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Article

Impact of Non-Timber Forest Product Use on the Tree Community in North-Western Vietnam

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Abstract: Trees providing non-timber forest products (NTFPs) are valuable forest resources, and their management can support conservation objectives. We analyzed the abundance of tree species providing NTFPs, recognized by local H'mong people, in both the strictly protected core zone and the low-intensity forest use buffer zone in north-western Vietnam. We identified 249 tree species, of which 48% were classified as NTFP species. The abundance of 35% of the NTFP tree species was significantly correlated with footpaths, indicating an influence of human activity. A multiple logistic regression model indicates that using NTFP trees for food, medicine, and root harvesting, increases the probability of an NTFP tree absence in the buffer zone. In contrast, the high density of species, and collections of fruit, leaf, and resin decrease the probability of an NTFP tree absence in the buffer zone. Further assessment with a logistic model indicated that NTFP use has lower impacts on the tree community than timber use. We think that the parameterized models will enable comparisons of different situations and forest types and be particularly helpful in evaluating potential changes in tree communities over time.

Keywords: logistic regression model; forest management; H'mong people; conservation

1. Introduction

Non-timber forest products (NTFPs) play an essential role in the livelihoods of humans living in, and adjacent to, tropical forests [1–4]. NTFPs are considered significant provisioning ecosystem services [5], providing food, medicine, fiber, and energy [6,7]. It has been proposed that harvesting NTFPs does not significantly alter forest structure, and NTFP use has less environmental impacts than timber logging and may be much better in line with conservation objectives [8,9]. Therefore, proper NTFP management is essential for achieving ecological, social, and economic benefits [7].

Primary forests are considered irreplaceable for sustaining tropical biodiversity [10]. Also, intact forests significantly contribute to mitigating global environmental issues and maintaining ecosystem functions and services [11]. Thus, preserving and restoring the integrity of such forests is an urgent priority [11]. One forest management intervention is the establishment of protected areas with surrounding buffer zones to safeguard remaining habitats and species [12,13]. The buffer zone also enhances the conservation value of the protected areas while providing local people with forest resources such as NTFPs [14,15]. Within the buffer zone, a presumably low impact use is permitted so as to reduce the pressure on protected areas [16,17]. In this context, it is crucial to know the effect of NTFP use on tree species abundance in order to better understand the effectiveness of current forest management regimes and, if needed, propose adjustments towards sustainable forest use.

The actual impact of NTFP exploitation depends on many factors, such as the intensity of collection and tree parts harvested [9,18–20]. Low intensity use of NTFPs, e.g., utilization only to meet domestic demands, seems to only slightly influence biodiversity [21]. In contrast, the collection of larger quantities, e.g., for commercial purpose, can lead to over-exploitation, decreased local abundance, and extinction of some species that provide highly desired products [19,22–25]. Sporadic collection of a few fruits or periodic harvesting of leaves may have a negligible impact on the plant population being exploited [26,27], but intensive exploitation of seeds, fruits, and flowers may lead to reduced species richness of a community over time [23,26,28]. Previous evaluations of the impact of NTFP extraction have mainly focused on specific tree species; however, knowledge of how the harvest of different NTFP tree parts and use purposes affect tropical forest tree communities remains scarce. Therefore, investigating the role of NTFP use in shaping tree communities, using a parameterized model, is necessary to provide quantitative information for improving conservational management.

The topic of different forest use types, and their influence on structures and functions of tropical forests, has already received substantial attention in the context of sustainable forest use. Frequently, NTFP use is praised as eco-friendly and only slightly influential regarding biodiversity, while timber logging can cause numerous negative ecological effects [29–32]. However, several authors have claimed that promoting NTFP use may also have negative influences on forest structure and may not meet forest conservation requirements [33,34]. Yet little quantitative information is known comparing these two forest use types. Therefore, quantitative analysis to compare these two forest use types may provide a deeper understanding of whether or not NTFP use has less impact on forest tree communities than timber use.

This study was conducted in north-western mountainous Vietnam within a biodiversity hotspot [35,36], a region where H'mong people reside and use forest resources for subsistence. The Ta Xua Nature Reserve has a strictly protected core zone and a buffer zone. In the buffer zone, NTFPs are collected by local H'mong people to fulfill their demands. The objectives of this study were (1) to assess differences in the abundance of NTFP tree species between the protected core zone and the buffer zone; (2) to analyze the impact of NTFP use on the abundance of NTFP species community; and (3) to examine whether NTFP use is less influential in changing forest tree communities than timber use. For this assessment, our analyses include detrended correspondence analysis and logistic regression models. The insights derived may improve understanding of the impact of forest use on tree communities and lay the basis for further assessments.

2. Materials and Methods

2.1. Study Area

The present study was conducted in the Ta Xua Nature Reserve, north-western Vietnam (21°13–21°26′ N, 104°16′–104°46′ E, see Figure A1 in Appendix A). The Nature Reserve has high, steeply sloping mountains rising from 320 m to 2765 m a.s.l. The climate is humid-tropical, influenced by the north-east monsoon. At the nearest meteorological station (Phu Yen, c. 40 km from Ta Xua Nature Reserve at 175 m a.s.l.), annual precipitation ranges from 1600 mm to 1900 mm, and the average temperature is 20 °C.

