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Species composition, plant cover and diversity of recently reforested wild lands near Dabao Highway in Longitudinal Range-Gorge Region of Yunnan Province, China

Dong, S. K.*, Cui, B. S., Yang, Z. F., Liu, S. L., Liu, J., Wang, J., Ding, Z. K., Gao, L. N. and Zhao, S. Q.

Environmental School of Beijing Normal University, Beijing, 100875, China.

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Deforestation, over-cultivation and rural growth have severely damaged native vegetation of woodlands along roadsides in the Longitudinal Range-Gorge Region of Yunnan Province. This study was conducted to evaluate the effect of different reforestation practices, which consisted of natural restoration or planting with tree seedlings that varied in species composition, coverage and diversity, on damaged roadside woodlands. Three randomly selected 10 m x 10 m plots in each reforestation practice were investigated. The results showed that the species composition, plant cover and species diversity of the planted communities varied with reforestation strategies and time since planting. A higher number of species, proportion of native species and woody plants, canopy cover and species diversity were found in naturally restored plots and in 3 - 4 year old plots that were planted with native plants. In the early stages of reforestation, herbs dominated the plant community in most plots, and woody plants became more important with time after reforestation. Preliminary results suggest that plant height can be used an auxiliary indicator of plant cover to assess ecosystem function status of the restoration project. Also, evenness may be easier to restore than species richness. Natural restoration or reforestation with native dominant plants is a good management strategy for vegetation restoration or improvement.

Key words: Vegetative characteristics, plant community, restoration, Southwest China.

INTRODUCTION

Land degradation, due to the root causes of over-population, poverty and lack of enforceable policies and reasonable management measures, is a worldwide environmental problem limiting the sustainable development of global society (Sisk et al., 1994; McCracken and Abaza, 2001; Reynolds and Smith, 2002; World Bank, 2002). Degraded ecosystems, with damaged biotic components, have diminished control over resources such as soil nutrients and water resources (Davenport et al., 1998). Seriously damaged lands not only lose control over resources, but also lose the capacity for self-repair and are unable to prevent additional degradation (Whisenant, 1999). Thus, they are less resilient to additional stress or damage and provide fewer environmental services (Myers, 1996). As these degrading processes continue, a threshold can be crossed exceeding the ability for the ecosystem to recover and desertification results, a dynamic and self-perpetuating process (Tivy, 1990; Thurow, 1991).

Since the early 1980s, China has achieved remarkable agricultural and rural growth with the de-collectivization of agriculture, which greatly reduced poverty but addressed many environmental problems such as resource loss and land degradation (Wang, 1999; Wang and Gao, 2001). The Longitudinal Range-Gorge Region of Yunnan Province, Southwest China is an example of a region which has been severely affected by agricultural de-collectivization (Peng and Wang, 2005), especially in the sites along the roadsides (Wang and Shi, 2001; Zhao, 2006). With excessive biomass removal and continued

*Corresponding author. E-mail: dongshikui@sina.com.

Table 1. Reforestation practices and sites description.

Reforest practices	Plantings	Reforest year	Distance to road (m)	Aspect	Slope	Soil type	Soil moisture
I	*Eucalyptus maideni*	2004	300-500	S	12	clay	35%
II	*Pinus yunnanensis*	2004	500-700	S	13	clay	30%
III	*Alnus nepalensis* and *Pinus yunnanensis*	2002	800-1000	S	12	clay	38%
IV	*Pinus yunnanensis*	2002	400-500	SE	11	clay	28%
V	*Pinus yunnanensis*	1999	600-800	SE	13	clay	32%
VI	*Pinus yunnanensis*	1994	150-200	SE	15	clay	35%
VII	None	2002	200-300	SE	10	clay	26%
VIII	None	2004	900-1000	SE	12	clay	25%

over-cultivation, plant populations changed, and biological diversity and productivity decreased. Continued reductions in plant productivity decreased litter and vegetative cover, which in turn increased erosion and desertification (He, 1991; Gao, 2003). Vegetation conservation and restoration in this region is becoming a significant regional and national concern (Liu et al., 2002). Presently, these lands are the focus of woodland forest restoration efforts by the local government (Liu, 2005).

An increasingly common goal of ecosystem restoration is to restore the high levels of plant species, traits and functional groups similar to that found in remnant sites (Pywell et al., 2003; Smith et al., 2003). However, no sites remain that can serve as a reference woodland forest for restoration in this region due to severe disturbance from agricultural production and rural development activities in the past. Most of the degraded lands have been reforested recently under one of China's National Ecological Construction Plans, "Returning Agricultural Land to Forest Land", which was established in 1999. Given the importance of colonization on forest stand composition and species spatial patterns (Oliver and Larson, 1996), evaluation of early restoration efforts on marginal agricultural lands is critical to assess the value of reforestation efforts and to aid in the planning of future plantings (Kruse and Groninger, 2003). In this sense, this study was proposed to evaluate the early success of different reforestation efforts.

