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Plant Diversity and Initial Data on Water and Soil Conservation

Plant diversity, water, and soil conservation of man-made versus natural forests in Mouding (25°24'09" N, 101°28'18" E), mid-Yunnan, were investigated and analyzed. Various plant communities exist in this mountainous region: 4-year-old shrubland, a 10- to 14-year-old plantation of Eucalyptus smithii*, a 35- to 45-year-old plantation of* Pinus yunnanensis*, a 35- to 45-year-old semi-natural forest of* Keteleeria evelyniana *and* Pinus yunnanensis*, a 35- to 55-year-old natural secondary forest of* Keteleeria evelyniana *and* Cyclobalanopsis glaucoides*, and a climax forest of* Cyclobalanopsis glaucoides, Castanopsis orthacantha *and* Castanopsis delavayi *as the original mid-subtropical, semi-moist, evergreen broad-leaved trees in the region. The species diversity and the regenerative quality were poorest under the* Eucalyptus *forest. The* Pinus *forest had the lowest interception and stemflow (26.4%) of rainfall, followed by the* Eucalyptus *forest (29.5%). The leaching loss of nutrients was greater in the two planted forests than in the natural ones. The soil under the* Eucalyptus *forest was impoverished and showed deterioration of its chemical characteristics, as compared to the shrubland, semi-natural, natural, secondary, and climax forests in the same area.*

Keywords: *Community structure; floristic composition; soil nutrients; water use efficiency; vegetation restoration; mid-subtropics; Yunnan; China.*

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Introduction

Plantations of fast-growing trees, mainly species of *Eucalyptus* and *Pinus*, are widespread in China. Today, *Eucalyptus* is being planted continually and in increasingly large areas. The planting of *Eucalyptus* and *Pinus* forests after deforestation is common for industrial wood, oil, pulp, and fuel production, and is seen as a form of vegetation restoration in China. With rapid development, vast monocultures of *Eucalyptus* have been established after deforestation all over the country. Increasingly also in southern and southwestern China, including Yunnan, fast tree growth and inexpensive land and labor combine to make industrial wood production especially popular.

However, the environmental impact of fast-growing exotic tree plantations has been internationally controversial (IFS 1989). Some argue that monocultures exhaust soil water and nutrient resources in the tropics and subtropics and prevent understory growth, resulting in decreased biodiversity and in further soil erosion and loss of fertility (Shiva et al 1982; Shiva and Bandyopadhyay 1983; Poore and Fries 1985; DeBell et al 1987; FAO 1992; Abbasi and Vinithan 1997). Bargali et al (1993) reported that *Eucalyptus* plantations lead to soil degradation in subtropical areas of the central Himalayas. Natural evergreen broad-leaved forest was superior in the decomposition of leaf litter and nutrient cycling when compared with fast-growing pine forest in central Yunnan (Liu et al 2000). Both natural forests and mixed stands have better hydrological function than single-species tree plantations (Liu et al 2003). The invasion of Australian ectomycorrhizal fungi introduced with eucalypt plantations into the Iberian Peninsula is threatening the diversity of Mediterranean ecosystems (Díez 2005). The amounts of nutrients exported from the fast-growing monoculture plantations are high (Merino et al 2003, 2005).

In opposing opinions, some studies, conducted mainly on sites with degraded soils and vegetation, have found that fast-growing tree plantations (eucalypts and other species) favor regeneration of undergrowth plants from surrounding forests, increasing biodiversity and fertility (Geldenhuys 1997; Harrington and Ewel 1997; Loumeto and Huttel 1997). Peng (2003) reported that artificial rehabilitation could generally accelerate the restoration process on degraded land in China.

In an effort to elucidate some of the questions related to the planting of *Eucalyptus* and other fast-growing species, this study examines plant diversity and water and soil conservation in different plant communities in a single geographical area. Around Mouding, central Yunnan, the original subtropical semi-moist evergreen broad-leaved forest has been almost completely destroyed. Wang et al (2002) reported that reforestation with *Pinus yunnanensis* and *Eucalyptus maideni* near Mouding changed the species composition and species diversity of forests as the vegetation recovered, and improved their ecological hydrology. The present paper studies the functioning of man-made and natural forests in subtropical China in greater detail. The aims are to evaluate (a) the hypothesis that fast-growing exotic *Eucalyptus* plantations lead to reduced plant diversity in the mid-subtropical area of China, and (b) the hypothesis that plantations of *Eucalyptus* use more water and nutrients than forests of other tree species in the area.