The reserve has a strictly protected core zone of 15,211 ha (Figure 1). Human disturbance activities such as logging, hunting, and collecting NTFPs are forbidden, and during our field work, signs of these activities were only rarely observed. Forest cover in the core zone is 87%, and forest types range from evergreen and broad-leaved rainforest at lower elevations, to coniferous forest mixed with some evergreen and broad-leaved species on the higher peaks [37]. The core zone can only be reached by footpaths, created either before the nature reserve was established, or in use now for ranger patrols, research projects, and tourists.

The buffer zone encompasses 24,674 ha above 900 m a.s.l. and has 44% forest cover. The forest is managed by the local H'mong people in accordance with forest management regulations mandated by the Law of Forest Protection and Development [38]. These regulations entail a maximum of 25 trees logged per year in the forest area of the buffer zone; however, signs of illegal logging were observed. NTFPs may also be gathered to fulfill local people's demands, but the regulations lack quantity specific limits. The harvesting of NTFP species in the area only supports the local people's needs; the commercial trading market has not yet developed. Land below 900 m a.s.l. is mainly agricultural land, with upland rice, maize, and sugarcane predominating [37].

Figure 1. The landscape and forest in the protected core zone of the Ta Xua Nature Reserve (**A**); a valuable non-timber forest product tree species, *Zanthoxylum myriacanthum* Wall. ex Hook. f., in the buffer zone. Its fruits are used as a spice (**B**); and a couple of local H'mong people, with the lady carrying some Non-timber forest products (NTFPs) collected from the forest in the buffer zone (**C**). Photos from Thi Hoa Hong Dao, Van Dung Phan, and Thi Thanh Dong.

2.2. Sampling Design

Based on a provisional forest cover map and a reconnaissance survey, land at an elevation between 1000 m to 1700 m a.s.l. was selected for the study. This included 73 ha in the core zone and 115 ha in the buffer zone. A grid system of 1400 cells of 1 cm^2 was created and overlaid on the map (the map scale of 1/50,000) of the study area to randomly place sample plots. Forty plots of 20 m × 20 m were established in each conservation zone, with the center of each plot located in the center of a selected cell [39].

2.3. Data Collection

In the sample plots, all standing trees with a diameter at breast height (DBH) of at least 6 cm were counted. DBH was measured, and trees were identified to species level by two botanists from the Vietnam National University of Forestry (VNUF), (Hanoi, Vietnam). Trees that could not be identified to species level were classified by genus or family and sorted into specimens for further study at the VNUF herbarium. Species providing NTFPs were directly identified by two H'mong persons who are experienced in NTFP collection in the region and participated in field work. In addition, specimens of NTFP species were collected for further ethnobotanical survey with the assistance of H'mong elders and traditional doctors. NTFP species were classified according to the tree parts harvested and use purposes in accordance with the knowledge of the H'mong people. NTFPs used for fuelwood purposes were excluded in this study. H'mong people usually fulfill their fuelwood demand by collecting fuelwood from their gardens, dead tree poles, and branches on the forest floor.

In the study plots, some additional information was also collected, such as: percentage of canopy closure, soil properties, slope inclination, elevation, numbers of footpaths, and tree stumps. The core and buffer zones had similar basic characteristics of site conditions such as elevation, soil pH, and slope inclination (see Table A1 in Appendix A). However, forest structure characteristics and intensity of human interference showed significant differences between the two conservation zones. DBH and canopy closure were higher, while the numbers of footpaths and stumps were lower in the core zone than in the buffer zone. A previous study in the nature reserve indicated that threatened and red-listed tree species are more abundant in the core zone than in the buffer zone [40]. An assessment of factors contributing to differences in the tree community in the core and buffer zones suggested that, at the tree level, timber trees with a large diameter have a high probability of absence in the buffer zone, which points to timber utilization [39].

To compare the impact of NTFP use and timber use on the forest tree community, an assessment of valuable timber tree species was conducted. Observed tree species were assigned as valuable timber species, according to two standard textbooks of Vietnam [41,42], with the criteria of: large tree size at maturity, stem straightness, hard and durable wood, fine-textured wood, wood dimensional stability, easy to work with, and use for many purposes. It means that these tree species often have a high economic value. In total, 54 tree species were assigned as valuable timber species and were described in the Supplement Data of [39].

2.4. Statistical Analysis

A *t*-test was used to test the difference between the means of the two conservation zones (significant if $p \leq 0.05$) if the data satisfied the criteria of normal distribution and homogeneity of variance. When these requirements were not met, the nonparametric Mann-Whitney *U*-test was applied.

Detrended correspondence analysis (DCA) was applied to analyze the relationships of the abundance of NTFP tree species with forest structure and human interference variables in the core and buffer zones. The main matrix contained the names and densities of NTFP tree species within a set of sample plots in the core and buffer zones, and a second matrix included the forest structural variables (percentage of canopy closure, species richness, tree density, tree DHB) and human interference variables (numbers of footpaths and tree stumps) from the same plots. Densities of NTFP tree species in the main matrix were log-transformed and standardized to achieve approximately standard normal distributions, and data in the second matrix were expressed relative to their maxima to ensure equal weighting before running DCA. Spearman correlation analysis was used to test the significant correlation of density of each NTFP tree species with the DCA axes scores.

