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Impacts of environmental factors and human disturbance on composition of roadside vegetation in Xishuangbanna National Nature Reserve of Southwest China

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Abstract

Vegetation-disturbance-environment relationships in Xishuangbanna Nature Reserve (XNR) was examined using multivariate analysis to understand the impacts of environmental factors and human disturbance on vegetation along the highway corridor. The results show that native forests were the best habitat for protected/endangered species and native species. The exotic plants *Eupatorium odoratum* and *Eupatorium adenophora* were found primarily in secondary forests and their presence was positively associated with altitude and soil potassium concentrations. The distribution of two protected plants, *Phoebe nanmu* and *Pometia tomentosa*, was negatively associated with road disturbance. Understanding the complex effects of environmental factors and human disturbance is key for developing conservation and restoration strategies for roadside plant ecosystems.

Keywords: Vegetation composition, diversity, gradient analysis, disturbance, environmental controls, historical land use, road construction, nature reserve

1 Introduction

Highway infrastructure development presents a particularly challenging balance between conservation and development [1,2]. The Simao-Xiaomengyang (Sixiao) Highway, China's section of Kunming-Bangkok international road, was planned to cut through the core zone of the Xiaomengyang Section of Xishuangbanna Nature Reserve (XNR), one of hotspots for tropical biodiversity in China and the world [3]. To meet the national priority of development, the natural reserve management authority, China's Forest Ministry, designated part of the core zone of XNR as an experimental zone to accommodate the development of the Sixiao Highway [4]. Although there has been

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an intense debate between environmentalists and development planners as to the program impacts of the Sixiao Highway on species and habitats in this area, there is little available evidence to support the arguments of either side due to limited site-specific research in this region. The objective of the present study was to better understand how highway construction has impacted vegetation in the XNR through inferring the species-disturbance-environment relationship by a multivariate method, Canonical correspondence analysis (CCA) [5].

2 Materials and Methods

2.1 Site description

The study site is located in the central area of the Xiaomengyang Section of XNR, Wild Elephant Valley (22°07′～22°23′N, 100°36′～101°18′E, 590～1600m a.s.l). The study area covers an 18.5 km length and 1 km wide section along the Sixiao Highway, which cuts through the newly defined experimental zone of the XNR. Climate in this area is subtropical continental with a dry and monsoonal wet season. The annual average temperature is 20.8℃ and annual precipitation is 1193.7mm with most of the rain occurring from May to November. The soils are dominated by loam or loam-clay soils, which are fine textured, well drained, and have high organic matter content (Table 1). Seasonal rain forests are dominated by *Antiaris toxicaria, Canarium album* and *Gironniera subaequalis*, and are the target vegetation for protection in the XNR. Secondary forests and open fields exist along the roadside in some locations.

Table1 Environmental conditions of the sampling transects

Transect No.	Plot No.	Latitude	Longitude	Altitude(m)	slope	Aspects	Soil types	Landuse types
1	1-3	N22º06'	E100°54'	748-760	10	SW	loam-clay	old fields
2	4-8	N22º10'	E100°53'	790-844	27	W	loam	native forest
3	9-12	N22º10'	E100°53'	760-774	15	NE	loam	native forest
4	13-15	N22º09'	E100°52'	849-859	50	SW	loam	secondary forest
5	16, 17	N22°08'	E100°53'	897-925	20	N	loam	native forest
6	18-20	N22°02'	E100°53'	811-842	26	NE	loam-clay	native forest
7	21-23	N22°08'	E100°53'	817-937	15	SE	loam-clay	old fields
8	24, 25	N22°10'	E100°52'	769-773	10	NW	loam-clay	native forest

2.2 Study design and treatment

To clarify the vegetation-disturbance-environment relationships in roadside habitats we measured plot-level environmental factors and human disturbance factors at each site. Environmental factors were classified into two types, geographic location and soil characteristics. Geographic location included longitude, latitude, altitude, slope and aspect and soil characteristics included soil type, moisture, pH, organic carbon content, total nitrogen, and phosphorus and potassium concentration. Two types of human disturbance, past anthropogenic practices and recent road construction, were considered in the study. As the intensity and duration of past human disturbances were not well documented, the intensity of historical human practices (HHP) was expressed by the successional stage of the vegetation, i.e., primary vegetation, secondary forests and old fields. The distance to the road (RD) was used as a measure of the disturbance associated with road construction [6-8].