Methods

Study site

Fieldwork was carried out at an experimental station in Samachang (1998 m) and at 2450 m on Mt Huafu, Mouding (25°24′09” N, 101°28′18”E), mid-Yunnan, China. The direct distance between the 2 study sites is only about 8 km, but 20 km by road. The mean annual temperature in the area is 15.7° C. Mean annual rainfall is 846 mm. The yearly rain season lasts from May to October. Soils in the study area are reddish, with pH values of the topsoil ranging between 3.1 and 4.1. Shrublands, man-made forests, semi-natural forest, natural secondary forest, and a climax forest form a complex ecosystem in this area.

Data

We established 15 permanent plots (40 x 10 m each) at the experimental station at 1998 m, representing degraded shrubland, man-made, and semi-natural and natural secondary forests at different succession stages. As a reference, we selected one plot of 40 m x 30 m at 2450 m on Mt Huafu, representative of the original subtropical semi-moist evergreen broad-leaved climax forest of the area. It is impossible to find a natural evergreen broad-leaved forest below 2400 m in the area. Though the reference site is located at a higher altitude than the experimental station, both sites still belong to the same climatic and soil zones, and were originally the same type of forest, ie semi-moist evergreen broad-leaved forest dominated by *Cyclobalanopsis glaucoides, Castanopsis orthacantha*, and *Castanopsis delavayi* (Wu et al 1987).

In May 2005, we identified all the woody species and measured their heights and diameters at breast height (DBH from 1 cm to 156 cm) for all stems ≥ 1.3 m tall. Saplings (130 cm > height ≥ 30 cm) and woody seedlings (30 cm > height > 3 cm) were identified, measured, and counted.

To determine the dominant species, dominance analysis (Ohsawa 1984) was applied. According to this scheme, in a community dominated by a single species, its relative dominance may be stated as 100%. If, however, 2 species dominate, the relative dominance of each should ideally be 50%, or if there are 3 co-dominants, 33.3%, and so on. The number of dominant species is that which shows the least deviation between the actual relative dominance values and the expected percent share of the corresponding co-dominant-number model. The deviation (d) is calculated by the following equation:

$$d = 1 / N \{\sum_{i \in} (x_i - x')^2 + \sum_{j \in U} x_j^2\}$$

where x_i is the actual percent share (here relative basal area is adopted) of the top species (T), ie the top dominant in the one-dominant model, or the 2 top dominants in the two-dominant model, and so on; x' is the ideal percent share based on the model as mentioned above; and x_j is the percent share of the remaining species (U). N is the total number of species.

Species diversity is shown by using the Shannon-Wiener index (Pielou 1969). The Jaccard index (beta diversity) was used to compare each of the different non-climax plant communities to the climax forest:

$$C_j = j / (a + b - j)$$

where C_j is the Jaccard index, a and b are the total number of species for the 2 communities, j is the number of common species among the 2 communities.

During the rainy seasons from May to October of 2001 and 2002, each day's precipitation was recorded by 2 auto rain gauges and 2 standard rain gauges in an open area of the experimental station. Also, 10 sample trees were chosen in each forest. Under the canopy of each sample tree, a global collector equal in diameter to each canopy was installed to collect the throughfall. In this study we combined the canopy interception and stemflow, using the formula:

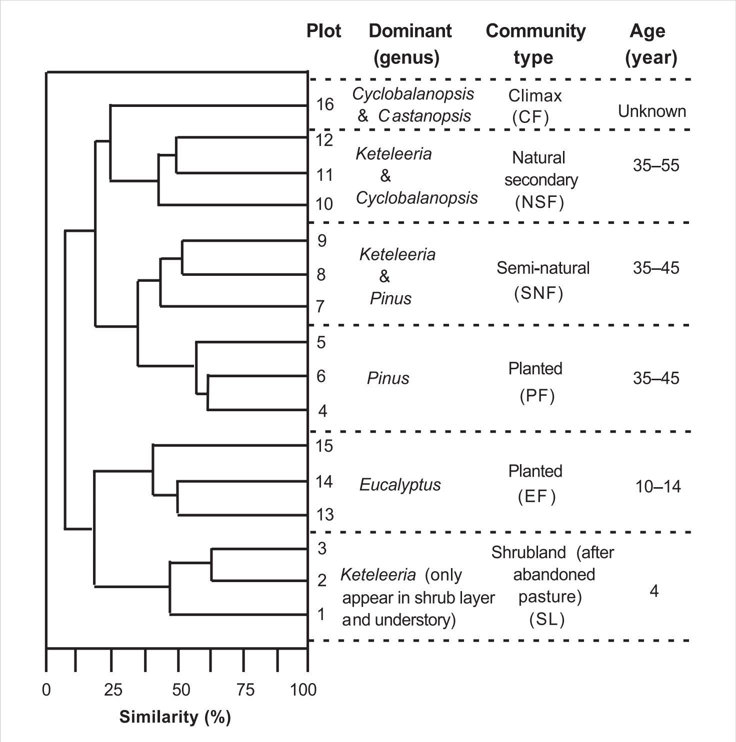
$$I_c + S_f = P - T_f$$

where I_c = interception; S_f = stemflow; P = precipitation; T_f = throughfall. On the basis of the data taken on the 10 sample trees, we calculated the canopy interception and stemflow for the forest as a whole.

