HUMAN AND ENVIRONMENTAL INFLUENCES ON PLANT DIVERSITY AND COMPOSITION IN BEN EN NATIONAL PARK, VIETNAM

VS Hoang[1], P Baas[2], PJA Keßler[3], JWF Slik[4], H Ter Steege[5] & N Raes[2]

[1]Biodiversity Centre, Vietnam Forestry University, Xuan Mai, Hanoi, Vietnam. E-mail: hoangvsam@yahoo.com
[2]National Herbarium of the Netherlands, NCB Naturalis, Einsteinweg 2, PO Box 9514, 2300 RA Leiden, the Netherlands
[3]Hortus Botanicus Leiden, Binnenvestgracht 8, PO Box 9516, 2300 RA Leiden, the Netherlands
[4]Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Yunnan, China
[5]Institute of Environmental Biology, Section Plant Ecology and Biodiversity, Utrecht University, Sorbonnelaan 14, NL-3584 CA, Utrecht, the Netherlands

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HOANG VS, BAAS P, KEßLER PJA, SLIK JWF, TER STEEGE H & RAES N. 2011. Human and environmental influences on plant diversity and composition in Ben En National Park, Vietnam. In order to understand the influence of human disturbance and the physical environment on plant biodiversity in Ben En National Park, Vietnam, we analysed species composition and density in forest plots with diverse soils and varying degrees of human disturbance. Soil factors significantly influenced tree species composition, although they only explained 5.7% of the observed data variance. Human factors (disturbance) were second most important in explaining species composition and density, accounting for 4.4% of variance. Changes in species composition related to human disturbance varied mostly independently of soils. The species composition of slightly and heavily disturbed forest differed significantly, with species of low conservation value being most common in heavily disturbed forest, while endangered species and important timber trees were most common in least disturbed forest. Density of treelets was higher in limestone forest than in non-limestone forest. Timber trees and other useful plant species used for a whole range of non-timber forest products (NTFPs) were more abundant in the less disturbed plots, which were located far away from villages and roads. Basal area in less disturbed forest was also larger than in heavily disturbed forest, indicating that the pressures of illegal logging and harvesting were closely connected to travel distances to nearest villages. Limiting the accessibility to forest resources should therefore be a priority in forest conservation as a first step to safeguard the rich biodiversity and stocks of useful plants in the park.

Keywords: Biodiversity conservation, disturbance, human impact, illegal logging, soils

HOANG VS, BAAS P, KEßLER PJA, SLIK JWF, TER STEEGE H & RAES N. 2011. Pengaruh manusia dan persekitaran terhadap kepelbagaian biologi serta komposisi tanaman di Taman Negara Ben En, Vietnam. Demi memahami pengaruh gangguan manusia serta persekitaran fizikal terhadap kepelbagaian biologi di Taman Negara Ben En, Vietnam, kami menganalisis komposisi spesies serta kepadatannya di plot hutan yang mempunyai tanah serta tahap gangguan manusia yang berbeza. Faktor tanah mempengaruhi secara signifikan komposisi spesies pokok. Bagaimanapun, faktor-faktor tersebut hanya menerangkan 5.7% varians data yang dicerap. Faktor manusia (gangguan) ialah faktor kedua penting dalam menerangkan komposisi serta kepadatan spesies, iaitu sebanyak 4.4% varians. Perubahan komposisi spesies yang berkait dengan gangguan manusia kebanyakannya berubah secara bebas daripada faktor tanah. Komposisi spesies bagi hutan yang sedikit terganggu berbeza dengan signifikan berbanding dengan hutan yang banyak terganggu. Spesies yang mempunyai nilai pemuliharaan yang rendah sangat banyak di hutan yang terganggu dengan teruk. Sebaliknya spesies terancam dan pokok kayu yang penting banyak didapati di hutan yang paling kurang terganggu. Kepadatan anak pokok lebih tinggi di hutan batu kapur berbanding hutan lain. Pokok kayu serta spesies pokok berguna yang diguna untuk membuat pelbagai produk hutan bukan kayu (NTFP) lebih banyak didapati di plot yang kurang gangguan yang terletak jauh dari kampung serta jalan. Luas pangkal pokok di hutan yang kurang terganggu juga lebih besar daripada hutan yang terganggu teruk. Ini menunjukkan tekanan pembalakan dan penuaian haram berkait rapat dengan jarak perjalanan ke kampung yang terdekat. Oleh yang demikian, mengehadkan jalan masuk ke hutan seharusnya diberi keutaman dalam usaha pemuliharaan hutan. Ini merupakan langkah pertama untuk melindungi kepelbagaian biologi yang kaya dan stok tanaman berguna di taman ini.