2.3 Field survey and data collection

Field surveys were conducted during the middle of the dry season from November to January in 2004 and 2005 following the modified design from Flory & Clay [8]. Eight transects of 0.3-1.0 km in length and 20 m in width were located along the road by a distance randomly. Transects were set perpendicular to the road and started at the edge of the vegetation along the road, which was either native or planted. Along each transect, 10×10 m plots were arranged at 10, 50, 200, and 500 m from the road for a total of 25 plots (Table 1). All plant species within each plot were identified and the species composition and numbers in each plot were quantified. Based on the data collected from the field survey, the species abundance and diversity were quantified. Species abundance was recorded as number of individuals of each plant. Species richness (Marglef index), diversity (Shannon-Weaver index) and evenness (Pielou index) were calculated following the formulas cited by Dong et al. [9].

2.4 Statistical Analysis

Canonical Correspondence Analysis (CCA) was used to identify the ecological relationships between the vegetation and the environment along the roadside. In order to assure objectivity of the gradient analysis, the species abundance data were used for ordination. This analysis was performed using Software for Canonical Community Ordination (Version 4.5) recently developed by Ter Braak and Smilauer [10].

3 Results

3.1 Ordination of the vegetation

The CCA-triplot simultaneously displays sample plots as points, species as points, and environmental variables as vector arrows as a means to visualize correlations among species, plots and environmental variables (Fig. 1). It is clear from the graph that historical land use (HHP), road construction (RD), and soil phosphorus (SP) were the most influential environmental factors affecting the vegetation composition along the roadside habitats in XNR as indicated by the length of these vectors. Altitude, slope, aspect and soil K concentrations were positively correlated with HHP. Soil moisture soil organic carbon, soil nitrogen, slope aspect, and soil type were all positively correlated with distance to the road. Only longitude and soil pH were positively associated with soil phosphorus concentrations.

The species *Imperata cylindrica* , *Solanum xanthocarpum*, *Hevea brasiliensis* and *Schizonepeta tenuifolia* and to a lesser extent *Digitaria ternata* clustered together in the old fields reflected by their closeness to sample points 23 on the graph, and their distributions were clearly controlled by RD. The species *Hydrocotyle nepalensis*, *Eclipta prostrate*, *Cynodon dactylon* and *Anaphalis sinica*, *Stachys oblongifolia* and *Vernonia patula* were clearly separated from the other species and tightly clustered near the SP environmental vector indicated that SP had a strong influence on controlling the distribution of these species. The two exotic species, *Eupatorium odoratum* and

Eupatorium adenophora, were more most abundant in secondary forests as indicated by their closeness to sample points 14 and 15, and were influenced positively by HHP.

