Effects of reforestation on soil carbon, nitrogen, phosphorus stoichiometric shifts depend on tree species in subalpine forests

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Soil stoichiometric ratio varies with climate factors, topography factors, soil texture and vegetation types. However, whether and how different tree species would affect soil C: N: P ecological stoichiometry, especially in alpine and subalpine, region remains less addressed. We examined how ecological stoichiometry of carbon (C), nitrogen (N) and phosphorus (P) respond to selected tree species in alpine plantations. Soil C:N varied greatly among soil layers and between sampling times, and the changes of soil C:N with soil depth depend on tree species examined. Soil N:P varied greatly among soil layers and across tree species, and verticaldistribution of soil N:P varied significantly with tree species examined. Soil C:P was mainly affected by tree species, soil layers, sampling time and interactive effect of between tree species and by soil layer. Across soil profiles, the C:N, N:P and C:P significantly negative correlated to increase in soil bulk density, whereas significantly positive correlated to increase in soil moisture and fine root biomass. At the 0-10cm depth, standing litter stock, arbor biomass/aboveground biomass and Margalef's index of plant community mainly accounted for the difference in soil C:N, N:P and C:P across target tree species, respectively. In conclusion, this implies that litter quantity and quality collectively control ecological stoichiometry of topsoil in subalpine plantations.

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Abstract

Soil stoichiometric ratio varies with climate factors, topography factors, soil texture and vegetation types. However, whether and how different tree species would affect soil C: N: P ecological stoichiometry, especially in alpine and subalpine, region remains less addressed. We examined how ecological stoichiometry of carbon (C), nitrogen (N) and phosphorus (P) respond to selected tree species in alpine plantations. Soil C:N varied greatly among soil layers and between sampling times, and the changes of soil C:N with soil depth depend on tree species examined. Soil N:P varied greatly among soil layers and across tree species, and vertical distribution of soil N:P varied significantly with tree species examined. Soil C:P was mainly affected by tree species, soil layers, sampling time and interactive effect of between tree species and by soil layer. Across soil profiles, the C:N, N:P and C:P significantly negative correlated to increase in soil bulk density, whereas significantly positive correlated to increase in soil moisture and fine root biomass. At the 0-10cm depth, standing litter stock, arbor biomass/aboveground biomass and Margalef's index of plant community mainly accounted for the difference in soil C:N, N:P and C:P across target tree species, respectively. In conclusion, this implies that litter quantity and quality collectively control ecological stoichiometry of topsoil in subalpine plantations.

Key words: ecological stoichiometry; tree species; plantation in alpine region; soil depth; litter; fine root.

Introduction

Nitrogen (N) and phosphorous (P) the most important nutrients limiting plant growth, regulate different biological processes in terrestrial ecosystems (Vitousek and Howarth, 1991; Güsewell, 2004; Reich and Oleksyn,2004; Elser et al., 2007).. A deficiency or less content of these two key nutrients leads to a higher C:N and C:P ratios, and their excess triggers C deficiencies(Tessier and Raynal 2003；Güsewell, Jewell et al. 2005). The biogeochemical cycles of C, N, and P in terrestrial ecosystems production, respiration and decomposition (Daufresne and Loreau 2001; The availability of N and P under relatively stable ecological conditions controls C storage(Hessen, Ågren et al. 2004; Yu, Wilcox et al. 2016).

Ecological stoichiometry addresses the equilibrium or interactions of the main elements as well as the correlations between elements and ecosystem functioning in an ecosystem (Güsewell, 2004; Cambardella, C.A et al.1992; Elser et al. 2000). Earlier studies have found that soil C: N ratio is strongly linked to the N mineralization rates of soil organic material and C allocation in forest ecosystems (Alberti, G., et al. 2015). The soil C, N, and P stoichiometry directly reflects soil fertility status, indirectly indicates the nutrient excess/limitation conditions of soil (Bing, H., et al. 2016), and in turn affects productivity and species composition of plantations (Wassen, M.J., et al. 2005; Mao, R., et al. 2016).