INTRODUCTION

Human disturbance affects plant populations and can modify interactions among species within communities (Huston 1994, Acharya 1999). Habitat loss, fragmentation and degradation are currently the most important threats to biodiversity (Primack 1993). However, human activities are highly variable in their influence on biodiversity (Putz et al. 2000). For example, numerous studies have shown that logged forests retain much of their original biodiversity despite the severe damage that logging can inflict on the forest ecosystem (Whitmore & Sayer 1992, Cannon et al. 1998, Meijaard et al. 2005).

Several interactions between human disturbance, environmental factors and plant diversity have been reported. For example, in logged or burnt forests, light levels are increased while tree density is reduced (Cannon et al. 1998, Uutera et al. 2000, Eichhorn & Slik 2006). The increased light levels usually result in the occurrence of many woody pioneers and herbaceous species, which in some cases, e.g. logged forests, positively influence diversity indices although the quality of the biodiversity is negatively affected (Fredericksen & Mostacedo 2000, Pinard et al. 2000, Eichhorn & Slik 2006). Within diverse tropical forests there is also evidence that natural variation in environmental factors, such as soil nutrients, canopy openness, slope and herb cover affect the distribution of tree species and forest composition (Duivenvoorden 1995, Potts et al. 2002).Therefore, identification of factors related to natural variation and human disturbance that affect biodiversity and forest vegetation structure is important because it may enable us to modify forest management practices in ways that protect these values (Pickett 1995).

Ben En National Park is one of the 30 national parks in Vietnam. It was established in 1992 to conserve the rich, but seriously threatened, biodiversity of the country. The park is inhabited by 18 000 local people belonging to five ethnic groups, namely, Kinh, Muong, Thai, Tay and Tho who continue to exert a strong influence on the natural environment. Illegal logging and harvesting of non-timber forest products (NTFPs) by both local people and people from outside the National Park continues (Tordoff et al. 2000, Hoang et al. 2008a). The park has strongly contrasting soil types and one of the challenges is therefore to disentangle effects of soils and human disturbance on species diversity and composition.

In earlier studies we described the flora and multiple uses of plant species in Ben En National Park in great detail (Hoang et al. 2008a, b, c). In this study we focused on the following questions: can human influences on species diversity and composition and tree density be separated from environmental factors, and if so, how do both affect plant diversity and composition in Ben En National Park? We have addressed these questions with special emphasis on economically important timber tree species, other useful species yielding NTFPs for the local economy and endangered (Red-listed) species. Answers are considered relevant for developing a sustainable management plan for Ben En and other National Parks in Vietnam.

MATERIALS AND METHODS

Research area

Ben En National Park is situated in the Nhu Thanh and Nhu Xuan districts of the Thanh Hoa province in Vietnam (19° 30'–19° 40' N, 105° 21'–105° 35' E (Figure 1). The Park is situated in a region of low hills surrounding an artificial lake. Altitude ranges from 20 to 497 m, with most areas being below 200 m. The lake is 50 m above sea level and covers 2281 ha. Small areas of limestone are also present (Tordoff et al. 2000). Soils in Ben En National Park are mainly ferralitic, while a small area around Lake Muc has alluvial soils (Anonymous 2000).

The core zone of the National Park covers 15 800 ha, while the buffer zone covers about 12 000 ha. The Ben En area was designated for the protection of fauna in 1979, changed to a nature reserve status in 1986, and to national park status in 1992. Major parts of the forest in Ben En National Park have been impacted by man (Hoang et al. 2008a). The forests were commercially logged as late as 1992 and small-scale illegal logging continues to this date (Tordoff et al. 2000, Hoang et al. 2008a, c). The effects of former logging activities were still evident in the plots established for this study and some of the stumps counted as indicators of human disturbance probably dated back from before 1992. Ben En National Park has 1389 vascular plant species belonging to 650 genera and 173 families (Hoang et al. 2008a).

