Uses and conservation of plant diversity in Ben En National Park, Vietnam

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Chapter 5

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

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ABSTRACT

In order to understand the influence of human disturbance and the physical environment on plant biodiversity in Ben En National Park, Vietnam, we analyzed 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 useful plants 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 are 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 park's rich biodiversity and stocks of useful plants.

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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-over 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; Uuttera 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, i.e. 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). Therefore, identification of factors related to human disturbance that affect biodiversity and forest vegetation structure is important because it might enable us to change to less destructive forest management types (Pickett 1995).

Within diverse tropical forests there is also evidence that 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). However, environmental factors can have a differential effect on plant diversity and forest composition (Potts et al. 2002). For example, soil factors and mean annual rainfall are more strongly related with floristic composition when compared with topography in lowland forests (Baillie et al. 1987; Potts et al. 2002; Slik et al. 2003; Eichhorn & Slik 2006).

Ben En National Park is one of 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: 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 (NTFP) by both local people and people from outside the National Park continues (Tordoff et al. 2000; Hoang et al. 2008 a). The park has strongly contrasting soil types and one of the challenges is therefore to disentangle effects of soils and human disturbance on species composition.

In this study we focus on the following questions: Can human influences on species composition be separated from environmental factors, and if so, how do both affect plant diversity and composition in Ben En National Park? Answers to these questions will be relevant for developing a sustainable management plan for Ben En and other National Parks in Vietnam.

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 (Fig. 5.1)). 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 2,281 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).

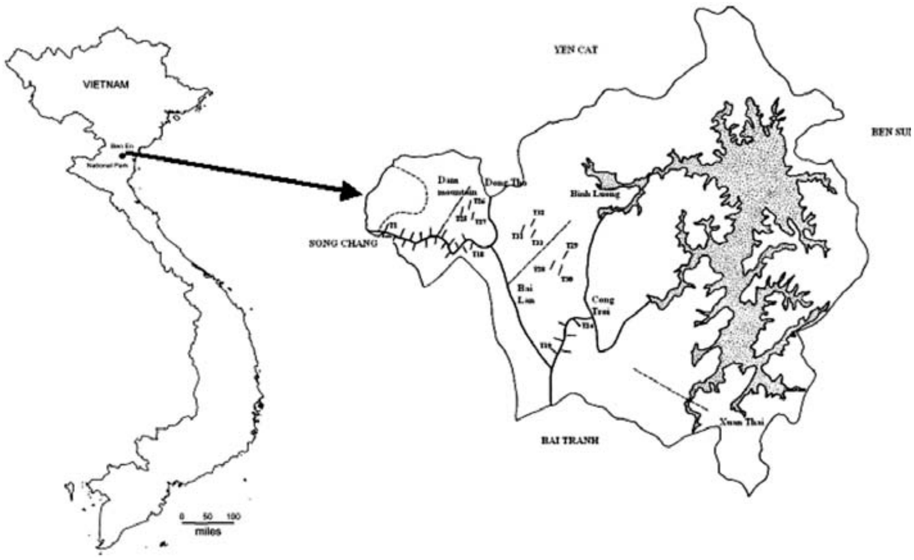

Fig. 5.1. Map of Ben En National Park in Vietnam
(inset – lakes are in grey; line transects are drawn in).

The core zone of the National Park covers 15,800 ha, while the buffer zone covers ca. 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 (Khoi 1996; Hoang et al. 2008 a). 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. 2008 a & c). Ben En National Park is estimated to have a total species number of vascular plants of ca. 1600 (Hoang et al. 2008 a). In a previous study 1389 vascular plant species were recorded, belonging to 650 genera and 173 families (Hoang et al. 2008 a).

METHODOLOGY

Plot inventory

For this study we established transects and plots in forest areas along the old logging road as well as in the forest interior (Fig. 5.1). No agricultural lands and shrublands were included. In total we established 33 transects, each 200 m long. Twenty-four of these transects were placed at 250 m intervals at right angles along the old logging road from the Song Chang forest ranger station to Cong Troi, while nine transects were established in the slightly disturbed forest interior (Fig. 5.1). The total length of these transects combined was ca. 7.4 km. Along each transect we established four 10 x 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 x 10 m) all trees with a dbh ≥ 5 cm were identified and their diameter measured. All treelets with a dbh < 5 cm, and h ≥ 1 m high were identified and their diameter measured in 5 x 5 m subplots within each 10 x 10 m plot. The data collected in each transect (four plots) were combined to so-called 0.04 ha plots to get a large enough sample size for subsequent statistical analyses.