Earlier studies have demonstrated that the soil stoichiometric ratio varies with climate factors (including temperature and precipitation), topography factors (elevation and latitude), soil texture and vegetation types (Cleveland, C.C. and D. Liptzin. 2007; Tian, H., et al.2010; Feng, D et al. 2017). Furthermore, reforestation could be a major factor influencing soil organic carbon (SOC) and total nitrogen (TN) content, as well as ecological stoichiometry (Davis, M., et al.2010; Deng, L et al.2015) . However, whether and how different tree species would affect soil C: N: P ecological stoichiometry, especially in alpine and subalpine region, remains unclear. Available literatures demonstrated that soil stoichiometric ratio varies with the species characteristics of plantations (Vinton, M.A. and I.C. Burke. 1995; Sardans, J., A et a. 2012; Lawrence, B.A et al.2013). Tree species are reported to influence soil properties through multiple mechanisms (Prescott, C.E. and S.J. 2013) . Firstly, tree species differ in the quality and quantity of inputs in the form of litter and root exudates (Aponte, C. and T. Marañón. 2012; Eric, P., et al. 2010). For example, broadleaf trees have higher litter and root turnovers, as well as the content of N, P in leaves and roots were higher in comparison with conifer trees. Additionally, C and N mineralization rates are greatly affected by tree species, since distinct dominant tree resulted in shifts in soil microbial community composition (Alberti, G., et al. 2015). Besides, the vertical pattern of C:N:P stoichiometry varied depending on ecosystem examined (Feng, D et al. 2017). However, there are only a few studies addressing the responses of soil C:N:P stoichiometric relationship to selected plantations in alpine and subalpine regions (Feng, D et al. 2017). Despite this, knowledge can guide our management to upgrade the ecological functioning of plantation species under global climate changes.

The main objective of this study was to evaluate the effect of commonly used tree species in plantations on soil C: N: P ecological stoichiometry. We hypothesized that: (1) the broadleaves species would exhibit better soil nutrient conditions than conifer species; (2) the variations in soil C: N: P stoichiometric ratio across tree species decrease with increase in soil depth; (3) litter stock, tree aboveground biomass and fine root biomass are major influencing factors of soil C:N:P ecological stoichiometry, whereas the effect size depends on soil depth.

Materials and methods

Study area

The study was conducted at the Mao Country Mountain Ecosystem Research Station (31° 37' N, 103° 54' E), Chinese Academy of Sciences in Sichuan, China. The annual mean temperature is 9.3 °C, with monthly temperature ranging from -0.9 °C in January to 18.6 °C in July. The mean annual precipitation is about 900 mm, with about 70% occurring during the growing season from May to September. The annual accumulated temperature ≥10°C is 2635.1°C. The soil type at the study site was a Calcic Luvisol according to the IUSS Working Group WRB (2007). The soil texture was silt loam with 15.5% and 15.3% of sand, 62.5% and 63.3% of silt, 21.9% and 21.5% of clay in the 0–10 cm, and 10–20 cm soil depths, respectively (Jiang, Y et al. 2011)

Forest types and management activities

In August 2007 and August 2018, three plantations of *Pinus tabulaeformis* (PT), *Larix kaempferi* (LAR), *Cercidiphyllum japonicum* (CJ)) and one native secondary shrubland (dominated by *Quercus liaotungensis* and *Corylus heterophylla*) were selected. We chose these tree species because they are commonly used when restoring or replacing native thicket in western Sichuan province, as was also the case with the study area. These plantations were established with terracing in the spring of 1987 on cutovers of primary thicket, which were clear-fallen in the autumn of 1986. They have not been fertilized since the establishment. Prior to establishment, the main soil properties in these plantations were similar to those of the native secondary coppice forest. The understory species were dominated by native broad-leaved species, including *Quercus aliena*, *Corylus heterophylla*, *Rosa* spp., *Spiraea* spp., *Phlanis umbrosa*, *Voila* spp., *Anaphalis* *sinica*, *Potentilla* spp., without any species being absolutely dominant. The other main characteristics of the forest stands are summarized in Table 1.

Vegetation measurements, soil sampling and analysis

In August 2007 and August 2018 three 10 × 10 m standard plots were randomly established in each of the three plantations (LAR, PT, CJ) and a native secondary shrubland. Stand density, tree height (H) and tree diameter at breast height (DBH) were recorded for each plot.

In each plot, to measure the aboveground biomass of each layer of understory vegetation, destructive sampling was carried out within five 2 m × 2 m quadrat, all aboveground biomass within each sampling category was clipped and oven dried at 65 °C to constant weight before weighing. The litter on the soil surface was collected from the same quadrats, mixed, dried at 65°C, and weighed. Soil samples were collected with a soil auger (50 mm diameter) in three depth increments (0–10, 10–20, 20–30 cm). The samples from each quadrat were mixed to give one sample per plot and depth. The soil samples were taken to the laboratory and the oven drying method (105 °C, 24h) was used to determine soil moisture content immediately. The soil bulk density was determined using stainless steel cylinders (100 cm^3) in triplicate for each treatment before soil sampling. The soil samples were air-dried after removing the gravel, animal and plant debris and breaking the large fractions. The air-dried soil sample was ground and then passed through 20-mesh (0.9 mm) and 100-mesh (0.15 mm) nylon sieves, respectively (Li, Ruirui et al. 2018). The processed samples were preserved for the determination of SOC, TN and total phosphorus (TP). SOC and TN were determined by combustion in a Macro Elemental Analyser (vario MACRO, Elementar Co., Germany). TP was measured using the sulphuric acid-soluble perchlorate acid- molybdenum antimony colorimetric method (Hu, B., et al. 2016). C, N, and P contents in leaves, litter, and soil samples were mass-based. The atomic ratios were determined according to the formula:

$$\mathrm{C{:}N} = \frac{\mathrm{C_{content}}/12}{\mathrm{N_{content}}/14} \quad \text{..(1)}$$

$$\mathrm{N{:}P} = \frac{\mathrm{N_{content}}/14}{\mathrm{P_{content}}/31} \quad \text{..(2)}$$

$$\mathrm{C{:}P} = \frac{\mathrm{C_{content}}/12}{\mathrm{P_{content}}/31} \quad \text{..(3)}$$

Statistical analysis

Three-factor analysis of variance (ANOVA) followed by Tukey HSD post-hoc analysis was used to determine differences in results for contents of SOC, TN and TP, as well as ratios of C:N, C:P and N:P across treatments with target tree species, soil depths and sampling time (2007 and 2018) as factors. Additionally, two-factor analysis of variance (ANOVA) followed by Tukey HSD post-hoc analysis was used to determine differences in results for contents of SOC, TN and TP, as well as ratios of C:N, C:P and N:P across treatments in the same sampling time with target tree species and soil depths as factors. Besides, one-factor analysis of variance (ANOVA) followed by Tukey HSD post-hoc analysis and student's T-test was used to examine the differences in results for contents of SOC, TN and TP, as well as ratios of C:N, C:P and N:P across target tree species/soil depth and between sampling times, respectively. Pearson correlation analysis was used to examine the correlations among aboveground biomass, diversity indices of plant community, standing litter stock, C-, N- and P- content, C:N:P stoichiometric ratios in litter and C:N:P stoichiometric ratios in topsoil. Additionally, the main influencing factors were selected by multiple linear regression using “step-AIC” function (R package: MASS) (Venables, W. N., and B.D. 2002) in R version 3.5.2. Furthermore, the corresponding contribution of selected factors were obtained by “relimpo” function (R package: relimpo) (Groemping, U. 2006) in R version 3.5.2. Finally, the determinant factors of soil (0-30cm) C:N:P stoichiometry were examined with multiple regression, with maximal soil water holding capability, BD, tree aboveground biomass, litter stock, fine root biomass, SOC, TN and TP contents as independent variables.

Results

Soil C, N and P stoichiometry

Soil C: N varied greatly among soil layers and between sampling times, and the changes of soil C:N ratio with soil depth varied with tree species examined (Table 2). Soil N: P varied greatly among soil layers and across tree species, and the changes of soil N:P ratio with soil depth varied with tree species examined (Table 2). Soil C:P was responsible to tree species, soil layers, sampling time and interactive effect of tree species by soil layer, suggesting the effect of tree species on soil C:P ratio depended on soil depth (Table 2).

Dynamics of Soil C, N and P stoichiometry

In 2007, the C:N ratios in soil at the depth of 0-10 cm and 20-30 cm were independent on tree species, but the C:N ratio in soil at the depth of 10-20 cm varied significantly with tree species (Fig. 1). Specifically, the highest C:N ratio was observed in soil of the PT plantation, followed by CJ plantation and shrubland, and the lowest C:N ratio was in the soil of the LAR plantation (Fig. 1). In 2018, the C:N ratios in soil at the depth of 0-10 cm and 10-20 cm varied significantly with tree species, whereas that in soil at the depth of 20-30 cm showed a stable level across tree species

(Fig. 1). Specifically, at the depth of 0-10 cm the highest C:N ratio in soil were observed in soil of the LAR plantations, followed by PT and CJ plantations, and the lowest C:N ratio was in the soil of the shrubland. At the depth of 10-20 cm the highest C:N ratio in soil was observed in soil of the PT plantation, followed by shrubland and LAR plantations and the lowest C:N ratio was in the soil of the CJ plantations (Fig. 1).

In 2007, the N:P ratio in soil at the depth of 0-10 cm varied significantly with tree species, but the N:P ratios in soil at the depth of 10-20 cm and 20-30 cm were independent on tree species (Fig. 1). Specifically, the highest N:P ratio was observed in soil of the shrubland, followed by LAR and PT plantations, and the lowest N:P ratio was in the soil of the CJ plantation (Fig. 1). In 2018, the N:P ratios among each layer was roughly the same as that in 2007 (Fig. 1). Specifically, at the depth of 0-10 cm the highest N:P ratio in soil was observed in soil of the shrubland, followed by LAR and PT plantations, and the lowest N:P ratio was present in the soil of the CJ plantation (Fig. 1).