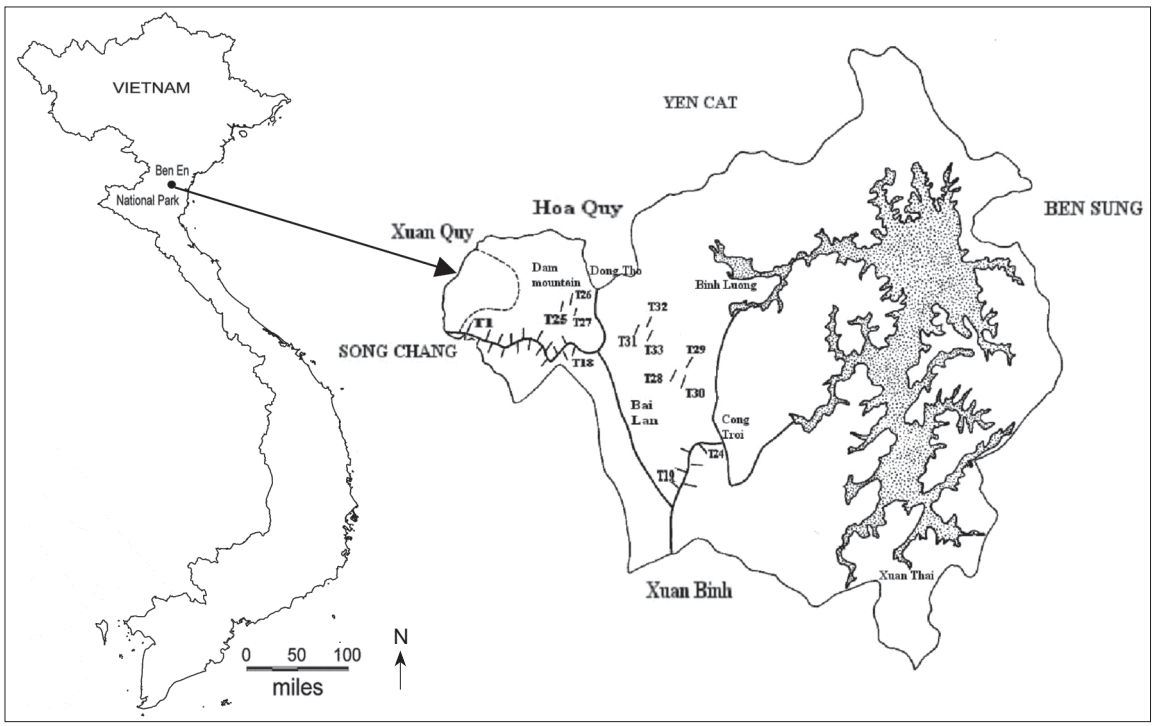

Figure 1 Map of Ben En National Park in Vietnam; lakes are in grey, line transects are drawn in

Methods

Plot inventory

For this study, carried out in 2008, we established transects and plots in forest areas along the old logging road (perpendicular to the road) as well as in the forest interior (dotted lines in Figure 1). Agricultural and shrub lands were not included. The slightly and heavily disturbed forests were distinguished by their physiognomy (number of vegetation layers, presence of big trees) and the frequency of stumps and foot paths found in the plots (Hoang et al. 2008a). In the slightly disturbed forest there were no (or very few) stumps and foot paths. In heavily disturbed forest, stumps and foot paths were common (two to five stumps and more than one foot path in each 0.04 ha plot) (Hoang et al. 2008a).

In total we established 33 transects, each 200 m long. In the heavily disturbed forest we established 24 of these transects, placed at 250 m intervals perpendicular to the old logging road from the Song Chang forest ranger station to Cong Troi. Nine transects were established in the forest interior and these only showed infrequent traces of disturbance and referred to as 'slightly disturbed' throughout this paper. The total length of these transects combined was about 7.4 km. Along each transect we established four 10 × 10 m plots at 40 m intervals, starting 50 m from the old logging road. This resulted in 132 plots for all 33 transects combined. In the 132 plots (10 × 10 m) all trees with a diameter at breast height (dbh) ≥ 5 cm were identified and their diameter measured. All treelets with a dbh < 5 cm, and height (h) ≥ 1 m high were identified and their diameter measured in 5 × 5 m subplots within each 10 × 10 m plot. The data collected in each transect (four plots) were pooled to 0.04 ha plots to get a large enough sample size for subsequent statistical analyses.

In each 10 × 10 m plot, we measured the percentage of herb cover, canopy openness and slope, counted the number of stumps and foot paths and observed the presence of limestone (Hoang et al. 2008a). The distances used in this paper represented the shortest average distance (measured along the logging road and forest trails) to the four nearest villages. Inhabitants from these four villages (Binh Luong, Xuan Binh, Hoa Quy, Xuan Quy) (Figure 1) illegally logged timber and harvested NTFPs in the research area.

Light availability in the 10 × 10 m plots was determined using hemispherical photographs taken at 1.5 m height in a north–south direction in the centre of each plot. Canopy openness

was then calculated using WINPHOT (Ter Steege 1996). Plot slopes were measured with a clinometer (Brunton Clino Master). Percentage herb cover was estimated in each 10 × 10 m plot. Canopy openness, slope and herb cover values of the plots were calculated by averaging the values of the four plots in each transect.