The probabilities of NTFP tree and species absence in the buffer zone were analyzed by logistic regression models. Predictor variables that satisfied assumptions of logistic regression (e.g., little or no multi-collinearity among the independent variables, linearity of independent variables and log odds) and were statistically significant in the Wald *z*-test were selected for the logistic models. Stepwise logistic regression was used to select variables for inclusion in the regression models. In the comparison of the different models, the model with the lowest Akaike Information Criterion (AIC) was selected. Odds ratios (ORs) and 95% confidence intervals (CIs) were used to compare the influence of different predictor variables. The probabilities of NTFP tree absence and species absence were calculated by transforming back to the original scale ($p = 1/[1 + e^{-\text{logit}\,(p)}]$), [43].

For each NTFP tree in the core zone, the absence of a similar tree was recorded if there was no tree in the buffer zone belonging to the same species and DBH class (the width of DBH classes was 10 cm). The probability of NTFP tree absence resulted in a multiple logistic regression model with the seven significant predictor variables. For predicting the probability of NTFP species absence, the presence or absence of the same NTFP tree species in the buffer zone was recorded. However, there was no significant predictor variables selected for the logistic model according to the Wald *z*-test.

Logistic regression analysis was also used to predict the probability of tree absence related to its use for NTFPs and/or timber. This probability was predicted by another multiple logistic regression model with the lowest AIC value and the participation of four significant variables. Data analyses were conducted using RStudio (version 0.99.491) [44] and PC-ORD software version 5.12 [45].

3. Results

3.1. NTFP Tree Species

In total, 249 tree species (DBH $\geq$ 6cm) were recorded in two conservation zones, of which 120 species (48%) were recognized as NTFP species by the H'mong people. The species richness of NTFP trees was lower but the stem density was higher in the buffer zone than in the core zone (Table 1).

Table 1. Non-timber forest product (NTFP) species and their proportion to all identified forest tree species in the core zone and the buffer zone. A total of 120 NTFP tree species were found in two conservation zones. (Means and standard deviations (SD), species(sp.), n = 40 plots of 400 m^2 per zone).

Characteristics of Tree Species	Zone	NTFP Species (Mean ± SD)	NTFP Species in Relation to All Species (%)
Species richness (sp./1600 m^2)	Core zone	99	51.3
	Buffer zone	81	46.8
No. of trees (tree/400 m^2)	Core zone	17.2 ± 5.9 ^{a}	46.4
	Buffer zone	24.5 ± 12.0 ^{b}	60.9
Diameter (cm)	Core zone	20.5 ± 4.4 ^{a}	-
	Buffer zone	16.6 ± 3.3 ^{b}	-
Basal area (m^2/ha)	Core zone	22.0 ± 12.6 ^{a}	42.9
	Buffer zone	18.2 ± 11.2 ^{a}	59.8

Different superscripts "a" and "b" indicate significant differences ($p \leq 0.05$).

NTFPs are categorized into six different use purposes. The largest number of NTFP species were used for medicine, followed by food, fiber, incense, fodder, and fish paralysis (coma) (Figure 2A). Leaves, bark, fruits, and roots are tree parts harvested most commonly, while branches, resin, and flowers are rarely used (Figure 2B). Appearance frequency of NTFP tree species, in the 40 sample plots, presents a similar sequence for use purposes and tree parts harvested (Figure 2C,D). Some NTFP species are used in combination with different components to serve multiple purposes. For example, the root bark and sour-sweet fruits of *Artocarpus tonkinensis* A. Chev. ex Gagnep. are edible, and are also used to treat lung disease, bleeding cough, back pain, and arthritis. Additionally, fruits of *Garcinia cowa* Roxb. ex Choisy can be used for food and treating fever (see in the Supplement Data of [39]).