In each 10 x 10 plot, we measured the percentage herb cover, canopy openness, slope, GPS-coordinates, noted the number of stumps, number of footpaths, and presence of limestone (Hoang et al. 2008 a). The distances used in this paper represent the shortest average distance (measured along the logging road and forest trails) to the four nearest villages. Inhabitants from 4 of these villages (Binh Luong, Xuan Binh, Hoa Quy, Xuan Quy) (Fig. 5.1) illegally log timber and harvest non timber forest products in the research area.

Light availability in the10 x 10 m plots was determined with the use of 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 x 10 m plot. Canopy openness, slope and herb cover values of the plots were calculated by averaging the values of the four plots.

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 analyzed at the Vietnam Forestry University, Vietnam following the Chin methods (Chin 2000; Le 2001). Total Ca, Mg, N, C, pH and exchangeable NH4 were determined. To analyze the relation between soil factors and plant diversity, soil data of the four plots in each transect were averaged.

Vouchers were collected of all plant species in the plots. One voucher of each specimen was deposited in the herbarium of the Vietnam Forestry University (VFU), additional vouchers were sent to the National Herbarium of the Netherlands (L) and to various specialists for identification.

Data analysis

A total of 245 tree species (dbh ≥ 5 cm), and 251 species of treelets (dbh < 5 cm, and h ≥ 1 m high, including juvenile stages of 146 of the 245 tree species) were recorded in the plots. For each plot the density of trees, treelets, tree basal area, and Fisher's-Alpha were calculated (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) (Hoang et al. b & c). A total of 54 useful plant species and 15 important timber trees were found within the plots (Hoang et al. 2008 c).

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

A Canonical Correspondence Analysis (CCA) was used to see which variables best explained the differences in species composition, be it environmental or human (Ter Braak 1986; McCune & Mefford 1999). CCA is a constrained ordination technique, where the ordination axes represent a relationship between species and environmental data (Press & Wilson 1978). This analysis was done with PCORD 5, using the abundance matrix of tree species in the plots, in order to determine how environmental and human variables were related to differences in tree species composition between the plots. 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 determine species that were significantly affected by human impact and environmental variables (indicator species). Simple regression analysis (SPSS 16) was used to determine whether a species was significantly correlated with a CCA axis. Only species with more than 5 stems were used in the correlation analysis. Simple regression analysis was 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, useful plants, important timber trees, and endangered species were different between slightly and heavily disturbed forest. 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. 2008 a). 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 (2 to 5 stumps and more than 1 foot path in each 0.04 ha plot) (Hoang et al. 2008 a).

RESULTS

Influence of human and environmental variables on tree composition in Ben En National Park

The first CCA axis explained 5.7% of data variance and was mainly determined by soil variables (Fig. 5.2). The second CCA axis explained 4.4% of data variance and was mainly determined by human impact variables. Tree species composition in the plots was therefore more strongly correlated with soil factors than with human disturbance. Especially Ca, Mg, pH and NH4 were 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 footpaths were strongly correlated with CCA axis 2, we used this axis as our human impact proxy for the remainder of our forest disturbance analyses. The slightly disturbed and heavily disturbed forest types are clearly recognizable along this axis in Fig. 5.2.