Soil samples were collected between 0 and 30 cm depth from a single location in the centre of each plot by using an auger with a diameter of 3 cm. Soils were analysed at the Vietnam Forestry University, Vietnam following the methods by Chin (2000) and Le (2001). Total Ca, Mg, N, C, pH and exchangeable NH_4 were determined. To analyse the relation between soil factors and plant diversity, soil data of the four plots in each transect were averaged.

Voucher specimens were collected from all plant species in the plots. One voucher of each specimen was deposited at the herbarium of the Vietnam Forestry University while the rest were sent to the National Herbarium of the Netherlands and various specialists for identification.

Data analysis

The density of trees, treelets, tree basal area, and Fisher's alpha were calculated for each plot (Fisher et al. 1943, Taylor et al. 1976). The usefulness of the plant species and importance of timber trees in Ben En National Park was determined by using standard participatory rural appraisal (PRA) techniques (PID & NES 1989, Ngai 2001) and use index (UI). For detailed descriptions of these techniques assessing both qualitatively and quantitatively the role of each individual species in the local economy see Hoang et al. (2008b, c).

The Red List species in Ben En National Park were identified based on the Red Data Book of Vietnam (IUCN 2006, Ban 2007) and their conservation status was assessed using the frequency of trees and stumps of these species found during the field inventory (Hoang et al. 2008a, b, c).

A canonical correspondence analysis (CCA) was used to assess which variables best explained the differences in species composition (Ter Braak 1986, McCune & Mefford 1999). CCA is a constrained ordination technique where the ordination axes represent the relationship between species and measured environmental data (Press & Wilson 1978). This analysis was done with PCORD 5 using the abundance matrix of tree species in the 0.04 ha plots and a matrix describing the environmental and disturbance conditions in each plot. If certain CCA axes are significantly related to human or environmental factors, they can be used as proxy for disturbance or environmental gradients.

The CCA analysis was also used to assess which species were significantly affected in their presence and/or abundance by human impact and environmental variables (indicator species). Simple regression analysis (SPSS version 16) was used to determine whether a species was significantly correlated with a CCA axis. Only tree and treelet species with more than five stems were used in the correlation analysis.

Simple regression analyses were also used to examine whether and how the human and environmental variables were related to plot data for trees, treelets, useful plants and important timber trees. One way ANOVA analysis was used to test whether the density of trees, other useful plants (NTFPs), important timber trees and endangered species were different between the slightly and heavily disturbed forest plots.

RESULTS

A total of 245 tree species (dbh ≥ 5 cm) and 251 species of treelets (dbh < 5 cm, h ≥ 1 m, including juvenile stages of 146 of the 245 tree species) were recorded in the plots. Of these, 54 were categorised as useful species (mainly NTFPs) and 15 species as important timber trees (Hoang et al. 2008c).

There were no significant correlations between individual and combined disturbance factors and Fisher's alpha diversity indices of trees and treelets, density of treelets and number of treelet species in our plots (data not shown). In the CCA analysis, the first axis explained 5.7% of variance in tree species composition and density and was mainly determined by soil variables such as Ca, Mg, pH and NH_4 (Figure 2). The second CCA axis explained 4.4% of the variance and was mainly determined by human impact variables such as distance from villages, stumps and foot paths. Tree species composition in the plots was therefore more strongly correlated with soil factors than with human disturbance. Ca, Mg, pH and NH_4 were especially important correlates. Human impact variables were almost exclusively correlated with CCA axis 2; these were mostly independent of soil variables. Since the distance

to villages, number of stumps and number of foot paths were strongly correlated with CCA axis 2, this axis was used as the human impact proxy for the remainder of our forest disturbance analyses. The slightly disturbed and heavily disturbed forest types are clearly recognisable along this axis in Figure 2.

Since soil factors (Ca, Mg, pH and NH_4) were strongly correlated with species composition along CCA axis 1 in the park, this axis was used as environmental axis. There were nine species with a strong and significant correlation with CCA axis 1 (Table 1). Of these, four species were positive indicators for limestone forest (highest