At the experimental station, 5 plant communities are represented: shrubland, *Eucalyptus smithii* plantation, *Pinus yunnanensis* plantation, semi-natural forest, and natural secondary forest. Each plant community contains 3 plots. Runoff plots were laid out for the 15 plots selected for the investigation at the experimental station. Along the lower edge of each plot we established a runoff catchment. For 3 plots established in each of the communities, the volume of surface runoff was collected and measured on every rainy day with an auto-fluviograph (Morgan 1995), from May to October over 3 years (2001, 2002, and 2003). For each sample of these plots, we did 3 replicated measurements, and the results were then averaged. Finally, for each plant community, the above averages were combined to produce a new average volume characterizing each of 5 plant communities. We also monitored soil erosion and leaching loss of soil nutrients.

Soil samples were taken in different seasons: March, May, September, and November of 2003. In each season, we collected 3 soil samples for each soil depth (0–30 cm, 30–60 cm, 60–90 cm) at 3 different micro-sites within each of the 16 plots (15 at the experimental station, one on Mt Huafu). Three replicated measurements for each soil sample were done. The mean values for each separate season were used to represent the soil properties of the respective depths for

FIGURE 1 Dendrogram of the 16 plots using Soerensen's similarity index, and group average clustering. CF: climax forest; NSF: natural secondary forest; SNF: semi-natural forest; PF: *Pinus* forest; EF: *Eucalyptus* forest; SL: shrubland.



each plant community. In view of the similarity of results for the 4 months, to avoid repetitive accumulation of data in this presentation, and because May stands at an intermediate point between the dry and wet seasons, the figures on soil chemical properties for that month were selected for presentation here. The chemical properties of soils were measured using the standard methods of forest soil analysis (Forestry Bureau of China 1999).

Results

Floristic composition and structural features of the plant communities

We grouped 6 plant communities from the 16 plots (Figure 1): 4-year-old shrubland (SL, plots 1–3) formed since a degraded pasture was abandoned in 2001; 10–14-year-old planted *Eucalyptus smithii* forest (EF, plots 13–15) which was planted in a degraded pasture in 1991, and partially cut for fuel during the year 1995; 35–45-year-old planted *Pinus yunnanensis* forest (PF, plots 4–5) which was sowed by an airplane early in 1960, with the *Pinus* trees subsequently partially cut for industrial wood around 1970; 35–45-year-old semi-natural *Keteleeria evelyniana* and *Pinus yunnanensis* forest (SNF, plots 6–9); 35–55-year-old natural secondary forest of *Keteleeria evelyniana* and *Cyclobalanopsis glaucoides* (NSF, plots 10–12) which in a natural process appeared after the evergreen broad-leaved forest was completely logged in 1950 but then was partially cut for fuel from 1965–1970; a climax forest (CF) of *Cyclobalanopsis glaucoides*, *Castanopsis orthacantha*, and *Castanopsis delavayi* (plot 16) as the original subtropical semi-moist evergreen broad-leaved forest of the area not affected by human activity.

Table 1 shows the relative dominance of woody species (stems ≥ 1.3 m tall) for each plant community. In the shrubland (SL), the shrub layer was composed of coniferous *Keteleeria evelyniana*, deciduous *Pyrus pashia*, *Rubus obcordatus*, *Berberis ferdinandi,* evergreen broad-leaved *Ternstroemia gymnanthera*, and *Camellia pitardii* var. *yunnanica*. The dwarf shrub *Vaccinium fragile* accounted for 45% coverage of the understory. The planted *Eucalyptus* forest (EF) and *Pinus* forest (PF) were strictly dominated by those species, though some deciduous broad-leaved and a few evergreen broad-leaved species were found in the shrub layer. The semi-natural forest (SNF) was dominated by *Pinus yunnanensis* and *Keteleeria evelyniana*. Here, the number of evergreen broad-leaved species increased as compared to the first 3 communities above. In the natural secondary forest (NSF) *Keteleeria evelyniana* and *Cyclobalanopsis glaucoides* were the dominant species, along with many evergreen broad-leaved species such as *Photinia serrulata*, *Michelia yunnanensis*, and *Symplocos chinensis*, with several species of the genus *Lithocarpus*. The climax forest (CF) was dominated by *Cyclobalanopsis glaucoides, Castanopsis orthacantha*, and *Castanopsis delavayi*, with 45.4%, 28.9% and 19.4% of relative percent of basal area (RBA), respectively.