Restoring community structure (e.g. species composi-tion and diversity) and ecosystem processes typically are listed as the two main objectives of restoration and vegetation improvement (Palmer et al., 1997; Lockwood and Pimm, 1999; Smith et al., 2000). Some researchers Bradshaw (1996), Hobbs and Norton (1996), and Martin et al. (2005) have proposed that the proportion of native species and plant diversity at all spatial scales are the criteria that should be used to evaluate the success of restoration efforts. We focus on these two criteria- the ratio of native plants in the species composition, and plant diversity at the site scale to to evaluate the success of reforestation projects implemented in recent years along the roadside of the Dabao Highway, Longitudinal Range-Gorge Region of Yunan Province, China. The overall goal of this study was to evaluate the effect of different reforestation practices on woodlands damaged by agricultural production and rural development, which included natural restoration and planting with different tree seedlings at different times before this survey on species composition, cover and diversity.

MATERIALS AND METHODS

Study site

The study site is situated beside the Laoying exit of Dabao Hingway, Longitudinal Range-Gorge Region of Yunan Province, China (N25º19', E99º12', 1836 m a.s.l.), a subtropical region, where reforestation projects were initiated in 1994 for restoring wildlands and the former evergreen woodland. Within the study site, there were 8 reforestation practices (RP) shown in Table 1. All RPs have been implemented on neighboring plots within the study site. Environmental characteristics of the plots of different RP, including location, aspect, slope, soil type and moisture, were recorded before the vegetation investigation (Table 1). Vegetation surveys were conducted in 2004 and 2005.

Sampling methods

Field investigations and sampling were conducted in October to November, when most of evergreen vegetation was still growing but past the rainy season. At the beginning of investigation, all plants species within each reforestation plot were identified and species composition (total number, life form, native plant ratio) were quantified. Species were classified into different functional groups based on their growth form: trees, shrubs and herbs (Polley et al., 2005). Quantitative characteristics of the vegetation including cover, height, number of individual species, functional groups and plant community were investigated in three 10 m x 10 m quadrats which were randomly placed in each RP plot. Simpson's diversity index, Marglef's richness index, and the Pielou evenness index were calculated following the formulas cited by Dong (1997).

Statistical analysis

Species composition, canopy cover, plant height, species diversity, richness and evenness of the plant communities and functional groups under each RP are presented as the means of three replicates. The effects of RP on vegetation characteristics were analyzed via ANOVA using a Generalized Liner Model of SPSS 10.0 (Huang et al., 2001).

RESULTS

Species composition of plant communities

There were a total of 69 species in the study site, with 4 exotic and 65 native species, 16 trees, 15 shrubs and 38 herb species (Table 2). In individual RP plots, there was a total of 1 species in RPI, 33 in RPII, 24 in RPIII, 15 in RPIV, 25 in RPV, 15 in RPVI, 33 in RPVII and 16 in RPVIII.

The species compositions of plant communities in the different RP varied greatly (Table 3). The plant community of RPI consisted of one species, the exotic tree, Eucalyptus maideni, a commercial tree imported from Southeast Asia. The community in RPII had a high species number (33, ranked 2nd of all plots), a relatively high proportion of exotic plants (12.1%), and the same proportion of tree and shrub species (18.2%). In RPIII, there were 24 plant species, with 91.7% native and 8.3% exotic species, and most species were herbs (62.6%). In RPIV, there were only 15 species (3 trees, 6 shrubs and 6 herbs) but a high proportion of these were exotic species (13.3%). The plant community of RPV was composed of 25 species, 92.0% of which were native species, and 12% were trees, 40% shrubs and 48% herbs. The plant community in RPVI had the highest proportion of both native species (93.3%) and trees (33.3%) among all plots, although the total number of species (15) was comparatively low. The plant community in RPVII had 33 species, the highest number among all plots, and had similar proportions of trees and shrubs. The plant community of RPVIII had only 12 species with a very high proportion of herbs (69.2%).

The results showed that the species composition varied with reforestation strategy and time. The RPI plots were replanted with E. maideni and produced a single-species community, as native plants can not co-exist with this fast-growing and shady tree. Plots of RPVI were replanted with the native trees, Pinus yunnanensis and Lyonia ovalifolia, and RPVII was naturally restored, both of which had more native species and trees in their species composition. Although the plot of RPIV was replanted with the native tree, P. yunnanensis, there was a low total number of species and a high proportion of exotic plants in the composition. In all replanted plots except RPI, the plant communities reached the highest number of species at the beginning of reforestation. In naturally restored plots, the highest species numbers were observed in the third or fourth growing year. A greater proportion of herbs were found in the early years following restoration. The proportion of shrubs increased with time following restoration after 4 - 5 years.