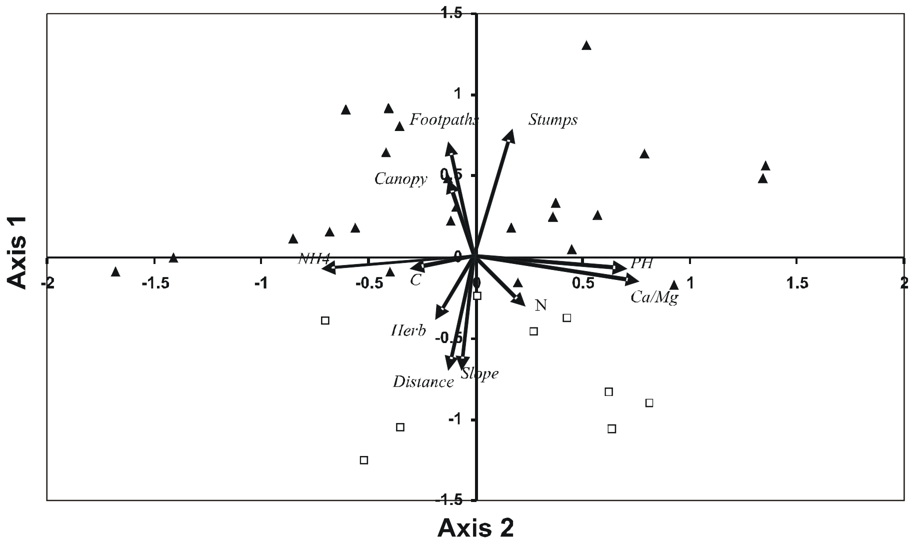

Fig. 5.2. Canonical Correspondence Analysis (CCA) showing the plots and environmental variables. The first axis explains 5.7% of the variance present in the data; the second axis explains 4.4% of the data variance. The slightly disturbed (white squares) and heavily disturbed (black triangles) forest types are well separated along axis 2.

Since soil factors, especially Ca, Mg, pH and NH4 were strongly correlated with species composition along CCA axis 1 in the Park we used this axis as environmental axis. There were nine species with a strong and significant correlation with axis 1 (Table 5.1); of these, four species were positive indicators for limestone forest, while five species were indicators for forest on acidic, and non limestone soils (Table 5.1).

Table 5.1. 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 (Verb)	1.894	6	0.95	0.025
Garcinia fagraeoides (Clus)	1.369	5	0.98	0.026
Vatica odorata (Dipt)	1.079	5	0.93	0.012
Callicarpa dichotoma (Verb)	1.032	8	0.87	0.027
Acidic soil and non limestone indicators				
Schefflera octophylla (Aral)	-2.374	10	-0.85	0.034
Syzygium wightianum (Myrt)	-1.755	23	-0.74	0.002
Canarium tramdenum (Burs)	-1.571	30	-0.75	0.001
Erythrophleum fordii (Caes)	-1.292	59	-0.55	0.005
Randia pycnantha (Rub)	-1.239	8	-0.92	0.015

Six species had a strong and significant correlation with CCA disturbance axis 2; two of these indicated heavily disturbed forest, while four species were indicators of slightly disturbed forest (Table 5.2).

Table 5.2. Indicator species for forest disturbance in Ben En National Park

Name of species	Axis 2	Number of stems per 0.04 ha	Correlation coefficient (r)	P Value
Disturbance indicators				
Claoxylon indicum (Euph)	1.523	6	0.97	0.026
Microcos paniculata (Til)	1.259	16	0.89	0.012
Indicators of low disturbance forest				
Diospyros montana (Eben)	-2.235	5	-0.98	0.046
Melientha suavis (Opil)	-1.364	11	-0.74	0.029
Heritiera macrophylla (Sterc)	-1.253	7	-0.88	0.023
Actinodaphne obovata (Laur)	-1.190	43	-0.59	0.007

Human impact on plant diversity in Ben En National Park

The density of trees, useful plants, and tree basal area were negatively correlated with human impact (Fig. 5.3 a-d). However, there were no significant correlations between 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). The number of stumps found in each plot abruptly declined over 6 km away from the villages (Fig. 5.4). Although Fig. 5.4 shows total absence of stumps in these distant plots, we did find occasional stumps outside the plots in these remote areas.

The CCA analysis showed that soil factors had a strong correlation with plant composition in Ben En National Park (Fig. 5.2). Our analysis also showed that there was no significant correlation between soil factors, density of trees (including important timber tree species), useful plants and tree basal area in the 0.04 ha plots. However, soil factors had a strong correlation with treelet stem density, with highest treelet density in limestone forests (Fig. 5.5).

Soil variables also showed a very weak but significant correlation with Fisher's alpha index for tree species.

Canopy openness was not significantly correlated with treelet density. However, there was a weak but significant correlation with basal area, and tree density (Fig. 5.6 & 5.7).