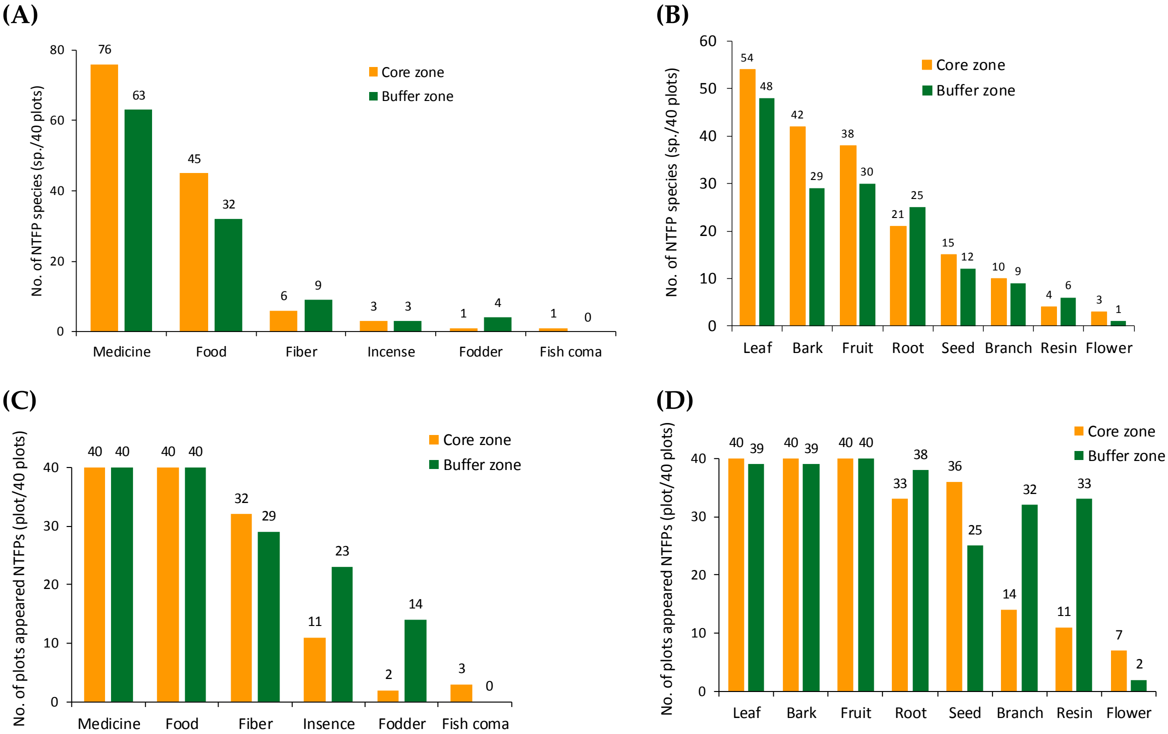

Figure 2. Number of NTFP tree species according to use purposes (**A**) and tree parts harvested (**B**); and number of sample plots that NTFP tree species appeared in according to use purposes (**C**) and tree parts harvested (**D**) in the core zone and the buffer zone.

3.2. NTFP Tree Species Abundance on Human Interference

The DCA indicates the correlation of the abundance of NTFP tree species with the variables of forest structure and human disturbance (Figure 3). The axis-1 (eigenvalue = 0.6) positively correlated with number of footpaths ($r = 0.3$, $p < 0.01$) and negatively correlated with total tree species richness ($r = -0.4$, $p < 0.001$). The axis-2 (eigenvalue = 0.43) had a negative correlation with total tree species richness ($r = -0.3$, $p < 0.005$). The density of 42 NTFP tree species (35% of total number of NTFP tree species) significantly correlated with one of the two DCA axes. Most NTFP tree species that mainly appeared in the core zone showed negative correlations with human disturbance (number of footpaths), whereas NTFP tree species that occurred mainly in the buffer zone showed positive correlations with the number of footpaths.

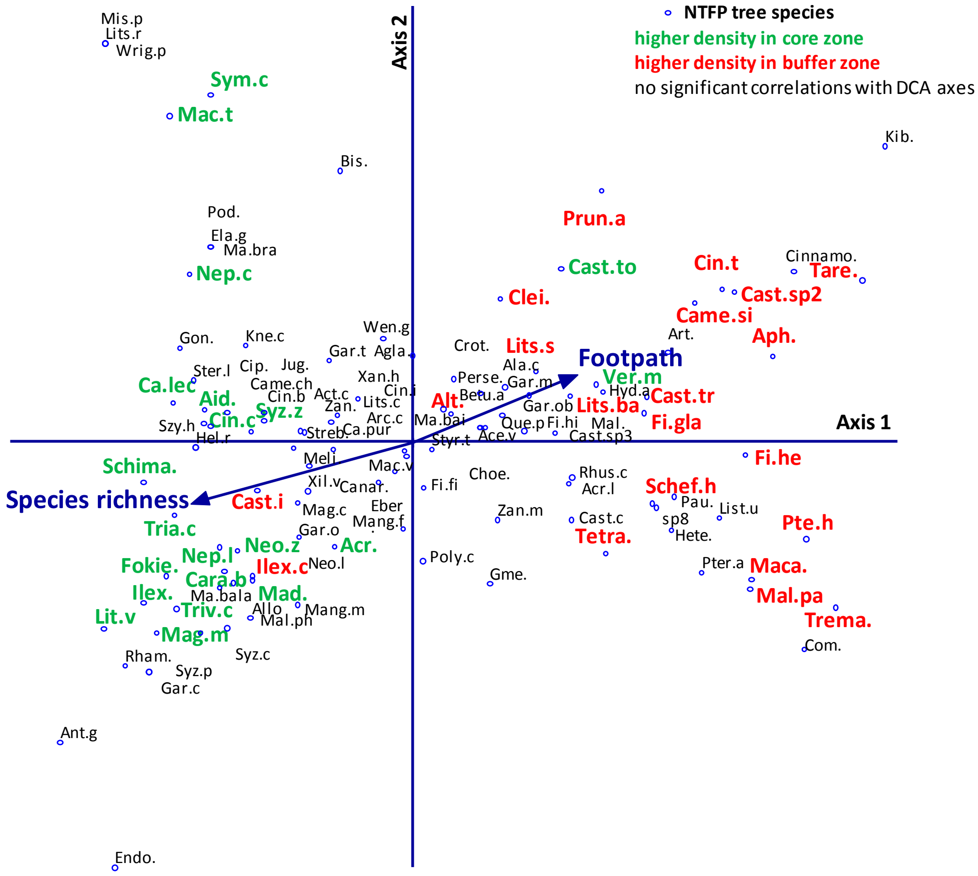

Figure 3. Detrended Correspondence Analysis (DCA) shows the correlations between the density of all 120 NTFP tree species in the core zone and the buffer zone, and forest structure and human disturbance variables. There are 42 NTFP tree species (shown in color) that correlate significantly with one of the two DCA axes. The other 78 NTFP species (shown in black) show no significant correlation with either of the DCA axes. Abbreviations for NTFP species are given in the Supplement Data of [39].