Vegetative characteristics of the plant communities

Table 4 shows that the RPI plot had complete plant cover with plant heights of 4.83 m, indicating RPI had the highest ($P < 0.05$) coverage and height among all RPs. The plant community of RPVI was ranked second in terms of both canopy coverage (95%) and height (3.60 m). Although the canopy coverage of RPIII and RPV was not different than RPVI, their canopy height was significantly lower ($P < 0.05$). Canopy coverage in RPII, RPIV and RPVII was similarly low (around 85%), but canopy height of RPII was significantly higher ($P < 0.05$) than the latter two. Canopy cover (70%) and height (0.40 m) of RPVIII was the lowest ($P < 0.05$) among all RPs.

Species richness, evenness and diversity of plant community greatly varied with the restoration practice and time (Table 4). Species richness index, species diversity index and species evenness index varied from 4.27 - 0.22, 0.74 - 0 and 0.62 - 0, respectively. The RPVII plot was highest ($P < 0.05$) in species richness among all plots. Species richness was significantly different ($P > 0.05$) among RPII, PRIII, PRIV, PRVI and PRVIII plots. In general, species diversity in the plots of RPIII, PRVI and PRVII was relatively high while those in the plots of RPII, RPIV, RPV and RPVIII were low in species diversity. In terms of species evenness, plant communities in the plots of RPIII and PRVI were higher ($P < 0.05$) than those in the plots of RPII, RPIV, RPV and RPVIII, and RPVII was not significantly different from plots RPII, RPV, RPVI and RPVIII. The single species community of RPI was extremely low in species richness (0.22), diversity (0) and evenness (0).

Vegetative characteristics of functional groups

Percent cover of the different functional groups (tree, shrub and herb) in the different reforestation plots are presented in Figure 1. Generally, herbs had a higher plant cover than shrubs in all plots except for RPI, and the percent cover of trees varied greatly from plot to plot. The dominant plant functional groups in the reforested plots in this study were either trees or herbs. As for different reforestation practices, RPI was the highest in the percent tree cover (95%) and RPVIII had zero percent cover of trees. RPII was higher ($P < 0.05$) than others in the shrub cover, whereas RPI had zero percent shrub cover. RPVII was significantly highest in the percent cover of herbs (around 80%) and RPI had no herbs.

Species richness varied with functional groups and reforestation practice (Figure 2). Species richness of herbs was generally higher than shrubs and trees under

Table 2. Species identified in the plots of different reforestation practices.

Species	Native/Exotic	Life form	I	II	III	IV	V	VI	VII	VIII
Eucalyptus maideni	Exotic	Tree	+							
Ternstroemia gymnanthera	Native	Tree							+	
Pinus yunnanensis	Native	Tree			+	+	+	+		
Pinus kesiya var. langbianensis	Native	Tree		+						
Pinus armandii	Exotic	Tree							+	
Alnus nepalensis	Native	Tree		+	+					
Viburnum ylindricum	Native	Tree					+		+	
Dalbergia minosoides	Native	Tree							+	
Populus yunnanensis	Native	Tree							+	
Betula alnoides	Native	Tree							+	
Juglans regia	Native	Tree		+						
Desmodium sequax	Exotic	Tree		+						
Lyonia ovalifolia	Native	Tree		+	+	+		+		
Rubus pectinellus	Native	Tree		+			+	+	+	+
Corylus chinensis	Native	Tree						+		
Lindera caudata	Native	Tree				+		+		
Artemisia subdigitata	Native	Shrub		+	+	+	+			
Vaccinium fragile	Native	Shrub		+			+	+		
Elsholtzia fruticosa	Native	Shrub		+	+	+	+	+	+	+
Inula cappa	Native	Shrub		+		+	+	+	+	+
Indigofera stachyoides	Native	Shrub		+	+					
Hypericum patulum	Native	Shrub		+	+	+	+	+	+	+
Kummerowia striata	Native	Shrub			+		+		+	
Rubus ellipticus var. *obcordatus*	Native	Shrub			+		+		+	
Dioscores sp.	Native	Shrub					+			
Triumfetta rhomboidea	Native	Shrub					+			
Melastoma normale	Native	Shrub							+	
Elaeagnus stellipila	Native	Shrub				+	+		+	
Rosa cymosa	Native	Shrub				+				
Lespedeza fornosa	Native	Shrub							+	
Isachne albens	Native	Herbage		+	+		+	+	+	+
Bidens pilosa	Native	Herbage		+						
Setaria viridis	Native	Herbage		+						
Digitaria ciliaria	Native	Herbage		+			+		+	+
Carpesium cernuum	Native	Herbage					+		+	+
Adenostemma lavenia	Native	Herbage		+						
Centotheca lappacea	Native	Herbage		+						
Notochaete hamosa	Native	Herbage		+					+	
Cyperus ollingeri	Native	Herbage		+	+					
Cynodon dactylon	Native	Herbage		+						
Centella asiatica	Native	Herbage		+	+	+			+	
Oxalis corniculata	Native	Herbage		+	+					
Eupatorium coelestinum	Exotic	Herbage		+	+	+	+	+		+
Veronica didyma	Native	Herbage			+	+			+	
Miscanthus sinensis	Native	Herbage			+					
Dicranopteris dichotoma	Native	Herbage						+		
Erigeron elongatus	Exotic	Herbage		+	+	+	+		+	
Clinopodium chinens	Native	Herbage							+	
Imperata cylindrica var. *major*	Native	Herbage			+			+		
Melasma arvense	Native	Herbage		+						+
Sagina japonica	Native	Herbage		+						