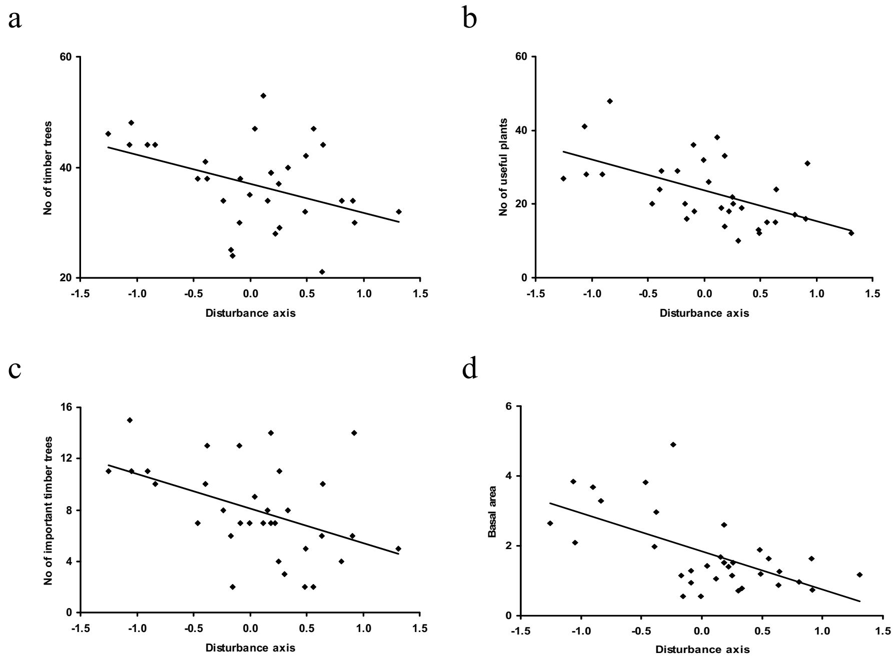

Fig. 5.3. Relation between disturbance CCA axis II and (a) tree density in the 0.04 ha plots; $R^2 = 0.16$; $P < 0.05$; (b) density of useful plants in the 0.04 ha plots; $R^2 = 0.31$; $P < 0.001$; (c) density of important timber trees in the 0.04 ha plots; $R^2 = 0.21$; $P < 0.01$; (d) tree basal area in the 0.04 ha plots; $R^2 = 0.38$; $P < 0.001$ (disturbance increases from left to right).

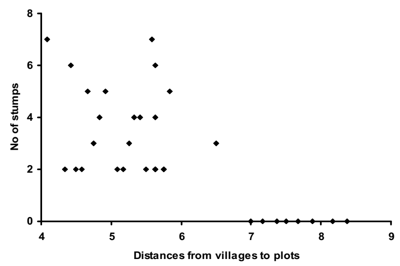

Fig. 5.4. Relation between the number of stumps per 0.04 ha plot and distance from villages to plots.

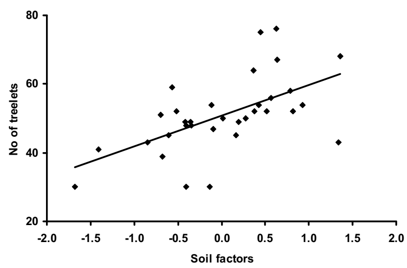

Fig. 5.5. Relation between soil CCA axis 1 and treelet density in the 0.04 ha plots: $R^2 = 0.33$; $P < 0.001$ (left to right indicates decreasing soil acidity and increasing occurrence of limestone).

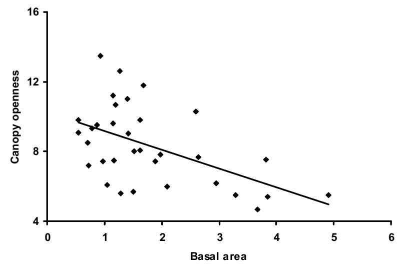

Fig. 5.6. Relation between canopy openness and tree basal area in the 0.04 ha plots: $R^2 = 0.27$; $P < 0.001$.

Fig. 5.7. Relation between canopy openness and tree density in the 0.04 ha plots: $R^2 = 0.13$; $P < 0.001$.