3.3. *NTFP Tree Species: Probability of Absence*

At the species level, no predictor variables were statistically significant in predicting the probability of absence according to the *z*-test. However, at the tree level, the probability of NTFP tree absence resulted in a multiple logistic regression model with seven significant predictor variables: harvesting for food purpose; harvesting of root; harvesting for medicine purpose; density of a species; and harvesting of fruit, leaf, and resin (in descending order of importance based on odds ratio) (Table 2). The multiple logistic regression model indicates that the use of an NTFP tree for food and medicine purposes and the harvesting of root increase the probability of NTFP tree absence in the buffer zone. In contrast, a high density of a species, and the exploitation of fruit, leaf, and resin decrease the probability of NTFP tree absence (also see Figure A2 in Appendix A).

Table 2. Multiple logistic regression model for predicting probability of NTFP tree absence: logit (p) = $-0.03 \times$ Density + $1.11 \times$ Food + $0.83 \times$ Medicine $- 1.15 \times$ Fruit $- 1.82 \times$ Leaf + $1.04 \times$ Root $- 2.21 \times$ Resin. Akaike Information Criterion (AIC) = 755.3; likelihood ratio test: $p < 0.001$; DBH: diameter at breast height.

Predictor Variable	Parameter Estimate	Standard Errors	*p* (*z*-test)	Odds Ratios	95% CIs	Type of Variable
Density of species (n/ha)	−0.03	0.006	<0.0001	0.97	0.96–0.99	continuous
Food	1.11	0.33	0.0007	3.04	1.59–5.82	0/1

Table 2. *Cont.*

Predictor Variable	Parameter Estimate	Standard Errors	*p* (*z*-test)	Odds Ratios	95% CIs	Type of Variable
Medicine	0.83	0.27	0.0020	2.30	1.35–3.94	0/1
Fruit	−1.15	0.28	<0.0001	0.32	0.18–0.55	0/1
Leaf	−1.82	0.24	<0.0001	0.16	0.10–0.26	0/1
Root	1.04	0.23	<0.0001	2.82	1.81–4.41	0/1
Resin	−2.21	0.77	0.0043	0.11	0.02–0.50	0/1
DBH (cm)	-		0.1139			
Fish coma	-		0.9822			
Seed	-		0.0868			
Flower	-		0.9821			

3.4. *NTFP* vs. *Timber Use*

We identified a total of 54 valuable timber tree species in the core and buffer zones, of which 46 appear in the core zone and 34 in the buffer zone. Most of the valuable timber tree species (67%, ~31 species in the core zone and 65%, ~20 species in the buffer zone) provide both NTFPs and valuable timber (i.e., multiple use species) (Figure 4).

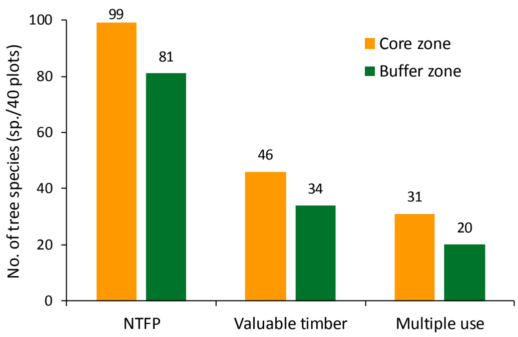

Figure 4. Number of tree species observed in the core and buffer zones according to tree uses for NTFPs, valuable timber, and multiple use.

Another logistic model was built to compare the impact of NTFP use and timber use on changes in tree communities. The model indicates that valued timber use and large tree diameter increase the probability of a tree absence in the buffer zone, while a high density of a species and NTFP use decrease the probability of tree absence (Table 3) (see also Figure A3 in Appendix A).

Table 3. Multiple logistic regression model for predicting the probability of tree absence according to tree use for timber and/or NTFPs: logit (p) = $-0.008 \times$ Density + $0.011 \times$ DBH + $0.471 \times$ Valued timber $- 0.546 \times$ NTFP; AIC = 1994.23; likelihood ratio test: $p < 0.001$.

Predictor Variable	Parameter Estimate	Standard Errors	*p* (*z*-test)	Odds Ratios	95% CIs	Type of Variable
Density of species (n/ha)	−0.008	0.0032	0.01	0.99	0.98–1.0	continuous
DBH (cm)	0.011	0.0035	0.0016	1.01	1.00–1.02	continuous
Valued timber	0.471	0.1415	0.0008	1.60	1.21–2.11	0/1
NTFP	−0.546	0.1146	0.0000	0.58	0.46–0.73	0/1

4. Discussion

4.1. *NTFP Tree Species*

The forests in the Ta Xua Nature Reserve were found to be rich in tree species, with a total of 249 tree species observed. Almost half of the tree species observed (48%) are recognized as NTFP species by the H'mong people. This number is similar to the percentage of NTFP tree species in the State of Pará, eastern Amazonia, Brazil (47% of 200 timber tree species used by Amazonian populations [46]), and slightly higher than that mentioned in the Menagesha Suba Forest, Ethiopia (42% of all 142 plant species providing NTFPs for the local community [47]). The results indicate that the H'mong people in this area possess a wealth knowledge regarding the use of forest trees for their subsistence.