Table 2. Contd.

Eulalia speciosa	Native	Herbage		+	+		+	+		
Glyceria acutiflora	Native	Herbage						+		
Anaphalis margaritacea	Native	Herbage		+	+		+		+	+
Gonostegia hirta	Native	Herbage		+	+					
Potentilla anserina	Native	Herbage		+	+		+		+	
Gnaphalium hypoleucuma	Native	Herbage							+	
Viola philippica	Native	Herbage							+	
Ainsliaea henry	Native	Herbage					+		+	+
Panicum brevifolium	Native	Herbage				+	+		+	
Gentiana rhodantha	Native	Herbage							+	
Eleusine indica	Native	Herbage				+	+		+	
Verbena officinalis	Native	Herbage							+	
Viola principis	Native	Herbage							+	
Carex balcans	Native	Herbage					+			
Ixeris denticulata	Native	Herbage		+	+					
Valeriana hardwickii	Native	Herbage			+					
Poa annua	Native	Herbage								+
Trollius ranunculoides	Native	Herbage		+						
Total number	69	69	1	33	24	15	25	15	33	12

Table 3. Species compositions of vegetation under different restoration practices.

Reforestation practices	Physical vegetation	Dominant species	Proportion of native plant (%)		Proportion of plant life form (%)		
			Native	Exotic	Tree	Shrub	Herbage
I	Forestry	*Eucalyptus maideni*	0	100	100	0	0
II	Shrubland-like	*Pinus yunnanensis*	87.9	12.1	18.2	18.2	63.6
III	Forestry	*Pinus yunnanensis* And *Alnus nepalensis*	91.7	8.3	12.5	25	62.5
IV	Shrubland -like	*Pinus yunnanensis*	86.7	13.3	20	40	40
V	Forestry	*Pinus yunnanensis*	92.0	8.0	12	40	48
VI	Forestry	*Pinus yunnanensis* and *Lyonia ovalifolia*	93.3	6.7	33.3	26.7	40
VII	Shrubland	*Hypericum patulum* and *Elsholtzia fruticosa*	91.7	8.3	27.8	22.2	50
VIII	Grassland	*Eupatorium coelestinum*	92.3	7.7	7.7	23.1	69.2

Table 4. Vegetative characteristics of plant communities under different restoration practices.

Reforestation practices	Canopy coverage (%)	Canopy height (m)	Species richness	Species diversity	Species evenness
I	100±0a	4.83±0.39a	0.22±0c	0e	0e
II	80±5.0c	1.27±0.23d	3.19±0.66b	0.57±0.14cd	0.39±0.4cd
III	91.7±5.0b	2.20±0.44c	3.18±0.45b	0.73±0.11ab	0.62±0.14a
IV	80±5.0c	0.90±0.17de	2.97±0.12b	0.52±0.06d	0.38±0.03d
V	96.0±1.7b	2.07±0.31c	3.04±0.57b	0.58±0.06cd	0.42±0.09cd
VI	95±0b	3.60±0b	3.26±0b	0.74±0a	0.58±0ab
VII	83±3.6c	0.63±0.21ef	4.27±1.07a	0.67±0.06abc	0.50±0.08bc
VIII	70±0d	0.40±0f	2.82±0b	0.61±0bcd	0.46±0cd