Figure 2 shows 7 structural features of the plant communities. The maximum height in the shrubland (SL) was 4.3 m, in the secondary forest (NSF) it was 18 m, and in the climax forest (CF) it reached 35 m, whereas it was 20 m for the semi-natural forest (SNF), 23 m for *Pinus* forest (PF), and 30 m for *Eucalyptus* forest (EF). Basal area (BA) density (expressed as total basal area per ha) was 0.5 m^2/ha in the shrubland, 39.9 m^2/ha in the semi-natural forest, 40.5 m^2/ha in the secondary forest, and 121.2 m^2/ha in the climax forest, while planted *Eucalyptus* had a basal area of 12.8 m^2/ha and planted *Pinus* forest one of 23.6 m^2/ha.

The number of woody species varied among the different plant communities, from 9 to 31. The secondary forest had a greater number of species (31) than the climax forest (26) because of its larger number of pioneer deciduous species. At 0.25 bit and 0.52 bit, the *Eucalyptus* and *Pinus* forests showed very low values on the Shannon-Wiener index (H'), while values for the secondary forest reached 1.88 bit and for the climax forest 1.94 bit. The Jaccard index (beta diversity) shows the differentiation in diversity between the climax forest and the other plant communities: *Eucalyptus* forest was the lowest (0.11), which indicated the least similarity

TABLE 1 Floristic composition of the woody species in each plant community. SL: shrubland; EF: *Eucalyptus* forest; PF: *Pinus* forest; SNF: semi-natural forest; NSF: natural secondary forest; CF: climax forest; RBA: relative percent of basal area. The dominant species in each plant community are indicated by an asterisk.

Plant community Woody species	SL (Plots 1–3) RBA (%)	EF (Plots 13–15) RBA (%)	PF (Plots 4–6) RBA (%)	SNF (Plots 7–9) RBA (%)	NSF (Plots 10–12) RBA (%)	CF (Plot 16) RBA (%)
Evergreen broad-leaved						
Ternstroemia gymnanthera	2.4			3.2	0.8	0.07
Lithocarpus polystachya	1.8	0.06			0.4	0.01
Camellia pitardii* var. *yunnanica	1			0.01	0.1	0.2
Myrica nana	0.6					
Myrsine africana		0.02	0.2	0.08	0.002	
Eucalyptus smithii		97.2*				
Eucalyptus globulus		0.1				
Olea yunnanensis			0.09	0.2	0.02	0.3
Cyclobalanopsis glaucoides			0.09	3.7	17.3*	45.4*
Machilus yunnanensis			0.01			0.3
Myrica adenophora			0.4	0.4		
Lithocarpus dealbatus				0.2	0.7	0.3
Lithocarpus megalophyllus				0.02	4.1	0.02
Photinia glomerata				0.02	0.2	
***Rhododendron* spp.**				0.02		
Photinia prionophylla				0.01		2.2
Viburnum cylindricum				0.002	0.004	
Rhododendron spinuliferum					1.1	
Lithocarpus confinis					1.1	0.03
Rhododendron spiciferum					0.6	
Photinia serrulata					0.1	
Michelia yunnanensis					0.09	0.002
Eurya nitida					0.06	0.04
Lithocarpus leucostachyus					0.03	
Symplocos chinensis					0.002	
Euonymus grandiflorus					0.001	0.06
Castanopsis orthacantha						28.9*
Castanopsis delavayi						19.4*
Ilex polyneura						0.3
Magnolia delavayi						0.2
Pittosporum brevicalyx						0.09
Mahonia veitchiorum						0.007
Subtotal	**5.8**	**97.38**	**0.79**	**7.862**	**26.709**	**97.759**
Deciduous broad-leaved						
Pyrus pashia	11.3	0.4	0.4	0.3	0.1	0.01
Berberis ferdinandi	0.5	0.1	0.02	0.01		0.001
Acacia mearnsii		0.8			0.008	
Viburnum foetidum		0.5	0.001	0.02	0.003	
Quercus variabilis		0.02				
Rosa longicuspis		0.009	0.1		0.002	
Rubus obcordatus	0.9	0.007				
Ostemeles schweriane		0.003		0.002	0.006	
Pyracantha fortuneana		0.002	0.02			
Cotoneaster franchetii			0.1	0.04		
Lyonia doyonensis				0.2	2.3	
Prunus conradiae				0.1		
Dichotomanthus tristaniaecarpa				0.03	0.3	
Vaccinium bracteatum				0.01	1.3	0.1
***Rosa* spp.**					0.05	
Schoepfia fragrans					0.009	
Meliosma yunnanensis						1.1
Acer hersii						0.9
***Styrax* spp.**						0.07
Subtotal	**12.7**	**1.841**	**0.641**	**0.712**	**4.078**	**2.181**
Coniferous						
Keteleeria evelyniana	77.3*	0.7	6.9	27.6*	64.5*	0.2
Pinus yunnanensis	4.2		91.5*	63.7*	4.9	
Subtotal	**81.5**	**0.7**	**98.4**	**91.3**	**69.4**	**0.2**
Total	**100**	**100**	**100**	**100**	**100**	**100**