Our study indicates that the NTFP tree species are mostly used for medicine. This usage has been attributed to the fact that living in a remote area limits access to basic health care services, leading to an increased demand for medicinal species by local people. The H'mong people have a traditional treatment system and readily use trees in providing healthcare. For example, NTFP tree species are used to treat several common diseases such as cough, fever, indigestion, rheumatism, and scabies (see in the Supplement Data of [39]). NTFP tree species are also used as food, or supplemental to other food products, and significantly contribute to household diet. Some species are used in their raw form without cooking, while others are only consumed after processing. The utilization of NTFP species for medicinal and food purposes was found to be reasonably high in other studies. For example, in Kangchenjunga Landscape, Eastern Himalaya of India [48], medicinal and edible plants were the most frequently used NTFP categories.

4.2. NTFP Tree Species Abundance in Relation to Human Interference

Evidence of anthropogenic disturbance has positive correlations with an increased density of some NTFP tree species, some of which are considered to be early successional species, such as *Cleistanthus monoicus* (Lour.) Müll.Arg., *Macaranga denticulata* (Blume) Müll.Arg., and *Ficus heterophylla* L.f. On the other hand, human interference also has positive correlations with a reduced abundance of other NTFP tree species and includes some considered as late successional species: Fujian cypress (*Fokienia hodginsii* (Dunn) A.Henry & H H.Thomas), *Magnolia mediocris* (Dandy) Figlar, *Schima superba* Gardner & Champ., and *Kurogane holly* (Ilex rotunda Thunb.). This shows that human interference had differing impacts on the abundance of NTFP tree species in the studied forest area. However, in our DCA results, many other NTFP tree species show no significant correlations with the DCA axes, indicating that selected factors of human disturbance have little-to-no impact on their densities.

4.3. Variables Related to the Probability of NTFP Tree Absence

Our logistic regression model suggests that NTFP use for either food or medicine purposes increases the probability of NTFP tree absence in the buffer zone. This might be because the demand for NTFPs for food and medicine is higher than the availability and regeneration capacity of the forest. From our model, signs of depletion in the abundance of useful food and medicinal tree species in the buffer zone are indicated. Thus, the need to monitor forest resources and emphasize sustainable harvesting is necessary. This is especially important in light of the changing population density and increased demand of the local H'mong people. The findings of our study partly contrast with the study on harvesting impacts of two medicinal tree species (*Catha edulis* (Vahl) Endl. and *Rapanea melanophloeos* (L.) Mez) in the Mpumalanga Lowveld, South Africa [49]. They reported that the densities of young medicinal tree species were higher in the harvested population than in the unharvested one. However, they also reported that the growth of mature trees was significantly lower in harvested populations compared with the unharvested.

In terms of tree parts harvested, the logistic model also indicates two contrasting effects on the abundance of NTFP tree species based on which tree parts are harvested. The harvest of roots increases the probability of NTFP tree absence, while the collection of fruits, leaves, and resin decreases the probability of NTFP tree absence. The results are consistent with several previous studies regarding tree survival. Harvesting of roots usually kills or fatally weakens the exploited plant species [50,51]. In contrast, harvesting of fruits and leaves may not directly affect the health of an individual tree, and only have a negligible effect on the plant population being exploited [52]. In terms of resin collection, several previous studies have found that recruitment rates in populations of *Copaifera reticulata* Ducke in Brazil remained unaffected by the harvesting of oleo-resins [53], and the reproductive output of *Khaya senegalensis* (Desv.) A.Juss. trees was not impacted by partial debarking [54]. In contrast, other studies found that leaf harvest hindered the conservation of exploited resources [55], and recurrent fruit harvest had negative effects on seedling and mature densities of tropical tree species, *Pentadesma butyracea* Sabine, in Benin [56].

4.4. Impacts of NTFP vs. Timber Use on Tree Community

Several studies have provided important information regarding the significant effects of timber logging on forest structure and ecological processes [57–59], and others have highlighted the negligible ecological destruction of NTFP extraction, e.g., [8,9]. In this study, we quantified the effects of NTFP harvesting and timber logging on the presence and absence of forest trees. Our multiple logistic model clearly indicates the different influences of NTFP use and timber use on the probability of tree absence. NTFP use reduces the probability of tree absence, but timber use increases the probability of tree absence. The results from our model are in line with the expectation that NTFP use has little impact on the tree community, whereas timber logging is more severe.

In the buffer zone, illegal logging was frequently observed, despite the forest management regulations that limit the permitted number of trees (25 trees) to be logged per year. This seems to be substantially contributing to the absence of large diameter and high value timber trees in the buffer zone. Therefore, the illegal logging should be more strictly controlled in the buffer zone.