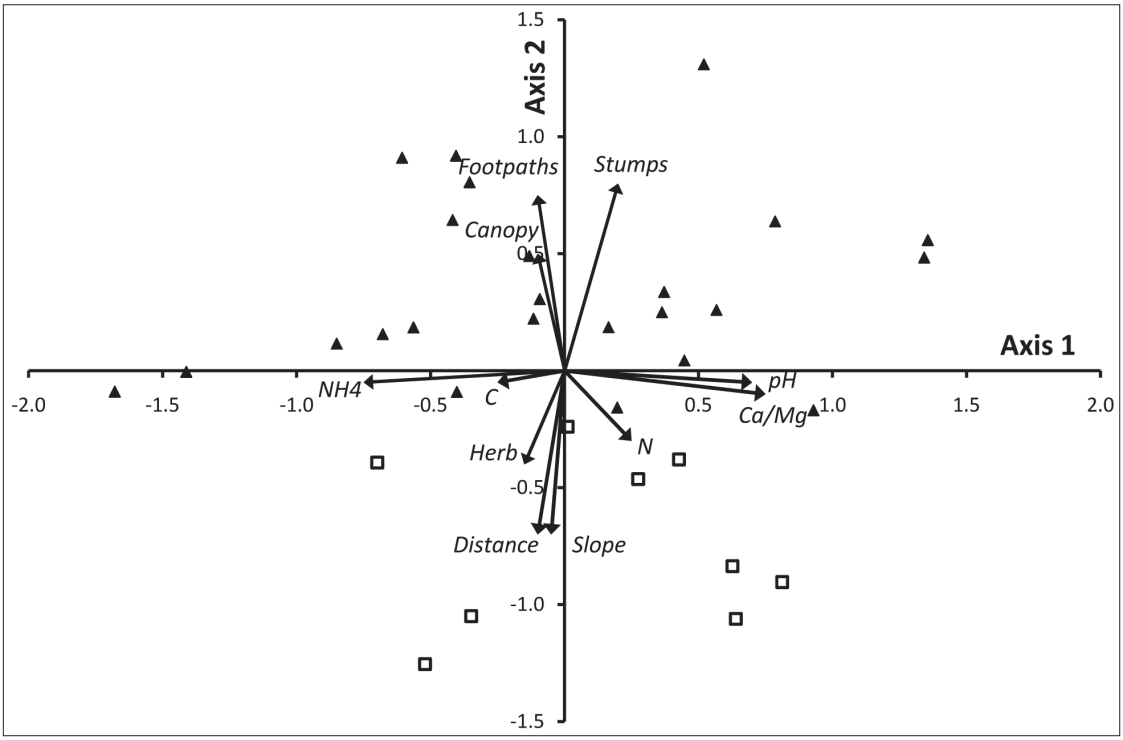

Figure 2 Canonical correspondence analysis (CCA) showing the plots and environmental variables. The first axis explains 5.7% of the variance present in the data, the second axis explains 4.4% of the data variance. The slightly disturbed (white squares) and heavily disturbed (black triangles) forest types are well separated along axis 2.

Table 1 Soil type indicator species in Ben En National Park

Name of species	Axis 1	Number of stems per 0.04 ha	Correlation coefficient (r)	p value
Limestone indicators				
Callicarpa macrophylla (Verbenaceae)	1.894	6	0.95	0.025
Garcinia fagraeoides (Clusioideae)	1.369	5	0.98	0.026
Vatica odorata (Dipterocarpaceae)	1.079	5	0.93	0.012
Callicarpa dichotoma (Verbenaceae)	1.032	8	0.87	0.027
Acidic soil and non-limestone indicators				
Schefflera octophylla (Araliaceae)	-2.374	10	-0.85	0.034
Syzygium wightianum (Myrtaceae)	-1.755	23	-0.74	0.002
Canarium tramdenum (Burseraceae)	-1.571	30	-0.75	0.001
Erythrophleum fordii (Caesalpinioideae)	-1.292	59	-0.55	0.005
Randia pycnantha (Rubiaceae)	-1.239	8	-0.92	0.015

Ca values), while five species were indicators for forest on acidic and non-limestone soils (Table 1). Six species had strong and significant correlations with CCA axis 2. Two of these indicated heavily disturbed forest, while four species were indicators of slightly disturbed forest (Table 2).

The density of trees, useful plants (NTFPs), and tree basal area were negatively correlated with human impact (Figure 3). The number of stumps found in each plot abruptly declined over 6 km away from the villages (Figure 4). However, we found occasional stumps outside the plots in these remote areas.