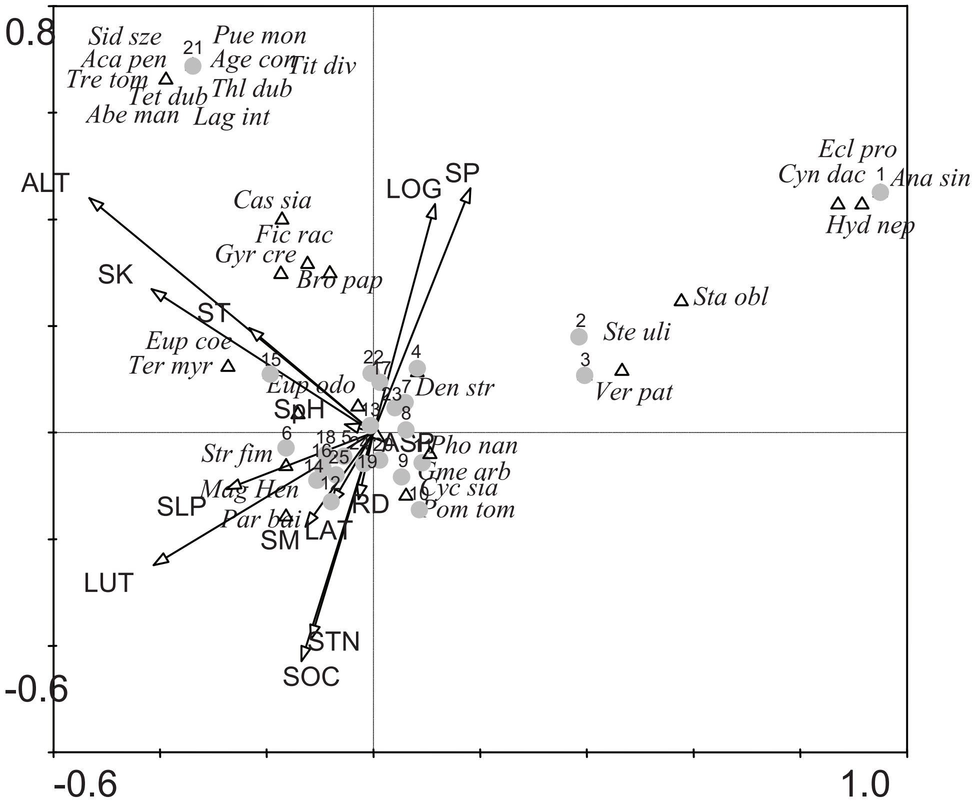

Figure 1. CCA ordination diagram with plant species (△), sample quadrates (● and number 1-25) and environmental variables (arrows) on the basis of species presence; first axis is horizontal, second axis is vertical. To avoid the crowd of the diagram, we only present the species with positions far from center and some important species (protected, exotic and cultivated species) in the diagram using the abbreviations as follows buted as follows: *Abe man=Abelmoschus manihot*, *Aca pen=Acacia pennata*, *Age con=Ageratum conyzoides, Ana sin=Anaphalis sinica*, *Bro pap=Broussonetia papyrifera*, *Cas sia=Cassia siamea*, *Cyc sia=Cycas siamensis*, *Cyn dac=Cynodon dactylon*, *Den str=Dendrocalamus strictus*, *Ecl pro=Eclipta prostrate*, *Eup coe=Eupatorium coelestinum*, *Eup odo=Eupatorium odoratum*, *Fic rac=Ficus racemosn*, *Gme arb=Gmelina arborea*, *Gyr cre=Gyrmra crepidioides*, *Hyd nep=Hydrocotyle nepalensis*, *Mag hen=Magnolia henryi*, *Par bai=Paramichelia baillonii*, *Pho nan=Phoebe nanmu*, *Pom tom=Pometia tomentosa*, *Pue mon= Pueraria montana*, *Sid sze= Side szechuensis*, *Sta obl= Stachys oblongifolia*, *Ste uli=Stellaria uliginosa*, *Str fim=Strophioblachia fimbricalys*, *Ter myr=Terminalia myriocarpa*, *Tet dub= Tetrastigma dubinum*, *Thl dub=Thladiantha dubia*, *Tit div= Tithonia diversifolia*, *Tre tom= Trema tomentosa*, *Ver pat=Vernonia patula.* The abbreviations of environmental variables are: LOG, longitude; LAT, latitude; ALT, altitude; SLP, slope degree; ASP, slope aspect; ST, soil type; SM, soil moisture; SpH, soil PH; SOC, soil organic carbon; STN, soil total nitrogen; SP, soil phosphorus; SK, soil potassium; LUT, Historical human practices; RD, distance to road.