4.5. Critical Evaluation and Outlook

Our study provides insights into NTFP use by the H'mong people and how it affects tree communities in the uplands of northwestern Vietnam. However, many things still remain unknown. For example, we do not know whether the NTFPs considered to be medicinal are actually effective. Considering differences in tree communities and divergent responses among NTFP tree species, there may also be other factors influencing tree species abundance, such as different seed dispersal mechanisms. In the case of animal dispersal, human presence may influence the behavior of these animals and cause an even more nuanced response in the forest community. In any case, the study would have benefitted from a larger number of replicates, and in particular, from additional locations possessing a protected core zone and a low intensity use buffer zone.

5. Conclusions

Our findings suggest that NTFP tree use is better than timber use in achieving conservation goals. The quantitative statistical assessment provides a reference for other inquires. The models and the respective parameters may help to assess the impact of forest use by the same ethnic group in different environmental settings, or different ethnic groups in a similar setting. It may also be helpful in understanding the effects of societal, economic, or environmental changes. In terms of forest management, the signs of the reduced abundance of NTFP tree species, especially for food, medicine, and roots, are indicated in the buffer zone. Therefore, new regulations should specify the quantity of NTFPs harvested to reduce the pressure on the tree community.

Author Contributions: The first and second authors conceived the study. The first author collected data, performed the data analysis, and wrote a first draft of the manuscript. The second provided guidance and reviewed the manuscript. Both authors read and approved the final manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix

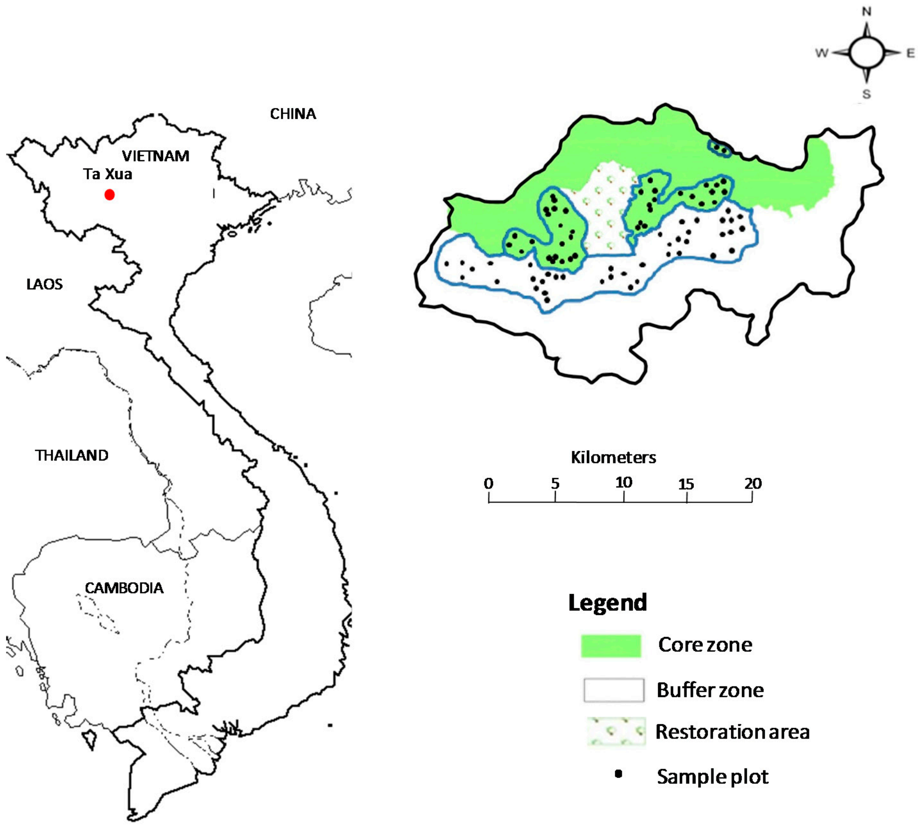

Figure A1. Vietnam and location of the Ta Xua Nature Reserve (**left**). The study area is enclosed by blue lines (**right**; 1000–1700 m a.s.l.). The black line indicates the administrative boundary of the nature reserve. Sample plots (40 in the core zone, 40 in the buffer zone) are indicated by black dots. This figure is modified after [39,40].