In 2007, the C:P in soil at the depth of 0-10 cm varied greatly with tree species, but the C:P in soil at the depth of 10-20 cm and 20-30 cm showed a comparable level across tree species (Fig. 1). Specifically, the highest C:P was observed in soil of the shrubland, followed by LAR and PT plantations, and the lowest C:P was observed in the soil of the CJ plantation (Fig. 1). In 2018, the C:P ratios in soil at the depth of 0-10 cm and 10-20 cm have shown roughly the same trend as 2007, however the soils at the depth of 20-30 cm has shown significant differences among different tree species (Fig. 1). Specifically, at the depth of 20-30 cm the highest C:N ratio in soils were observed in soil of the shrubland, followed by CJ and PT plantations, and the lowest C:N ratio was in the soil of the LAR plantations (Fig. 1).

Relationships between soil C, N, and P stoichiometric ratios, soil properties, stand factor, each component biomass, litter and shrubland C, N, P concentration and stoichiometric ratios

Across soil profiles, the C:N, N:P and C:P significantly decreased with increase in soil bulk density, whereas significantly increased with increase in soil moisture and fine root biomass (Fig. 2). At the topsoil, the C:N was significantly positively correlated with litter stock (P<0.001), whereas negatively correlated with fine root biomass and C content of litter (P<0.05). The N:P was significantly positively correlated with understory biomass (P<0.001), understory biomass/aboveground biomass (P<0.001), arbor & shrub richness (P<0.001), Margalef's index (P<0.001), Shannon-Wiener index (P<0.001), Pielou evenness index (P<0.001), but negatively correlated with arbor biomass (P<0.001), aboveground biomass (P<0.001), arbor biomass/aboveground biomass (P<0.001), P content of litter (P<0·05) and Simpson dominance index (P<0.001). The C:P was significantly positively correlated with arbor & shrub richness (P<0.001), Margalef's index (P<0.001), Shannon-Wiener index (P<0.001), Pielou evenness index (P<0.001), but negatively correlated with arbor biomass (P<0.001), aboveground biomass (P<0.001), arbor biomass/aboveground biomass (P<0.05), C content of litter (P<0.05), litter C:N (P<0.05) and Simpson dominance index (P<0.001) (Table S2).

Based on the results of multiple linear stepwise regression and relative importance contribution analysis of selected factors, we found that soil C:N at the topsoil was affected by standing litter stock and fine root (r^2=0.76, F=13.96, P=0.002), and the standing litter stock contributed to 67.31% of the variation (Fig.3). Soil N:P at the topsoil was affected by P content of litter, Margalef's index and arbor biomass/aboveground biomass (r^2=0.98, F=120.50, P<0.001), and the arbor biomass/aboveground biomass and Margalef's index contributed to 48.26% and 38.42% of the variation, respectively (Fig.3). Soil C:P at the topsoil was affected by carbon content of litter and Margalef's index (r^2=0.81, F=19.27, P<0.001), and the Margalef's index contributed to 75.97% of the variation (Fig.3)

Discussion

The element contents and stoichiometric ratios of soil nutrients provide important information about soil quality and the composition of organic matter. The ecological stoichiometry of soil nutrients provides information about soil quality status, interactions between soil nutrients and plant-soil feedbacks. Soil C:N is a sensitive indicator of soil quality, C reserves, N reserves, and the C and N cycles in ecosystems (Güsewell, Jewell et al. 2005), and soil C:N ratio is negatively correlated to N mineralization rate. Soil C:P reflects the ability of soil P mineralization, and a low soil C:P favors microorganisms to decompose organic matter and desorb nutrients, thus provides higher soil available P content (Tian, H., et al. 2010). Soil N:P can measure the N saturation status and it is used to determine the thresholds for soil nutrient limitation (Güsewell, Jewell et al. 2005). In our study soil C:N at the depth of 0-30 cm ranges from 14.5 to 15.5 in the examined ecosystems, which is slightly higher than the global average C:N of 14.3 (Yue, K., et al. 2016). Soil C:P at the depth of 0-30 cm ranges from 184 to 299 in the examined ecosystems, which is higher than China's average of 136 (Tian, H., et al. 2010) and lower than the global average of 186 (Yue, K., et al. 2016). Soil N:P at the depth of 0-30 cm ranges from 12.9 to 19.4, which is higher than that of global and China's average (13.1 and 9.3, respectively) (Tian, H., et al. 2010; Yue, K., et al. 2016).