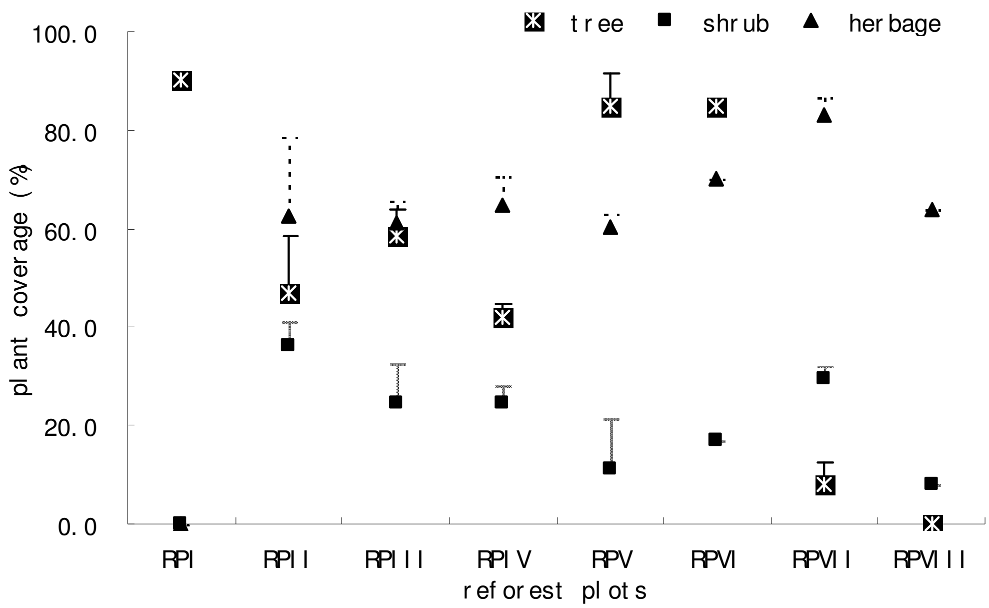

Figure 1. Percent coverage of functional plant groups in different reforest plots.

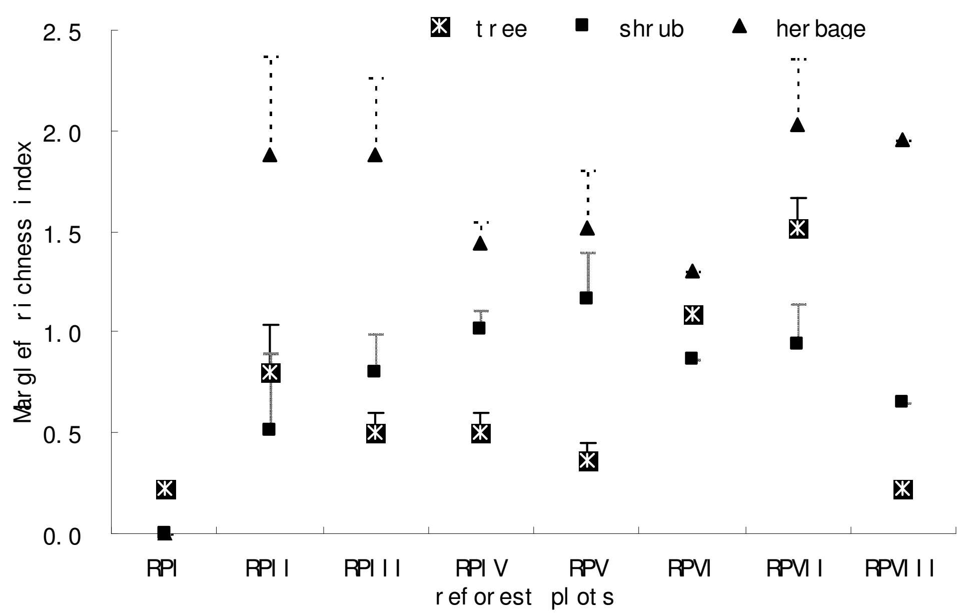

Figure 2. Special richness of functional plants groups in different reforest plots.

the same reforestation strategy, except for RPI. Species richness of the shrub group was higher than species richness of trees under reforestation practices RPIII, RPIV, RPV and RPVIII but lower under remaining reforest practices. Species richness of trees was as low as 0.22 in RPI and RPVIII plots, meaning only one tree species per 100 m2, while it was as high as 1.52 while in RPVIII plot, meaning 7 tree species per 100 m2. Species richness of shrubs was highest (1.21) and lowest (0) under RPV and RPI reforestation practices, respectively. Species richness of herbs was greater than 1.30 under all reforestation practices except for RPI, meaning there were more than 6 herb species per 100 m2.

There was great variation in species evenness among both functional groups and reforestation strategies (Figure 3). Under reforestation practices of RPII, RPIII and RPVII, tree evenness was highest, shrub lowest and herbs were in between. Under RPV and RPVIII, evenness of shrubs was highest; trees, lowest and herbs, medium. Under RPIV and RPVI, herb evenness was