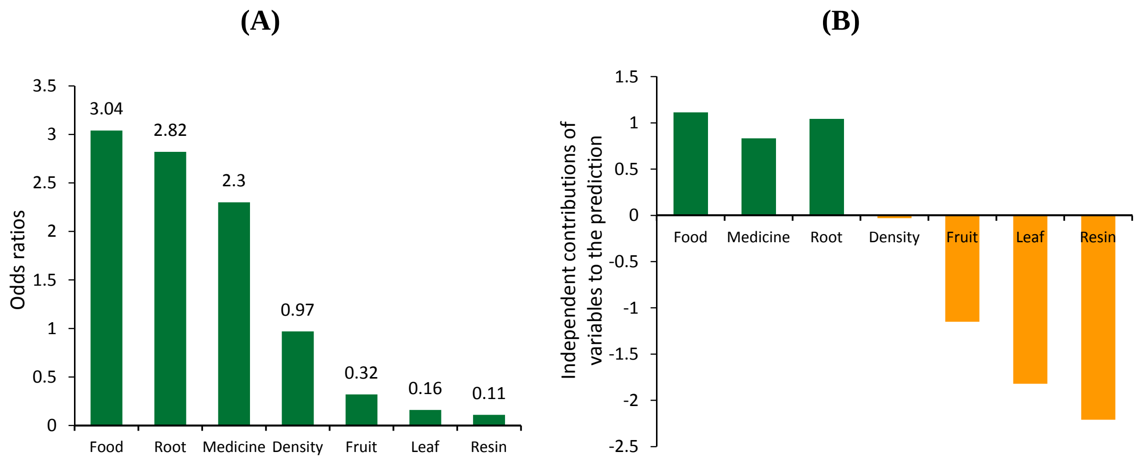

Figure A2. The importance of predictor variables by odds ratios (**A**) and the independent contributions of each predictor (**B**) to the prediction probability of NTFP tree absence in the multiple logistic model according to tree parts harvested and use purposes.

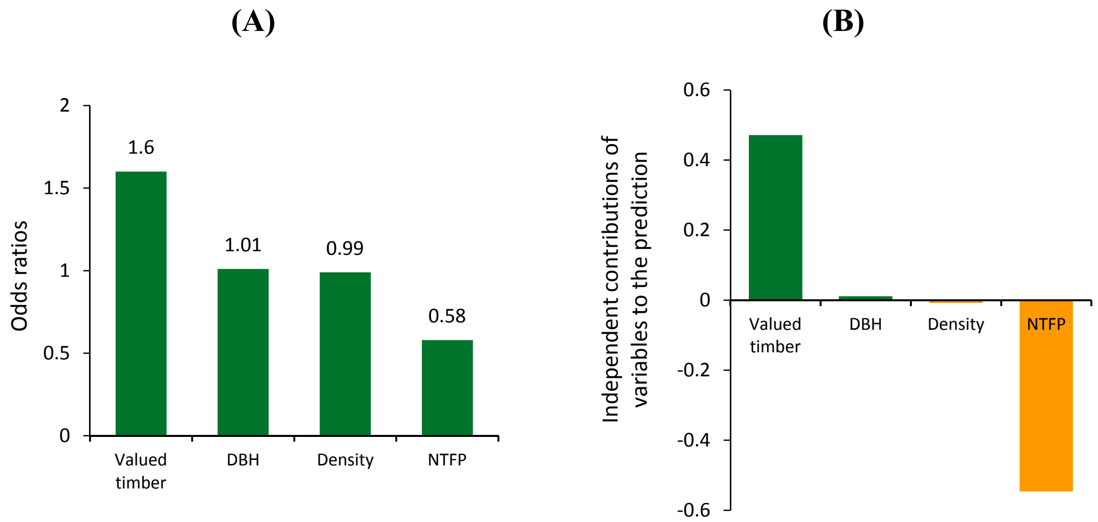

Figure A3. The importance of predictor variables by odds ratios (**A**) and the independent contributions of each predictor (**B**) to the prediction probability of tree absence in the multiple logistic model according to tree use for NTFPs and/or timber. DBH: diameter at breast height.

Table A1. Site conditions and forest characteristics of the two conservation zones. (Means and standard deviations, n = 40 plots per zone). This table is modified after [39].

	Core Zone	Buffer Zone
Total study area (ha)	72.8	115.1
Mean of elevation (m a.s.l.)	1449.1 ± 62.6^{a}	1363.3 ± 86.7^{b}
Lowest and highest elevation (m a.s.l)	1326; 1587	1248; 1557
Slope inclination (degree)	39.5 ± 7.7^{a}	35.9 ± 5.4^{b}
Northern aspect (degree)	47.7 ± 44.8^{a}	92.1 ± 56.7^{b}
Soil pH	4.7 ± 0.4^{a}	4.7 ± 0.4^{a}
Sand (%)	18.6 ± 6.4^{a}	21.3 ± 6.6^{ab}
Silt (%)	43.2 ± 6.4^{a}	42.9 ± 7.4^{ab}
Clay (%)	38.2 ± 7.3^{a}	35.8 ± 9.3^{a}
Organic matter (%)	3.0 ± 1.5^{a}	4.3 ± 1.2^{b}
Litter thickness (cm)	4.7 ± 2.0^{a}	3.4 ± 1.5^{b}
Species richness (sp./40 plots)	193	173
No. of species (sp./plot)	22.1 ± 5.1^{a}	19.3 ± 5.9^{b}
Density (tree/plot)	37.0 ± 10.0^{a}	40.3 ± 14.3^{a}
Diameter (cm)	21.4 ± 3.4^{a}	16.6 ± 3.0^{b}
Basal area (m^2/ha)	52.9 ± 21.4^{a}	30.4 ± 15.4^{a}
Canopy closure (%)	88.4 ± 7.2^{a}	84.5 ± 9.4^{b}
Stump (no./plot)	0.6 ± 0.8^{a}	1.6 ± 1.6^{b}
Footpath (no./plot)	0.9 ± 0.6^{a}	1.5 ± 0.8^{b}

Different superscripts "a" and "b" indicate significant differences ($p \leq 0.05$).

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