Our analysis also showed that there was no significant correlation between combined soil factors, density of trees (including important timber tree species), useful plants and tree

Table 2 Indicator species for human disturbance in Ben En National Park

Name of species	Axis 2	Number of stems per 0.04 ha	Correlation coefficient (r)	p value
Human disturbance indicators				
Claoxylon indicum (Euphorbiaceae)	1.523	6	0.97	0.026
Microcos paniculata (Tiliaceae)	1.259	16	0.89	0.012
Indicators of low human disturbance				
Diospyros montana (Ebenaceae)	-2.235	5	-0.98	0.046
Melientha suavis (Opiliaceae)	-1.364	11	-0.74	0.029
Heritiera macrophylla (Sterculiaceae)	-1.253	7	-0.88	0.023
Actinodaphne obovata (Lauraceae)	-1.190	43	-0.59	0.007

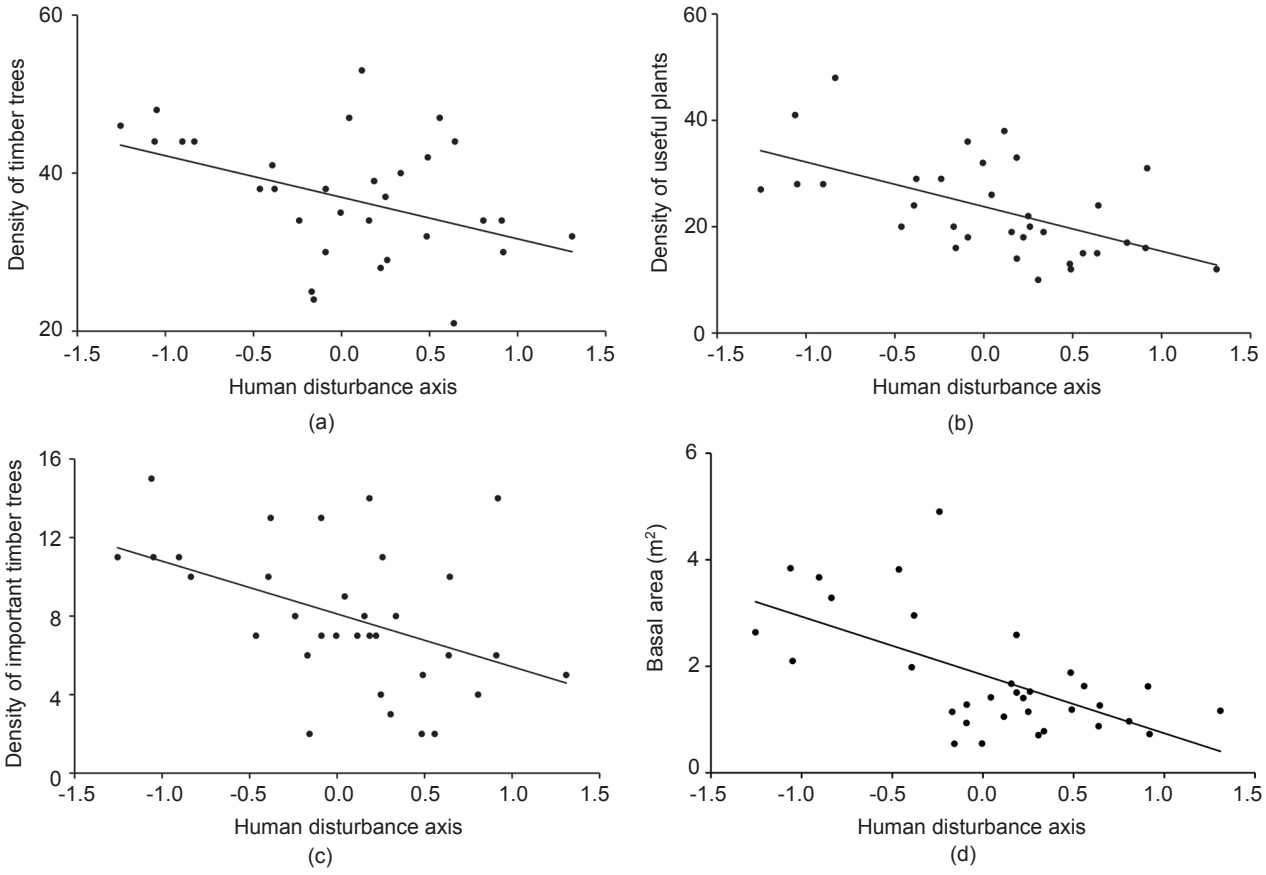

Figure 3 Relation between disturbance CCA axis II and (a) tree density in the 0.04 ha plots; $r^2 = 0.16$, $p < 0.05$, (b) density of useful plants in the 0.04 ha plots; $r^2 = 0.31$, $p < 0.001$, (c) density of important timber trees in the 0.04 ha plots; $r^2 = 0.21$, $p < 0.01$, and (d) tree basal area in the 0.04 ha plots; $r^2 = 0.38$, $p < 0.001$ (disturbance increases from left to right)

basal area in the 0.04 ha plots. However, soil factors had a strong correlation with treelet stem density (results for the rest were not significant), with highest treelet density in limestone forests (Figure 5). Soil variables also showed very weak but significant correlation with Fisher's alpha index for tree species (data not shown).