FIGURE 2 Seven structural features of the plant communities. SL: shrubland; EF: *Eucalyptus* forest; PF: *Pinus* forest; SNF: semi-natural forest; NSF: natural secondary forest; CF: climax forest. Diversity index H' according to Shannon-Wiener.

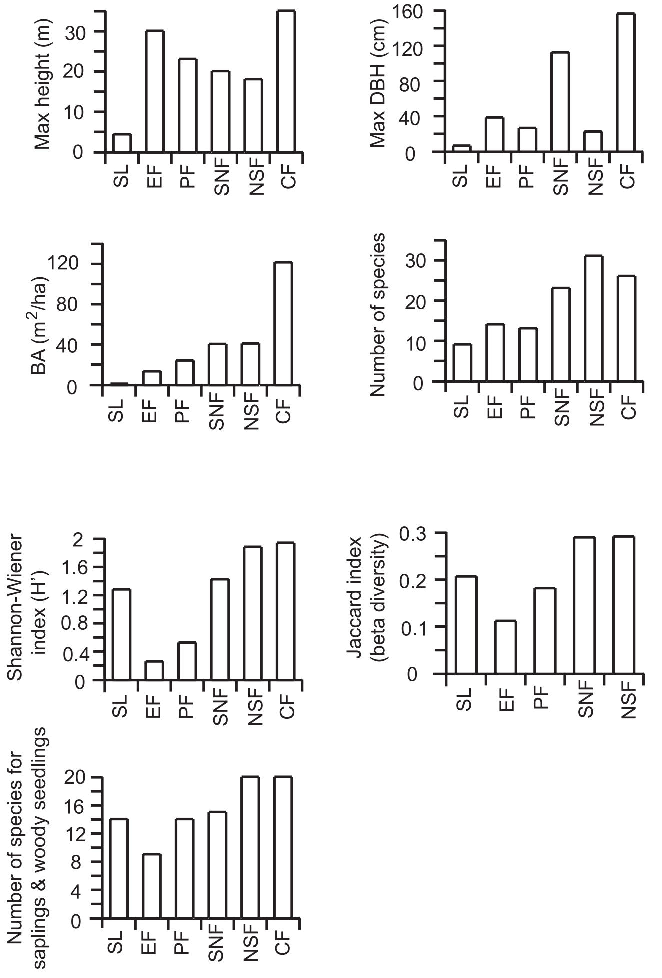
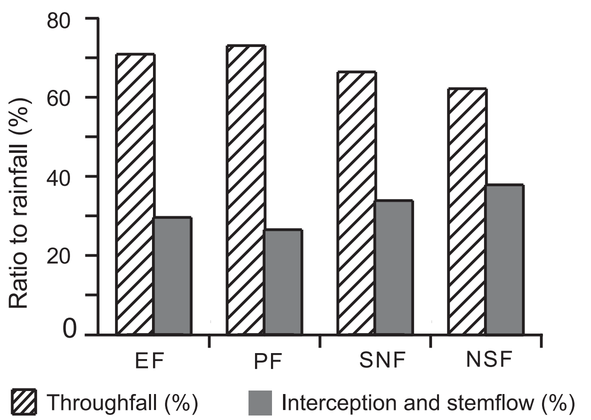


FIGURE 3 Ratio of interception and stemflow to rainfall, and throughfall to rainfall, for *Eucalyptus* forest (EF), *Pinus* forest (PF), semi-natural forest (SNF), and natural secondary forest (NSF).



with the climax forest; on the other hand, the semi-natural and secondary forests, with the same index of 0.29, more closely resembled the climax forest. The number of species of saplings and woody seedlings was the lowest (9) in the *Eucalyptus* forest, and next lowest in the shrubland (14) and *Pinus* forest (14).