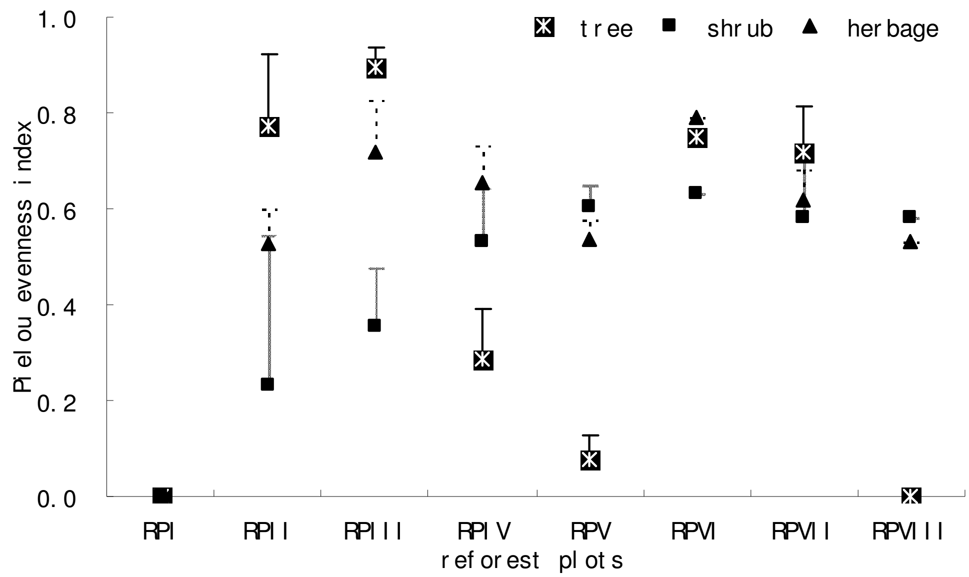

Figure 3. Special evenness of functional plant groups in different reforest plots.

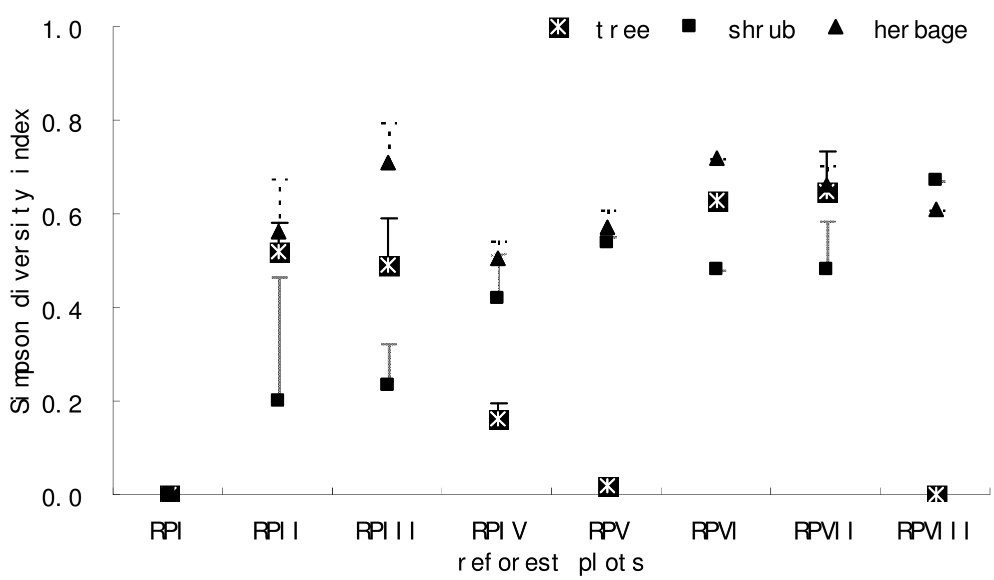

Figure 4. Special diversity of functional plant groups in different reforest plots.

highest. Under RPI, all functional groups had species evenness of zero. The highest species evenness for trees (0.90) was observed in RPIII plot, and zero species evenness of trees was found in RPVIII plots. Shrub reached the highest species evenness (0.65) under RPV, and herbs were highest in species evenness (0.70) under RPIII.

Species diversity also varied greatly with both functional groups and reforestation strategy (Figure 4). Herb diversity was highest; shrub, lowest and trees, medium under reforest practices of RPII, RPIII and RPVI. Herb diversity was highest; shrubs, medium; tree diversity, lowest under RPIV. Herb and shrub diversity was equal and tree diversity was zero under RPV. Species diversity of herbs and trees was similar and both higher than shrub diversity under RPVII. Species diversity of shrubs was highest among the three functional groups and that tree diversity was zero under RPVIII. Under RPI, all functional groups had a species diversity of zero. The highest species diversity of trees (0.65) was observed in RPVII plot, and zero species diversity of trees was found in RPVIII plot. Shrub diversity was highest in RPVIII (0.70), and herb diversity was highest in RPIII and RPVI (0.75).

DISCUSSION

Ecosystem restoration is becoming a common way of bringing back native species and their habitats. Although studies of restoration success for native vegetation are still few in number, a common conclusion emerged from many studies on different ecosystems (Wilkins et al., 2003). Seedlings of multiple species are expected to emerge, survive and establish reproducing populations, and then populations are expected to assemble into a community similar to the original system (Martin and Milsey, 2006). Restoring community structure (that is, species composition and diversity), one of the two main objectives of restoration and vegetation improvement, was stressed in the current study to quantitatively assess the success of restoration practices implemented in woodlands along the Dabao Highway in Longitudinal Range-Gorge Region of Yunan Province.