3.2 Species abundance along environmental and disturbance gradients

The species points and sample points (plots) in Fig. 2 jointly represent the dominant patterns of the species abundance insofar as these can be explained by the environmental factors measured in this study. Nearly all endangered or protected species sampled in this study were found in native forest habitat (sample points 6, 8, 11, 16, 18, 20, 25), except for *Paramichelia baillonii* was found secondary forest (sample site 14). The distribution pattern

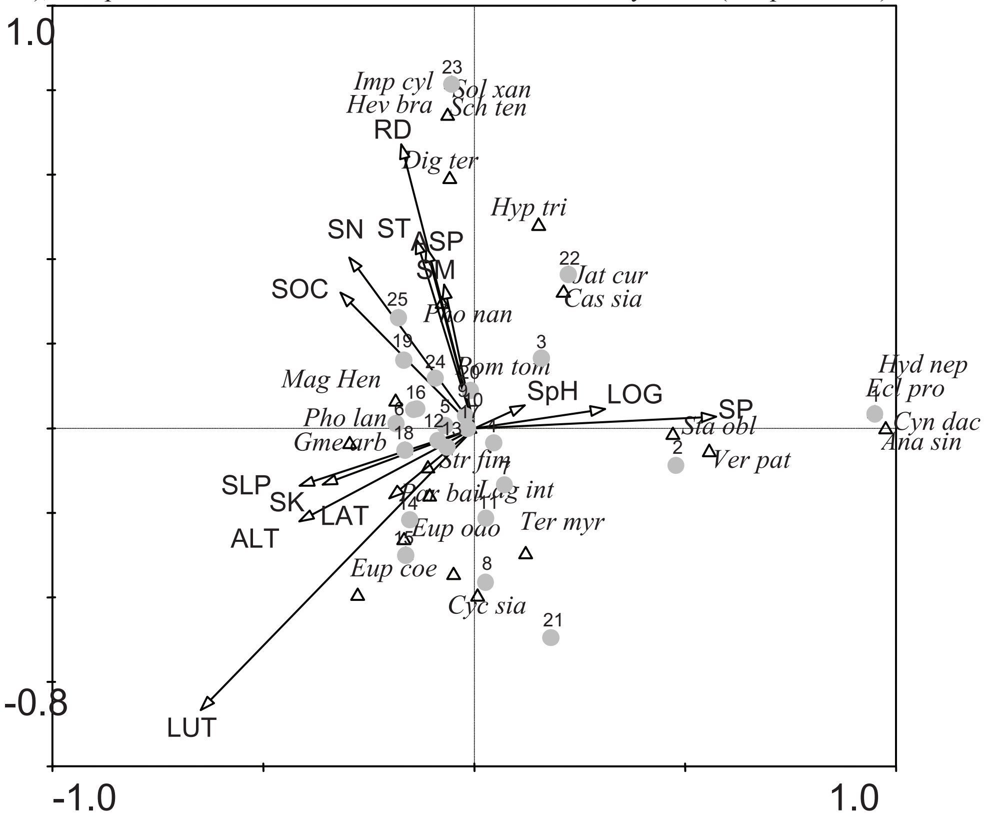

Figure 2. CCA ordination diagram with plant species (△), sample quadrates (●and number 1-25) and environmental variables (arrows) on the basis of species abundance; first axis is horizontal, second axis is vertical. To avoid the crowd of the diagram, we only present the species with positions far from center and some important species (protected, exotic and cultivated species) in the diagram using the abbreviations as follows buted as follows: *Ana sin=Anaphalis sinica*, *Cas sia=Cassia siamea*, *Cyc sia=Cycas siamensis*, *Cyn dac=Cynodon dactylon*, *Dig ter=Digitaria ternata*, *Ecl pro=Eclipta prostrate*, *Eup coe=Eupatorium coelestinum*, *Eup odo=Eupatorium odoratum*, *Gme arb=Gmelina arborea*, *Hey bra=Hevea brasiliensis*, *Hpy tri= Hypoestes triflora*, *Imp cyl=Imperata cylindrica*, *Jat cur= Jatropha curcas*, *Lag int=Lagerstroimia intermedia,* *Mag hen=Magnolia henryi*, *Par bai=Paramichelia baillonii*, *Pho lan=Phoebe lanceolata*, *Pho nan=Phoebe nanmu*, *Pom tom=Pometia tomentosa*, *Sch ten=Schizonepeta tenuifolia*, *Sol xan= Solanum xanthocarpum*, *Sta obl= Stachys oblongifolia*, *Str fim=Strophioblachia fimbricalys*, *Ter myr=Terminalia myriocarpa*, *Ver pat=Vernonia patula.* The abbreviations of environmental variables are: LOG, longitude; LAT, latitude; ALT, altitude; SLP, slope degree; ASP, slope aspect; ST, soil type; SM, soil moisture; SpH, soil PH; SOC, soil organic carbon; STN, soil total nitrogen; SP, soil phosphorus; SK, soil potassium; LUT, Historical human practices; RD, distance to road.

of endangered or protected species along the gradient of the distance to road shows that *Phoebe nanmu* and *Pometia tomentosa* were abundant in the sites near the roadside and the rest were abundant in the sites far from the roadside. Two exotic species, *Eupatorium odoratum* and *Eupatorium adenophora* were more abundant in the plots of secondary forest, reflected by their closeness to sample points 14 and 15. The abundance of these two plants was correlated positively with soil potassium and negatively with the distance to road. The cultivated species, *Cassia siamea*, was more abundant in the plot of old fields, reflected by its location at the sample point 22. The abundance of this plant was positively associated with the distance to road, i.e., the closer to the road was, the more *Cassia siamea* was.