Hydrological characteristics

The ratios of canopy interception and stemflow to rainfall, and throughfall to rainfall, for the planted forests and semi-natural and natural secondary forests, are shown in Figure 3. The throughfall was the highest in the *Pinus* forest (PF), followed by the *Eucalyptus* forest (EF) > semi-natural forest (SNF) > secondary forest (NSF). On the other hand, the *Pinus* forest had the lowest (26.4%) interception and stemflow of rainfall, followed by *Eucalyptus* forest (29.5%), while the semi-natural and natural secondary forests exceeded 33%.

On the basis of the 2001–2003 data for the plant communities at the experimental station (see Methods section), the *Pinus* and *Eucalyptus* forests had higher rates of surface runoff, with 1607.2 m^3/ha and 1193.8 m^3/ha, respectively (Figure 4), whereas the secondary forest had the lowest value, 103.6 m^3/ha. Soil under *Eucalyptus* forest had the most erosion (876.5 kg/ha), 16 times greater than the secondary forest and almost 5 times more than the shrubland. It also showed the greatest leaching loss of total P (348.2 g/ha), about 6 times higher than the secondary forest, and about 5 times more than the shrubland. Leaching loss of total N and total K had patterns similar to those of surface runoff.

Chemical properties of soils

Figure 5 represents the chemical properties of soils among the various plant communities. The soil under the *Eucalyptus* plantation showed the least air-dried water content (14.1–15.2%) at depths of 0–60 cm as compared to the other plant communities. Organic matter, total N, and available P and K generally decreased at greater depths. The organic matter in the soil, and its content of total N and available P and K were the highest in the climax forest (CF), followed by the secondary forest (NSF) > the semi-natural forest (SNF) > the *Pinus* forest (PF) > the shrubland (SL) > the *Eucalyptus* forest (EF). The data presented on soils are for 16 plots only and must be qualified as preliminary; continued measurement over the coming years may lead to refinement of the results, but this sequence seems unlikely to change. The greatest C/N ratio (41.3% at the depths of 0–30 cm, 42.3% for 30–60 cm) was present in the soil under the *Eucalyptus* forest, indicating the low decomposition rate of the *Eucalyptus* litter and low nitrification in the soil under that forest. The low nitrification in the soil is probably because of allelopathic effects (toxins) of eucalypt litter, which could inhibit the growth of other plants in the understory and the activity of some microbes in the soil.

Discussion

Plant diversity

According to Peng (Peng and Fang 1995; Peng 2003), in tropical and subtropical regions of China, fast-growing plantations can be generally regarded as a pioneer stage of evergreen broad-leaved climax forests that accelerate the process of succession and improve the development of species diversity. The present study strongly indicates that such is not the case for *Eucalyptus* plantations in the mid-subtropical region of Mouding, Yunnan. The species diversity in the planted *Eucalyptus* forest is particularly low, and the regenerative quality of the understory is also low. Therefore, the study supports the first hypothesis mentioned above, ie that fast-growing exotic *Eucalyptus* plantations lead to reduced plant diversity in the study area.