Species-dependent effects on Soil C:N:P stoichiometry

Consistent to our hypothesis, the soil C:N:P stoichiometry varied greatly with tree species examined (Fig. 1). In the topsoil (0-10 cm), C:N ratios in LAR and PT plantations are greater than CJ plantation and shrubland, implying higher N mineralization rate in shrubland. Three likely reasons account for this finding. Firstly, litter inputs differ across the examined plantations (Table 1). Secondly, the microclimate, the quantity and quality of root exudates and rhizodeposits, as well as soil microbial community, change with plant species (Zhang, C., et al. 2011; Ohta, T., T. Hiura, and N. Lupwayi. 2016; Aoki, M. and K. Fujii 2012), which jointly influence soil nutrient status and its stoichiometric ratio. Previous studies have shown that broadleaf litter is more decomposable than needle litter in boreal forests (Laganière, J., D. Paré, and R.L. Bradley. 2010). Besides, allocation of C to roots is directly proportional to photosynthesis (Sakai, T., et al. 2005), and understory shrubs generally have a lower photosynthetic capacity than overstory trees (Lieffers, V.J., et al.1999). Nevertheless, the C:N ratio of conifer stands is greater than broadleaf stands may be related to the canopy density and high light interception of conifers reduce the light efficiency on the forest floor (Sakai, T., et al. 2005; Lieffers, V.J., et al.1999).

Vertical change pattern of soil C:N:P stoichiometry

Consistent to our hypothesis, the C:N, C:P and N:P in soil varied greatly with soil depth (Table 1; Fig. 1). Overall, the C:N, C:P and N:P in soil decreased with the soil depth increase (Fig. 1). This finding is in agreement with previous studies addressing vertical pattern of soil C:N:P stoichiometry in forest soils (Tian, H., et al. 2010; Feng, D., et al. 2017; Tischer, A., K. Potthast, and U. Hamer. 2014; Li, H., et al.2013). These result show that soil nutrients decreased with soil depth, which could be due to the topsoil layer environmental factors being more sensitive and the return of nutrients from litters (Tian, H., et al. 2010). Therefore, soil nutrients are first concentrated on the topsoil and then transferred to the subsoil layer with water or other medium. Furthermore, soil C:N ratio decreased with the soil depth among different plantations, which could be because with the decomposition process occurs, easily decomposed materials elapsed and N is immobilized in decayed products and microbial biomass, leaving behind more durable materials with slower decomposition rates and lower C:N ratio (Yang, Y.H., et al. 2010) . The organic matter in subsoil layer is more humified and older than that on topsoil layer, thus in the continually decreasing soil C:N ratio with soil depth (Yang, Y.H., et al. 2010; Callesen, I., et al. 2007). Additionally, difference in soil nutrient associated with changes in soil microbial dynamics, litter decomposition, food web, and soil nutrient accumulation and circulation (Zhao, F., et al. 2015; Griffiths, B.S., A. Spilles, and M. Bonkowski. 2012) . Besides, the decrease in soil temperature with the increase of soil depth (Jackson, R.B., et al.2000) may account for the decreased soil C:N:P stoichiometric ratios in lower depth.

Potential factors regulating soil C:N:P stoichiometry

In partial agreement with our third hypothesis, we found that associations between soil C:N:P ecological stoichiometry and standing litter stock, tree aboveground biomass, as well as fine root biomass varied with soil depths. This is also in agreement with our earlier result (Feng, D.2017), the relative contribution of factors varied among soil depths and the examined soil ecological stoichiometry in soil. Firstly, the C:N, N:P and C:P across soil profiles negatively related to bulk density, while positively related to both soil moisture and fine root biomass (Fig. 2). Besides, the difference in C:N, N:P and C:P across examined plantations at the topsoil can be greatly explained by standing litter stock, arbor biomass/aboveground biomass and Margalef's index of plant community, respectively (Fig. 3). Additionally, the correlations between environmental factors and stoichiometric ratios depended on the elements considered. In summary, the effects of tree species and soil depth on soil C:N:P stoichiometry associated with bulk density, soil moisture, as well as the quantity and quality of aboveground litter inputs and underground fine root.

Conclusions

We observed strong tree-specific and depth-dependent effects on soil C:N:P stoichiometry in subalpine plantations. In general, topsoil C:N, C:P and N:P are higher than that of subsoil layer at 0-30 cm depth profiles. The observed variations of C:N, N:P and C:P ratio among soil profiles are closely related to differences in soil bulk density, soil moisture, as well as the quantity and quality of aboveground litter inputs and underground fine root across plantations examined. Whereas the difference in C:N, N:P and C:P at the topsoil across target tree species significantly linked to standing litter stock, arbor biomass/aboveground biomass and Margalef's index of plant community, respectively. These results highlight that differences in soil nutrients status after reforestation depend on litter quantity and quality of selected tree species as well as soil physical attributes.