4 Discussion

Species-sites relationships in CCA ordination diagram indicate that the habitat types strongly influenced the presence and abundance of key plant species. Native forest was the best habitat for most protected/endangered species and primitive species. This means that native forest should be the priority for roadside habitat protection in this area. Secondary forest, as habitats with high human interventions, may serve as source for invasion of exotic species into more pristine environments [11, 12]. Higher light and bare soil exposure may have favored alien plant establishment [6, 8].This is why two alien plants, *Eupatorium odoratum* and *Eupatorium adenophora* were found abundant there. One protected species *Paramichelia baillonii* was also abundant in secondary forest. Restoration of secondary forest is necessary to facilitate the growth of protected species and to control the invasion of exotic species. Old fields was abounded rubber forest or farm land, on which *Cassia siamea* has been planted to form a highly appreciated fuelwood used by the local people due to quick regrowth of the branches of this plant. A better control of upperstorey timber cutting is required to maintain this land use type.

Species-environment relationships in CCA ordination diagram indicate that altitude and soil potassium were most important factors affecting the presence of *Eupatorium odoratum* and *Eupatorium adenophora* and historical land use was one of the most influential factors that determines the abundance of these two alien plants. That is in agreement with other researchers' reports that the distribution of alien species was highly related to land use patterns [12, 13] and our preliminary finding that *Eupatorium adenophora* (also named *Ageratina adenophora*) was more susceptible to total soil potassium (unpublished data). Better land use and reduced soil potassium may be the solutions to control the invasion of alien species. In present study, it was found that road disturbance played very important role in determining the distribution of two protected plants of *Phoebe nanmu* and *Pometia tomentosa*. Higher abundance of these two protected species near roadside means that moderate disturbance derived from road construction and traffic may favor their survival and growth. This is a proof to support the view that the effects of roadwork on the vegetation and its environment were complex and sometimes positive [14].

The results of this study appear to indicate understanding complex effects of environmental factors, land use and road disturbance is very important to develop and implement the strategies to protect or restore elements of biological diversity and integrity of roadside ecosystems. They can provide a baseline to formulate the plans of roadside habitats protection or restoration

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