Species composition

It was reported by several researchers (Lockwood and Pimm, 1999; Smith et al., 2000) that species composition can reflect the process of vegetation succession and be used as one of the objectives of vegetation restoration and improvement. The proportion of native species in the composition was a very important indicator for assessing the success of the restoration practice (Bradshaw, 1996; Hobbs and Norton, 1996). The number and abundance of species of the climax community may also be important for the success of restoration, which can be assessed by using reference sites. However, the development of the species composition in restored sites toward a state that resembles the appropriate reference sites was, at best, extremely slow and may not eventuate at all. And, if succession does occur, the time scale required for restored sites to match the target state may range from several decades to the centuries (Anand et al., 2005).

The results from current study show that the community in RP I was a pure stand of E. maideni, an introduced commercial tree. Our observations suggest that shading of this fast-growing plant suppressed the growth and abundance of other species. This is consistent with Brown and Bugg's finding (2001) that transplanted forbs with immediately adjoining perennial grasses grew better if the former was in full sunlight than if overtopped by the adjacent perennial grass. Weeding management of the commercial forests might have contributed to the pure stands of E. maideni, but local residents said that weed control was done infrequently. The pure stand of E. maideni has high economic value for oil and compound production. Risk of death or degradation from environmental stress (draught, frost, disease etc.) and disturbance (fire, logging etc.) might impose a risk with the extensive use of this species in forest restoration and improvement projects. Moreover, non-native species may not fulfill the same function as native species (Jordan et al., 1996).

The RPII plot was replanted with the native tree, P. yunnanensis, the same year that RPI was planted, but many more species were found in the RPII plots due to less shade suppression of new seedlings of this slow-growing plant. At early stages of succession, pioneer plants of perennial grasses and annual weeds can grow very well under high light conditions, which may account for the high proportion of exotic plants and herbs in these plots. Although the proportion of shrubs and trees was not high, the data suggest that there is a potential for restoring the damaged lands into natural woodlands.

The RPIII plot was reforested in 2002, two years before RPI and RPII, with a combination of P. yunnanensis and Alnus nepalensis, the two dominant species of the primary vegetation in this site as recorded in literature (Wu, 1980). Although the plant community was still dominated by pioneer herb species at the early stages of succession, the proportion of exotic plants decreased dramatically. In comparison, in the RPIV plot planted solely with P. yunnanensis in the same year, there was a low number of species due to the fact that there were few herbs. This may be attributed to interspecific competition or allopathic interactions with neighboring plants within the community, which needs to be studied further. As concluded by Cairns (1996), the species composition matters during vegetation restoration or improvement.

In the RPV plot planted with P. yunnanensis in 1999, the first year the national policy of “Returning Agricultural Land to Forest Land” was implemented, native plants took an important position, community and woody plants increased in proportion to herbs over time as succession progressed. In the RPVI plot planted with P. yunnanensis in 1995, five years earlier than RPV was reforested, more trees were found in the species composition of secondary vegetation. It can be concluded from the decreased proportion of exotic plants and herbs in these plots that the vegetation was progressing through succession. These two reforestation strategies can speed up natural restoration processes of the vegetation to some extent.

The naturally restored plot of RPVII was rich in the total number of species, woody species and herbaceous species, and the proportion of native species was high. Thus, it may be concluded that, with time, the degraded woodlands can recover from their seed pool in the soil. Because the vegetation in the RPVIII plot was in the early stages of restoration, the species composition was much simpler and was dominated by herbaceous pioneer species. Although the species composition of the naturally restored and planted communities was not entirely the same, common species were found in both treatments (except for RPI). The same finding was reported by Reay and Norton (1999) in a restored temperate of New Zealand rainforest. These authors stated that there was a similarity in the composition of tree regeneration (that is, individuals recruited after the original plantings) between the restored sites and an older naturally regenerating site. Both of these findings illustrate that alternative ways can be used in successful restoration and improvement efforts in terms of the restoration and improvement efforts in terms of the species composition.

Plant cover

Plant cover is effective in preventing erosion to the extent that it absorbs the kinetic energy of raindrops, covers a large proportion of the soil during periods of the year when rainfall is heavy, slows down runoff, and keeps the soil surface porous (Zhang et al., 2005). Whatever the slope, cropping technique, extent of soil fragility or climatic conditions, complete plant cover ensures a high level of soil and water conservation. Plant cover may have a priority in any effort to improve water management, infiltration, biomass production and soil conservation. Some researchers have used plant cover as an indicator to assess ecosystem functional status in restoration projects (Maestre et al., 2006).