Canopy openness was not significantly correlated with treelet density. However, there was a weak but significant correlation with basal area and tree density (Figures 6 and 7). Density of Red-listed species showed weakly significant decline with increasing human disturbance (Figure 8).

DISCUSSION

The CCA analyses showed that soil explained more variance in tree species composition in Ben En National Park than human disturbance (Figure 2). This is probably because Ben En National Park has strongly contrasting soil types, i.e. limestone on the one hand and ferralitic/alluvial soils of varying acidity on the other. The special characteristics of limestone floras in terms of species composition and forest structure have been well documented for several regions in South-East Asia (Whitmore 1984, Vidal 2000, Lan et al. 2006). Soil factors, especially Ca and Mg, are also important factors for forest composition in Ben En National Park, which correspond to findings in forests of North Borneo (Potts et al. 2002, Davies et al. 2005).

The two axes in the CCA only explained 10.1% of data variance. However, low percentages of explanation of forest composition gradients by environmental parameters are not uncommon in tropical forests. For instance in an Amazonian

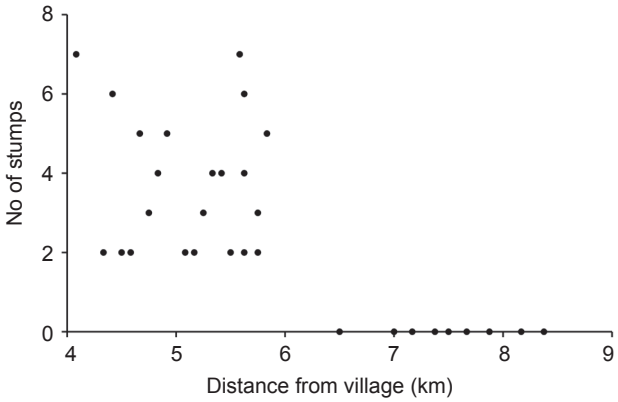

Figure 4 Relation between the number of stumps per 0.04 ha plot and distance from villages to plots

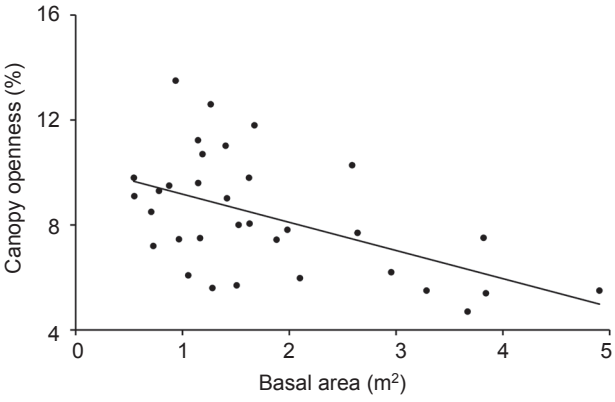

Figure 6 Relation between canopy openness and tree basal area in the 0.04 ha plots; r^2 = 0.27, $p < 0.001$

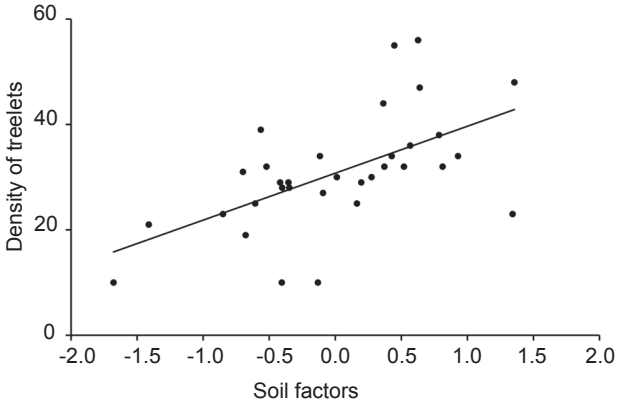

Figure 5 Relation between soil CCA axis 1 and treelet density in the 0.04 ha plots; $r^2 = 0.33$, $p < 0.001$ (left to right indicate decreasing soil acidity and increasing occurrence of limestone)