DISCUSSION

Human and environmental impact on plant diversity and composition in Ben En National Park

Our CCA analyses showed that soil is the most important factor for forest composition in Ben En National Park, even more important than the influence of human disturbance (Fig. 5.2). This is doubtlessly because Ben En National Park has strongly contrasting soil types: 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 Southeast 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 corresponds to findings in forests of North Borneo (Davies et al. 2005; Potts et al. 2002).

The two axes in the CCA only explain 10.1% of data variance. The low percentage of explanation of human and environmental factors on forest composition in Ben En National Park might be due to the fact that the inventory did not include very heavily disturbed shrublands, and bamboo forest. When those areas would have been included the explanatory power of the disturbance CCA axis would doubtlessly have been much higher. Low percentages of explanation of forest composition gradients by environmental parameters are not uncommon in tropical forests. For instance in an Amazonian 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) and, since many tropical tree species are rare, most species were only represented by a few individuals. This means that our analysis includes much random statistical noise since it is impossible to determine habitat preference for species with four or fewer individuals.

While the impact of human disturbance on the species composition in the forest appears to be limited (Fig. 5.2), its impact on tree density and basal area is considerable (Fig. 5.3). We observed a 13.4% decline in density of all trees (both timber trees and treelets), 16.7% in timber trees, 30% in useful plants, 30.8% in endangered species, and 36.4% in important timber trees. This is comparable to selectively logged forests elsewhere in the tropics, where basal area and density of trees are much reduced (Kao & Iida 2006). It must therefore be feared that without appropriate measures plant resources will 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 the human disturbance seems not to affect relative species abundances much 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 and even increased over time, even though tree density was strongly reduced by logging.

Two out of the four indicator species for low disturbance forest are listed in the Red List of Ben En National Park: *Actinodaphne obovata* (Lauraceae) and *Melientha suavis* (Opiliaceae) (Table 5.2; Hoang et al. 2008 a). In addition to that, *Actinodaphne obovata* (Lauraceae) is an important timber tree species. In contrast, none of the species indicating disturbance is listed in the Red Data Book of Vietnam and the Red List species in Ben En National Park, and none of them are important timber trees. Indeed, the number of Red List species in the Park has a significant negative correlation with the disturbance CCA axis (Fig. 5.8), emphasizing the conservation value of slightly 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 is higher on limestone soils than on other soil types (Fig. 5.5). This conforms to results from tropical forests in Sarawak and New Guinea, where the number of shrubs and treelets was also found to be higher on limestone (Whitmore 1984; Chapman & Wang 2002). This is apparently caused by a deficiency in certain plant nutrients, and poor water retention of limestone substrates (Whitmore 1984).

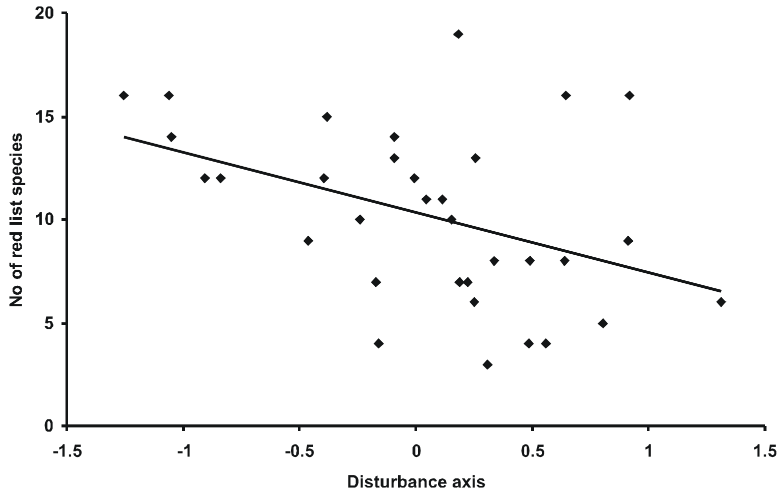

Fig. 5.8. Relation between disturbance CCA axis and density of Red list species in the 0.04 ha plots; $R^2 = 0.18$; $P < 0.05$.

CONCLUSION

Soil types and human disturbance have a 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 are closely connected to accessibility and transport costs. Prevention of forest conversion is urgently needed, by 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 the next steps.