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Figure 1

Figure 1 Soil C:N,N:P,C:P in the soil depth of different tree species and sampling time

Note: Capital letters indicate significant differences between different tree species was sampled time in 2018 and lower-case letters indicate significant differences between different tree species was sampled time in 2007(P<0.05).

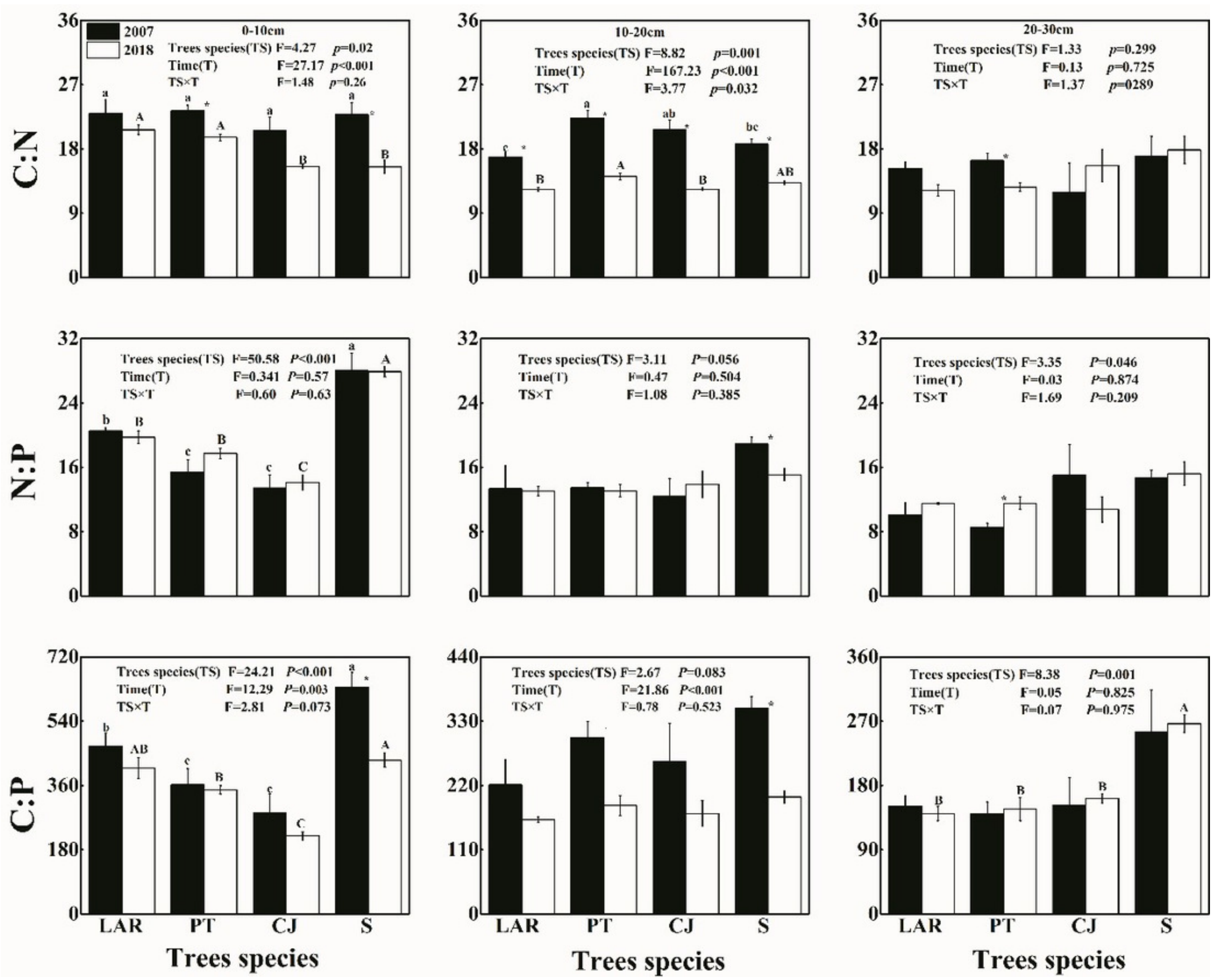

Figure 2

Figure 2 Relationships among soil(0-30cm) C, N, and P stoichiometric characteristics, bulk density fine root biomass and soil moisture