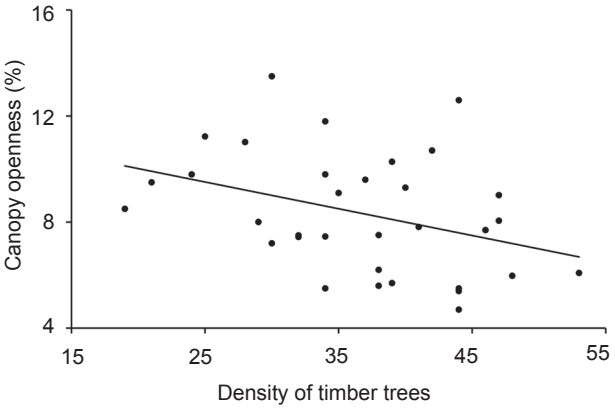

Figure 7 Relation between canopy openness and tree density in the 0.04 ha plots; $r^2 = 0.13$, $p < 0.001$

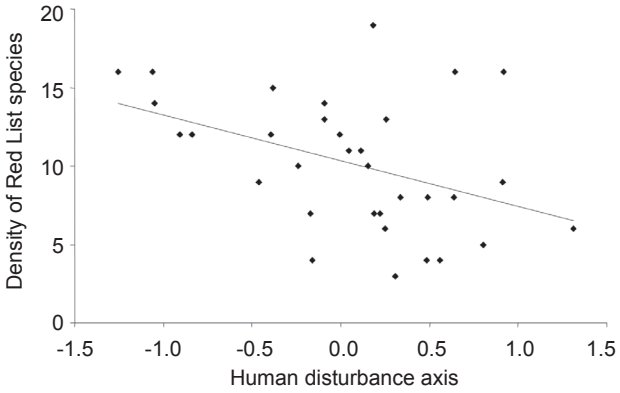

Figure 8 Relation between disturbance CCA axis and density of Red List species in the 0.04 ha plots; $r^2 = 0.18$, $p = 0.014$

forest, environmental factors (drainage, flooding, humus forms and soil nutrient status) only explained 6.2% of data variance by the first two canonical axes (Duivenvoorden 1995). In addition, plots that we surveyed were relatively small (0.04 ha). Since many tropical tree species were rare and most species were only represented by a few individuals, this might have resulted in random statistical noise.

While the impact of human disturbance on the species composition in the forest appeared to be limited (Figure 2, axis 2 explained 4.4% of variance), its impact on tree density and basal area was considerable. There was 13.4% decline in density of all trees (both timber trees and treelets), i.e. 16.7% in timber trees, 30% in useful plants (mostly NTFPs), 30.8% in endangered species and 36.4% in important timber trees (Figures 3 and 8). This is comparable to selectively logged forests in Cambodia where basal area and density of trees are much reduced compared with unlogged forests (Kao & Lida 2006). Therefore, it is clear that without appropriate measures plant resources will ultimately become depleted in the future, also in the areas further away from villages if illegal harvesting continues. Despite the large impact of disturbance on tree densities and basal area, human disturbance had no significant correlation with Fisher's alpha for tree species. This is an indication that human disturbance, although it affected species composition, did not seem to affect species richness in the forests of Ben En National Park. Comparable findings were reported by Slik et al. (2002) in forests of Kalimantan where Fisher's alpha index in selectively logged forest did not differ significantly from undisturbed forest but instead increased over time even though tree density was strongly reduced by logging.

Two of the four indicator species for low disturbance forest are listed in the Red List of Ben En National Park, namely, *Actinodaphne obovata* (Lauraceae) and *Melientha suavis* (Opiliaceae) (Table 2, Hoang et al. 2008a). In addition, *A. obovata* is an important timber tree species. In contrast, none of the species with a positive correlation with disturbance is listed in the Red Data Book of Vietnam nor the Red List species in Ben En National Park, and none of them are important timber trees. Indeed, the Red List species in the Park—including a number of valuable timber species—had a weakly significant negative correlation with the disturbance CCA axis (Figure 8), emphasising the conservation value of the slightly disturbed (i.e. least disturbed) forests in the area.

Soil factors were not significantly correlated with tree density, number of species and Fisher's alpha index in Ben En National Park. However, the density of treelets was higher on limestone soils than on other soil types (Figure 5). This conforms to results from tropical forests in Sarawak and New Guinea, where the numbers of shrubs and treelets are also higher on limestone (Whitmore 1984, Chapman & Wang 2002).

CONCLUSIONS

Soil types and human disturbance had a small but significant effect on forest composition in Ben En National Park. Human disturbance had a strong negative impact on forest structure, leading to lowered densities of timber trees, useful plants, especially important timber trees and Red List species. Disturbance levels decreased with distance to villages, indicating that the pressures of illegal logging and harvesting were closely connected to accessibility and transport costs. Prevention of forest conversion is urgently needed, through strict law enforcement within the park, to protect the important timber trees and endangered species before they become locally extinct. Reforestation and ecosystem restoration in the heavily disturbed forests and shrublands should be given immetiate serious attention by the management board of the park.

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