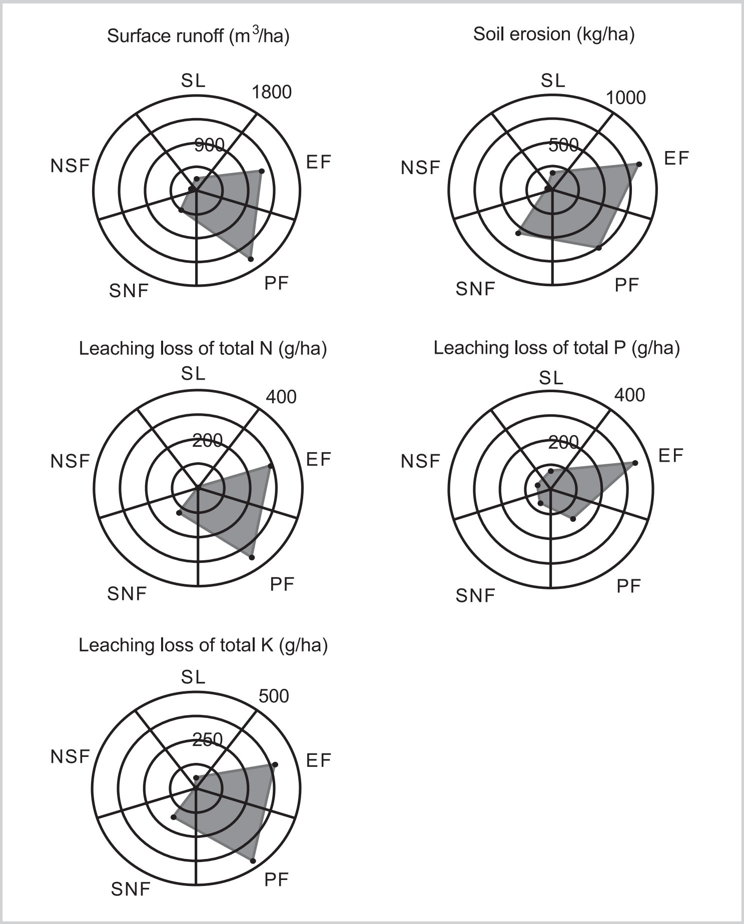
As a possible factor yet to be investigated, note evidence that some *Eucalyptus* species produce toxins, ie allelopathic effects that inhibit the growth of understory (del Moral and Muller 1970; Alexander 1989; Basanta et al 1989). However, another study (da Silva Junior et al 1995) has reported that *Eucalyptus grandis* did not show any allelopathic effect on many native species that colonize its understory in different regions of Brazil. Schwartz et al (2000) have argued that tree species diversity and productivity have a positive relationship with ecosystem function that can contribute to conservation of biodiversity. Erskine et al (2006) have suggested that multi-species plantations can generate greater productivity and make ecological gains, and should be more broadly pursued than monoculture plantations as a reforestation method.

Water use efficiency

Research has shown that the evapotranspiration of *Eucalyptus* markedly increases annual evaporative losses (Calder 1992). Planted *Eucalyptus* forests do not retain water in the drier areas of sub-Saharan Africa and India, which receive less than 1000 mm of annual rainfall (Gewin 2005). Measurements of forest evapotranspiration were not made in this study. However, the study shows that the soil from 0–60 cm contains less water under *Eucalyptus* than under other plant communities. Baldy et al (1970) found that eucalypts dry out soil faster than pines. In a desert area in Israel (annual rainfall 200 mm), the roots of *Eucalyptus* extracted soil moisture mainly during the season with rainfall (Stibbe 1975). Eucalypts were used to drain marshes near Rome in the 18th and 19th centuries (Ghosh et al 1978).

Natural forests and mixed stands have high canopy interception as a result of their more complex vertical structure, compared to single-species plantations (Liu et al 2003). In the study area, rain interception and stemflow in *Pinus* and *Eucalyptus* forests are lower than in the semi-natural and natural secondary forests. Predictable results are large surface runoff and leaching loss of soil nutrients.

FIGURE 4 Radar-diagram of soil surface runoff, soil erosion, and leaching loss of total N, P, and K. The data for each item are totals for 2001–2003, except for total N and K, which are for 2003. SL: shrubland; EF: *Eucalyptus* forest; PF: *Pinus* forest; SNF: semi-natural forest; NSF: natural secondary forest.



Soil nutrients loss

Data covering 2001–2003 show loss of soil nutrients by erosion in *Eucalyptus* forest to be somewhat greater than under the other plant communities. The organic matter in the soil under the *Eucalyptus* was lowest, perhaps reflecting the chemistry of the litter and its low decomposition rate (high C/N ratio, see Figure 5). Poggiani et al (1983) measured nutrient content in different parts of the trees in an 8-year-old *Eucalyptus saligna* plantation in São Paulo State, Brazil. They reported that the soil was very poor in P and K, and in contrast, high in biomass. Bargali et al (1993) compared the properties of the top 30 cm of soil under plantations of 1- to 8-year-old *Eucalyptus* (the hybrid *E. tereticornis*) and in adjacent natural mixed broad-leaved forest in the subtropical zone of the central Himalaya. Soil chemical

