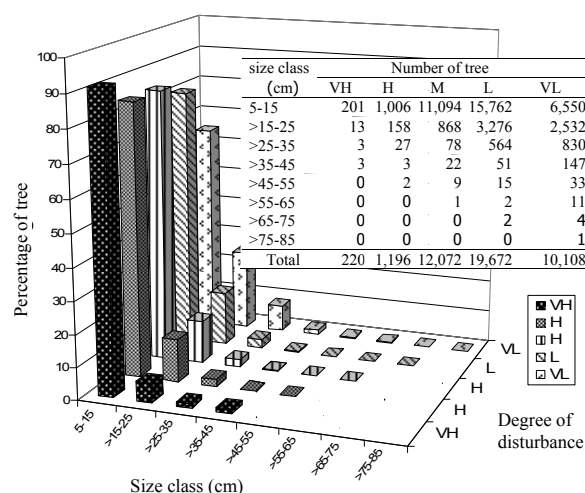


Figure 2. Proportions of trees in each degree of disturbance, classified into different size class. Most of the trees in this area are found in the smallest size (DBH 5 - 15 cm).

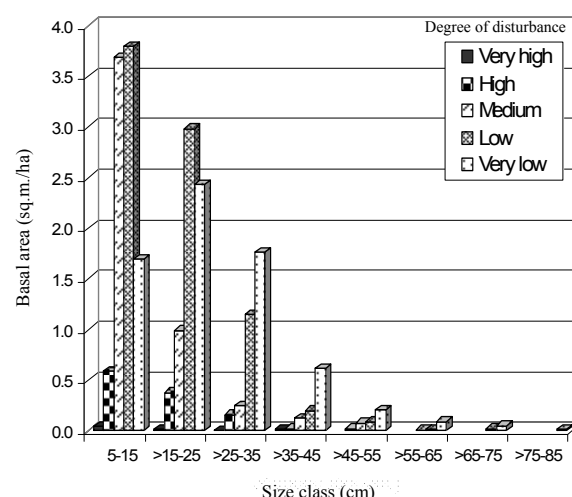


Figure 3. Basal area of trees in each degree of disturbance, classified into different size classes. Except for the VL area, the basal area is highest in the smallest size (DBH 5 - 15 cm) due to natural succession.

Floristics diversity and composition

The results indicate that the different degrees of disturbance affect the species diversity and species composition. The Richness index increases from the VH to VL area. Unlike the Shannon-Wiener's index, the highest Richness value is in the VH area and the Lowest in L area (Table 2). The difference between the Richness and Shannon-Wiener's index is that Shannon-Wiener's index considers the number of trees of each species in the area, while the Richness index considers only the number of species in the area. Moreover, the Evenness index of the M, L and VL areas are lower than that for the VH and H areas. It means that there are some dominant trees present in each of the M, L and VL areas. This notion is clearly

supported by the IVI index in table 3. *Dipterocarpus tuberculatus* is the dominant species in the M area, while *Shorea obtusa* and *D. tuberculatus* are the dominant trees in the L area, as well as both *S. obtusa* and *Shorea siamensis* as the dominant species in the VL area. The impact of disturbance on species diversity tends to follow the intermediate disturbance hypothesis that stated 'the highest diversity of tropical rain forest trees should occur either at an intermediate stage in succession after a large disturbance or with smaller disturbances that are neither very frequent or infrequent; either represents an open non-equilibrium'.^(3,4)

Table 1. Floristic quantitative characteristics (Mean $\pm$ SD) in different degrees of disturbance.

Degree of Disturbance	Area (ha)	Cumulative Tree no.	Cumulative Stem no.	Stem no / Tree no	Tree density (tree/ha)	Stem density (stem/ha)	Basal area (sq.m./ha)
VH (n=3)	12.80	220	303	1.38: 1.00 a*	10.6 $\pm$ 13.9 a	14.6 $\pm$ 25.3 a	0.16 $\pm$ 0.28 a
H (n=3)	7.28	1,196	1,556	1.30: 1.00 a	161.6 $\pm$ 36.4 b	202 $\pm$ 47.9 b	2.35 $\pm$ 0.31 b
M (n=3)	12.00	12,072	13,658	1.13: 1.00 a	1,006 $\pm$ 193 bc	1,138 $\pm$ 171 c	10.3 $\pm$ 0.28 abc
L (n=4)	16.00	19,672	20,883	1.06: 1.00 a	1,230 $\pm$ 259 c	1,305 $\pm$ 277 c	16.5 $\pm$ 1.7 c
VL (n=4)	16.00	10,108	10,856	1.07: 1.00 a	632 $\pm$ 142 c	679 $\pm$ 159 c	13.7 $\pm$ 1.8 c

Note: In VH Area, the SD of tree and stem density were very high because of different orchard tree density among plots. Moreover, there were 2 plots of mango (*Magifera indica* L.) orchard with well care.