The fast growing non-native E. maiden in the RPI plot resulted in complete canopy cover with tall plants which have the potential for water conservation, but, conversely, the low soil surface cover (herbs or litter cover) may create problems of high surface runoff. In comparison, the RPVI plot had both high canopy cover and well-developed vegetation structure, and its function of water conservation may be higher. Although the replanted vegetation in the RPII, RPIV and RPVII plots were relatively low in canopy cover, the well-developed structure of the plant communites might increase their water conservation function. The plant cover of the naturally-restored community in the RPVIII plot was quite, which may decrease its water conservation function.

Plant cover can be used to compare the abundance (dominance) of species of widely different growth forms, because it is not biased by the size and distribution of individuals (Mueller-Dombois and Ellenberg, 1974; Whitaaker, 1975). The results of functional groups cover in this study indicate that in the early stages of reforestation, herbs dominated the plant community in most plots (except RPI), and woody plants became more important with time after reforestation. In addition, the reforestation strategy can affect the plant cover of the different functional groups, and thus affect their dominance in the community.

Plant height can reflect the growth rate of vegetation, which may be partly associated with plant cover. It is evident that the vegetation in the plot of RPI reforested with the fast-growing plant, E. maideni, was much higher in plant cover and that in the RPII reforested with the slow-growing tree, *P. yunnanensis*. Although some researchers reported that ground cover thins with age, since restoration plantings increase due to competitive interactions between the growing tree stratum and the dense largely exotic ground cover of the restored vegetation (Wilkins et al., 2003). It was found in this study that taller vegetation increased with age, since restoration in RPVI resulted in higher plant cover. If our findings can be further tested, plant height might be used as an auxiliary indicator of plant cover to assess ecosystem functional status in restoration projects.

Species diversity

Species diversity components were used by some researchers to assess ecosystem restoration success (Jordan et al., 1996; Anand et al., 2005; Martin et al., 2005). Species diversity has two components (Stirling and Wilsey, 2001): evenness (how evenly abundance or biomass is distributed among species) and richness (number of species in unit area). High evenness can increase invasion resistance, total and below-ground productivity, and can reduce local plant extinction rates (Wilsey and Polley, 2002, 2004; Smith et al., 2004). Species richness and recruitment were found either negatively or positively correlated in a number of saturation studies in grasslands (Tilman, 1997; Levine, 2000; Franzén, 2001). It was also concluded by some researchers (Brown and Bugg, 2001) in grassland restoration studies that there may be challenges to establishing multiple grass and forb species, although initial species richness can be controlled in restoration projects.

It was found in this study that species diversity of the plant community varied with the reforestation practice and time. Natural restoration (RPVII) or reforestation with native dominant plants (RPIII and RPVI) can lead to high species diversity by the 3rd or 4th year following planting. High species richness of the naturally restored community of RPVII implies that there was a positive relationship between richness and natural restoration. In contrast to Sluis's finding (2002), a decrease in species richness was not observed in our study. Two communities, either totally planted with native dominant plants but in the early years since restoration (RPIII), or partly planted with native dominant plants but in later years since restoration (RPVI), were high in species evenness. These two plant communities may have high invasion resistance, and high total and below-ground productivity according to previous researcher's findings cited before.

In the past, several studies of grassland restoration practices found that diversity and richness were much lower in the restored than remnant sites (Kindscher and Tieszen, 1998; Sluis, 2002; Martin et al, 2005), and comparisons between restored and remnant sites revealed no differences in evenness (Kindscher and Tieszen, 1998; Martin et al., 2005). In the present study, such comparisons were not possible, as there were no remaining reference or remnant sites. However, the preliminary conclusion that can be drawn by comparing species diversity between the different reforestation strategies that natural restoration or reforestation with native dominant trees are reasonable choices for vegetation restoration or improvement.

Because the native woodlands were dominated by woody plants in the past, the colonization of these species is of particular interest. In the present study, it was found that species diversity of functional groups indicates that diversity and richness of herbs was generally higher than that of shrubs and trees under different reforestation practices, whereas species evenness of woody plants was greater than that of herbs in some cases. This implies that small-scale species evenness may be more easily restored than species richness. This result can further support Martin et al. (2005) finding from a grassland restoration study that small-scale evenness may be easier to restore than richness.

Conclusion

The different reforestation treatments had significant effects on species composition, plant cover and species diversity, and thus affected the ecological function of plant communities. Therefore, decisions and regulations related to reforestation strategies, such as re-vegetation planning, species selection, seedling management should be carefully considered before implementation. Reforestation with native dominant woody plants or natural restoration is a reasonable choice for reforestation projects implemented in areas along the roadside of Dabao Highway, Longitudinal Range-Gorge Region of Yunan Province, China. Our conclusions have important implications for national and regional policies governing the regulation of ecosystem restoration and improvement.

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