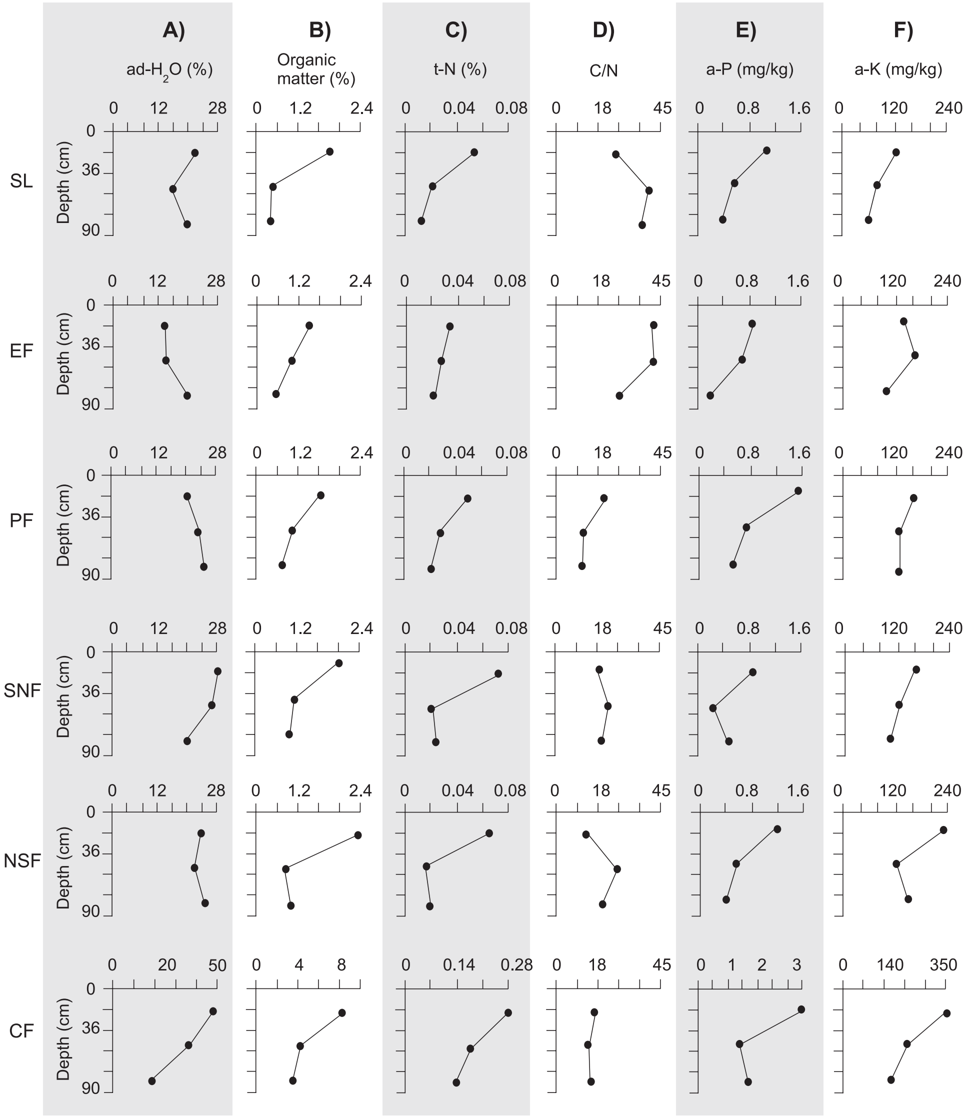


FIGURE 5 Soil chemical properties. ad-H_2O = air-dried water; t-N = total N; C/N = ratio of organic C to total N; a-P = available P; a-K = available K. SL: shrubland; EF: *Eucalyptus* forest; PF: *Pinus* forest; SNF: semi-natural forest; NSF: natural secondary forest; CF: climax forest (scale different from previous plant communities!).

properties, notably organic carbon, total N, P, and K, decreased as a result of reforestation with *Eucalyptus* and further decreased with increasing age of the plantation.

The present study also shows that the soil under *Eucalyptus smithii* has very low levels of nutrients such as total N, available P, and K. Moreover, afforestation with *Eucalyptus* has the potential to alter the coarse particulate organic matter (CPOM) dynamics to differences in the timing and nutrient content of CPOM input, and to cause loss of the natural vegetation (Molinero and Pozo 2004). Merino et al (2005) have studied nutrient exports under different harvesting regimes in fast-growing forest plantations in southern Europe. The results showed that the nutrient exports in such areas can be reduced by selection of suitable tree species, lowering the planting density, increasing the length of the rotation, and reducing the intensity of harvesting.

Though data covering additional years would serve to refine the figures on surface runoff, leaching loss of soil nutrients, and their concentration in the soil, the study lends support to the second hypothesis cited in the Introduction: that *Eucalyptus* plantations use more water and nutrients than forests of other tree species in the area.

Conclusion

Like many exotic introduced species, eucalypts may thrive at the expense of their environment. This is plainly the case in the subtropical area of Yunnan, as seen in the data for the present study, which is representative of the region. For eucalypt plantations to be truly beneficial, their disadvantages must be counterbalanced. Today's advanced agronomic science surely provides the means to meet this great challenge. We suggest that eucalypts can be planted in very small and limited areas for local economic benefit, but are not suitable for planting in large areas as a means to restore forest cover.

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