* Mean followed by a different letter in the same column are significantly different (Turkey test: $P < 0.05$)

Table 2. Ecological indices in different degrees of disturbance.

Degree of Disturbance	Total number of species	Av. number of species	Species Index	Shannon-index	Evenness Index
VH (n=1)	47	47	3.85	3.31	0.24
H (n=3)	62	38.7 ± 18.5	4.13 ± 0.58	2.83 ± 0.64	0.26 ± 0.03
M (n=3)	87	65.3 ± 3.1	4.47 ± 0.05	2.76 ± 0.44	0.21 ± 0.01
L (n=4)	88	59.0 ± 13.1	4.48 ± 0.21	2.03 ± 0.55	0.19 ± 0.01
VL (n=4)	103	71.8 ± 12.7	4.63 ± 0.17	3.07 ± 0.49	0.21 ± 0.01

Note: In VH only one plot was selected as representative of the other two because the other two plots were only a mango (*Magifera indica* L.) orchard. It will affect the result of diversity index.

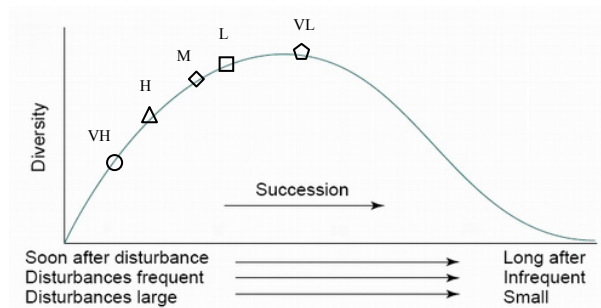
Table 3. The first 10 maximum values of the importance value index (IVI).

Order	IVI of the different degree of disturbance				
	VH	H	M	L	VL
1	<i>Tamarindus indica</i> 27.74	<i>Dalbergia</i> sp. 25.64	<i>Dipterocarpus tuberculatus</i> 44.45	<i>Shorea obtusa</i> 68.91	<i>Shorea obtusa</i> 31.30
2	<i>Dalbergia</i> sp. 22.29	<i>Dipterocarpus obtusifolius</i> 21.39	<i>Shorea obtuse</i> 33.41	<i>Dipterocarpus tuberculatus</i> 60.88	<i>Shorea siamensis</i> 30.71
3	<i>Chukrasia tabularis</i> 21.62	<i>Morinda tomentosa</i> 18.70	<i>Pterocarpus macrocarpus</i> 16.41	<i>Dipterocarpus obtusifolius</i> 25.29	<i>Pterocarpus macrocarpus</i> 16.10
4	<i>Pterocarpus macrocarpus</i> 18.73	<i>Shorea obtusa</i> 17.35	<i>Croton roxburghii</i> 9.32	<i>Aporosa</i> sp 1. 9.31	<i>Dipterocarpus tuberculatus</i> 13.54
5	<i>Millingtonia hortensis</i> 13.42	<i>Dipterocarpus tuberculatus</i> 17.23	<i>Morinda tomentosa</i> 8.79	<i>Shorea siamensis</i> 6.96	<i>Dipterocarpus obtusifolius</i> 8.66
6	<i>Mangifera indica</i> 12.55	<i>Lagerstroemia macrocarpa</i> 11.95	<i>Cratoxylum formosum</i> 8.78	<i>Irvingia malayana</i> 5.21	<i>Xylia xylocarpa</i> 8.07
7	<i>Morinda tomentosa</i> 10.62	<i>Aporosa</i> sp 1. 11.82	<i>Xylia xylocarpa</i> 8.77	<i>Pterocarpus macrocarpus</i> 5.06	<i>Shorea roxburghii</i> 7.99
8	<i>Croton roxburghii</i> 8.88	<i>Pterocarpus macrocarpus</i> 10.02	<i>Dalbergia</i> sp. 7.21	<i>Morinda tomentosa</i> 4.49	<i>Lagerstroemia duperreana</i> 6.46
9	<i>Shorea obtusa</i> 8.47	<i>Strychnos nux-blanda</i> 9.27	<i>Aporosa</i> sp 1. 6.71	<i>Anthocephalus chinensis</i> 4.30	<i>Phyllanthus columnaris</i> 5.91
10	<i>Lagerstroemia macrocarpa</i> 8.16	<i>Diospyros ehretioides</i> 8.91	<i>Anogeissus acuminata</i> 6.63	<i>Dalbergia</i> sp. 3.57	<i>Aporosa</i> sp 1. 5.78

Note: *Dalbergia* sp. in different columns is the same morphospecies (if not actual species), but was not identified to species since no flowers were available.