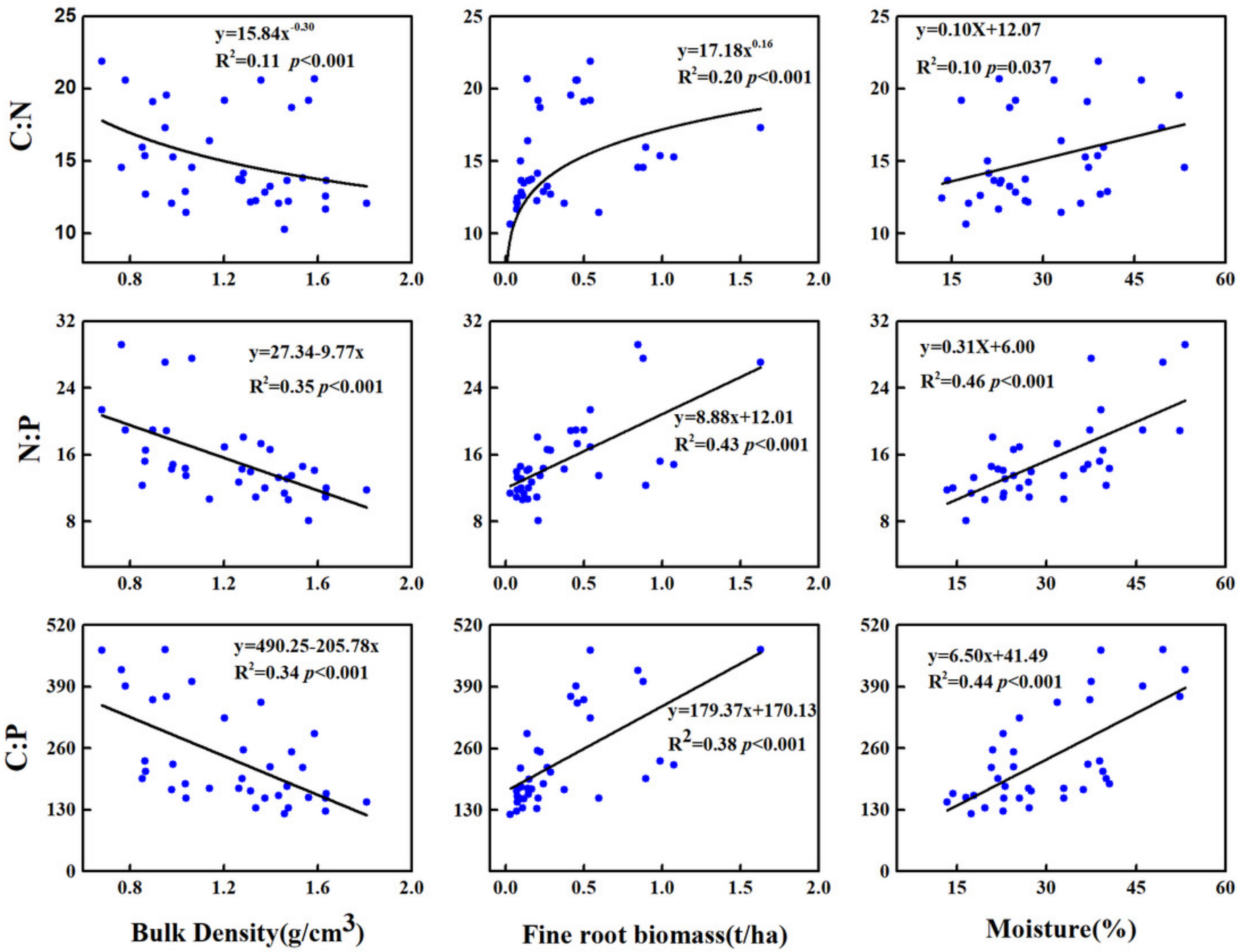

Figure 3

Figure 3 The multiple and stepwise equations relative importance among soil(0-10cm) C, N, and P stoichiometric

Note: FR-biomass_Fine root biomass; L - stock_litter stock; AI:A_arbor biomass/aboveground biomass; SR_ Margalef index; L-P_litter phosphorus; L-P_litter carbon *. *P*<0.05, **. *P*<0.001