The overall picture of forest disturbance in each area

The succession stage at each degree of disturbance by modifying the intermediate disturbance hypothesis with our results of floristic properties is shown in Figure 3.



**Figure 3. Estimated succession stage of the five degrees of disturbance in the study area
(Adopted from Shield and Burslem⁽⁴⁾)**

The VH area is in the early stage of succession, whilst the H area is in a more advanced part of the early – mid succession stage compared with the VH area. The M and L areas are more developing and oscillated towards the climax stage soon. This secondary forest has the potential to recover to be a healthy forest, especially in the M and L areas. However, during the study period, we found that villagers still harvest non-timber forest products. This could be an occasional disturbance event to the forest. Therefore the appropriate management plan

could be set up in a participatory way with local people. Moreover, the permanent plots may need to monitor the long term succession of the forest area.

Soil properties

The soil properties are summarized in table 4 and reveal that the different degrees of disturbance tend to reduce the soil fertility, excepted in the VH area where the level of nutrients are higher than others due to the use of fertilizer (formula: 15-15-15).

Table 4. Soil properties in the difference degrees of disturbance (pH = pH of soil in water by ratio 1:1, OM = organic matter, N = total nitrogen, C:N ratio = ratio of organic carbon and total nitrogen, AviP = available phosphorus, K = exchangeable potassium, Ca = exchangeable calcium, Mg = exchangeable magnesium).

Degree of disturbance		Soil properties (Mean $\pm$ SD)							
		pH	OM (%)	N (%)	C:N ratio ¹	AviP (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Depth 20 cm	VH (<i>n</i> =3)	6.75 $\pm$ 0.64 a ²	2.39 $\pm$ 0.47 a	0.1073 $\pm$ 0.0500 a	12.9:1	17.6 $\pm$ 19.7 a	52.1 $\pm$ 30.8 a	195 $\pm$ 77 b	74.5 $\pm$ 39.1 a,b
	H (<i>n</i> =3)	5.39 $\pm$ 0.13 a	1.40 $\pm$ 0.41 a,*	0.0618 $\pm$ 0.023 a	13.1:1	2.42 $\pm$ 1.53 a	16.0 $\pm$ 5.2 a	41.2 $\pm$ 19.9 a	23.3 $\pm$ 4.16 a
	M (<i>n</i> =3)	5.39 $\pm$ 0.08a	3.14 $\pm$ 1.00 a	0.1198 $\pm$ 0.0440 a	15.2:1	3.75 $\pm$ 2.25 a	20.0 $\pm$ 2.8 a	124 $\pm$ 75 b	89.1 $\pm$ 56.6 a,b
	L (<i>n</i> =4)	5.19 $\pm$ 0.18 a	2.62 $\pm$ 0.57 a,*	0.0910 $\pm$ 0.0200 a	16.8:1	2.13 $\pm$ 0.91 a	27.1 $\pm$ 8.5 a	120 $\pm$ 47 b	58.6 $\pm$ 3.35 b
	VL (<i>n</i> =4)	5.08 $\pm$ 0.12 a	3.24 $\pm$ 1.75 a	0.1304 $\pm$ 0.0600 a	14.5:1	4.22 $\pm$ 2.71a	29.4 $\pm$ 12.5 a	98 $\pm$ 21 b	81.9 $\pm$ 52.4 a,b
Depth 40 cm	VH (<i>n</i> =3)	5.98 $\pm$ 0.69 a	1.74 $\pm$ 1.15 a	0.0782 $\pm$ 0.0280 a	12.9:1	27.1 $\pm$ 20.1 a	58.9 $\pm$ 29.2 a	164 $\pm$ 139 a	65.3 $\pm$ 7.51 a
	H (<i>n</i> =3)	5.18 $\pm$ 0.13 a	0.61 $\pm$ 0.21 a	0.0280 $\pm$ 0.0060 a	12.7:1	1.10 $\pm$ 0.52 a	10.3 $\pm$ 7.2 a	36.4 $\pm$ *30.0	41.3 $\pm$ 18.5 a
	M (<i>n</i> =3)	5.18 $\pm$ 0.14 a	1.78 $\pm$ 0.83 a	0.0751 $\pm$ 0.0290 a	13.8:1	1.72 $\pm$ 1.11 a	16.9 $\pm$ 3.6 a	9-13 $\pm$ 50.8 a	52.6 $\pm$ 47.1 a
	L (<i>n</i> =4)	4.96 $\pm$ 0.16 a	1.34 $\pm$ 0.44 a	0.0700 $\pm$ 0.0200 a	11.2:1	2.47 $\pm$ 0.50 a	34.5 $\pm$ 19.1 a	73. $\pm$ 41.2 a	72.0 $\pm$ 5.92 a
	VL (<i>n</i> =4)	4.89 $\pm$ 0.18 a	2.30 $\pm$ 1.27 a	0.1059 $\pm$ 0.0500 a	12.6:1	3.02 $\pm$ 3.05 a	25.5 $\pm$ 20.4 a	72.8 $\pm$ 44.1a	85.8 $\pm$ 45.7 a

Note = Calculated from mean Organic carbon and mean of total nitrogen

2 = Mean followed by the different letter in same column and same depth is significantly different (Turkey test: $P < 0.05$)

* = Mean followed by this letter is significantly different between 2 depth of that disturbance area (Turkey test: $P < 0.05$)

The soil pH ranged from 4.89 to 6.75. Most were weakly acidic, as is normal for the soil in deciduous forests.⁽¹⁰⁾ The higher pH values arose from the burning activity, in order to prepare the land for agriculture. Forest fires induce nutrient loss, such as nitrogen, phosphorus and chlorine.⁽²⁴⁾ On the other hand, ash from the burned weeds and grasses returns the base-form cation to soil. Both the loss of nutrients and the added base-form cations reduce the soil acidity.^(9,25) The decrease in the soil pH values correspond to the disturbance gradient, from high to low. This may be caused by the increasing soil OM that is generated from the litter during the succession processes. The OM component of the soil has the ability to catch the acid-form cations in soil, so reduces the soil pH.⁽²⁴⁾

Total N, in general, can be estimated as being 5% of the soil OM level.⁽¹⁸⁾ In reasonable accord, the total N in this study was found to be 4.47% of soil OM level. The change in the total N level correlates with the OM levels reported in other studies.^(5,26) In these results, the soil OM and total N are in accord with previous studies which found that disturbed forests and lands converted for agricultural activity have a lower OM level than the primary forest.^(12,27) In general, the soil C:N ratio is adequate for soil microbial activity when within the range of from 10:1 to 30:1,⁽²⁴⁾ whilst the C:N ratio in this study ranges from 11.2:1 to 16.8:1. Thus the five sites with different degrees of disturbance appear to have enough nitrogen availability.

The available P and exchangeable K are at the highest values in the VH area, in accord with to the fertilizer application. Excluding the VH area, available P and exchangeable K tend to increase from the H to the VL area. The changing of available P and exchangeable K after disturbance in this study also corresponds to the previous studies.^(12,28) The mean soil properties, including the pH, OM, total N, C:N ratio, available P and exchangeable K, do not show any statistically significant difference ($P>0.05$) within the same soil depth. It is possible to explain this as that the soil properties have recovered.

Exchangeable Ca in the H area is the lowest and is statistically significantly different ($P>0.05$) compared to the other areas. Previous studies have suggested that the deciduous dipterocarp community stock Ca in the branch and twig's biomass at around 76%.⁽²⁶⁾ The low numbers of trees in this area, with no return of twigs and branches to the soil, may cause Ca depletion and so this low Ca value.

Exchangeable Mg shows an unpredictable changing pattern along the disturbance gradient, similar to that reported in a previous study by Sahunalu and others.⁽²⁶⁾ The level of Mg in this study may not be related to degree of disturbance, but it may be caused by the difference in the parental material of the soil.⁽²⁴⁾

CONCLUSION AND FURTHER STUDIES

The different degrees of disturbance cause different degrees of impact on the deciduous forest by changing the forest structure, changing the ecological indicators in terms of the diversity and species composition as well as changing the soil qualities. Our results conclude that the agricultural technique applied in this area seems not to disturb the soil properties too much, at least for those characters measured, and some soil properties can recover within 15 years of succession. However, the agricultural activities impacted the forest quantitative characteristics much more severely and they have not recovered within this 15 year period of succession. Although some forest and soil properties have a tendency to recover, the ecological functions of forest are important to investigate whether they are actually recovering or not.

Future studies are to promote the sustainable use of forest resources as well as their economic status in this area. Therefore, coupled with the ecological data from this study, the effective management plan for this area can be set up under ecological and socio-economic aspects in a participatory way. For example, we can delineate the area which has a high tree density and harvest some small trees in order to enhance the growth rate of the others. The harvested trees can be used for villager's livelihood or modifying furniture as a carbon sequestration in wood.

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