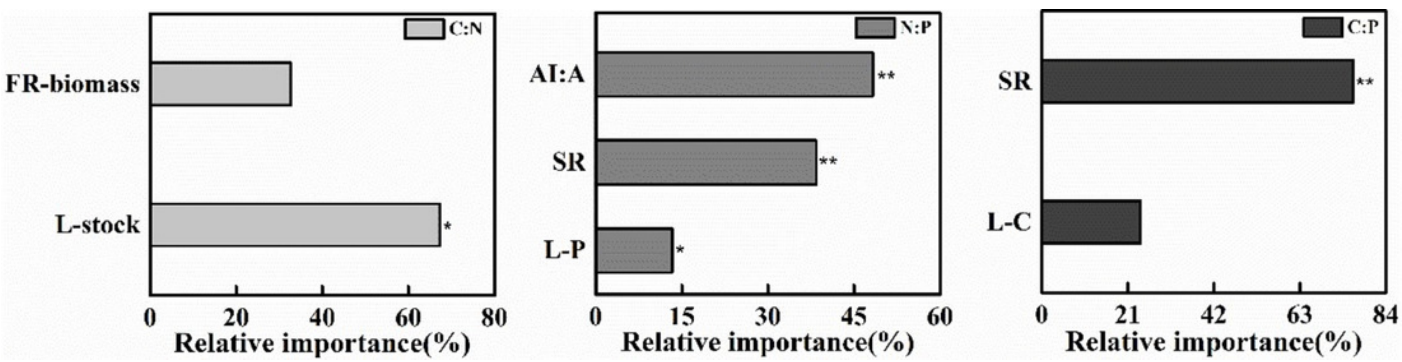

Table 1(on next page)

Table 1 The basic stand information of different plantations in this study area

Table 1 The basic stand information of different plantations in this study area

Note：LAR :*Larix kaempferi*; PT: *Pinus tabulaeformis*; CJ : *Cercidiphyllum japonicum*; S: shrubland. C-density : canopy density; Height : tree height; DBH: diameter at breast height; SD:stand density.

Plantation	Elevation (m)	Aspect	Slope (°)	Canopy	Height (m)	DBH (cm)	SD (trees· ha^{-1})
LAR	2070	NE	14	0.9	11.69	16.29	1200
	2070	NE	15	0.8	10.18	11.31	2200
	2081	N	21	0.98	11.62	13.66	1000
PT	2066	N	9	0.85	9.62	8.67	5100
	2065	N	6	0.89	11.68	10.89	4000
	2073	N	20	0.96	10.65	8.29	2700
CJ	2056	NW	10	0.9	11.84	12.15	2900
	2068	NW	19	0.93	11.47	11.97	3400
	2020	NW	18	0.89	13.17	11.6	3300
S	1933	N	17	0.94	5.95	3.87	15100
	1948	NW	22	0.9	3.9	2.81	15300
	1953	NW	18	0.86	5.91	3.47	12500

Table 2 Summary of the linear mixed model for the effects of soil layer, trees spices and sampling time on variables of soil C:N ,N:P,C:P

	Depth (D)			**Tree species (TS)**			**Time (T)**			**D * TS**			**TS * T**			**D * TS * T**		
	df	F	P	df	F	P	df	F	P	df	F	P	df	F	P	df	F	P
C:N	2	26.85	<0.001	3	2.04	0.12	1	41.88	<0.001	6	2.91	0.02	3	0.61	0.61	6	2.07	0.07
N:P	2	53.15	<0.001	3	27.02	<0.001	1	0.00	0.99	6	7.18	<0.001	3	1.01	0.40	6	1.35	0.25
C:P	2	104.03	<0.001	3	24.27	<0.001	1	23.47	<0.001	6	7.18	<0.001	3	1.90	0.14	6	1.19	0.33

Table 3 The different plantations component of biomass in this study area

Note：AL-biomass _Arborous layer biomass; U-biomass _Understory biomass; L-stock_ Litter stock; TA-biomass _Total aboveground biomass; AL:TA_ Arborous layer biomass : Total aboveground biomass; U:TA_ Understory biomass: Total aboveground biomass; Lower-case letters indicate significant differences between target trees (*P*<0.05).

Plantation	AL- biomass ($t\cdot ha^{-1}$)	U-biomass ($t\cdot ha^{-1}$)	L-stock ($t\cdot ha^{-1}$)	TA-biomass ($t\cdot ha^{-1}$)	AL:TA	U:TA
LAR	91.63±13.35bc	0.29±0.095b	8.35±0.41a	100.27±13.68bc	0.91±0.010c	0.003±0.0007b
PT	157.16±37.57ab	0.26±0.037b	7.72±0.44a	165.13±38.03ab	0.95±0.012b	0.002±0.0004b
CJ	210.65±8.20a	0.25±0.147b	3.94±0.17b	214.84±8.29a	0.98±0.001a	0.001±0.0006b
S	29.26±2.53a	10.69±1.308a	3.87±0.89b	43.81±3.41c	0.67±0.012d	0.245±0.0279a