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Original Research Paper

Diversity of Plants on the Alluvial Islands of Lijiang River Basin and the Physicochemical Properties of their Soil

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ABSTRACT

Alluvial islands are unique river landscapes. The vegetation composition of Alluvial islands and the physicochemical properties of its soil are good indicators for studying plants in its riparian zone. This study explores and determines the relationship between the biological diversity of vegetation and the physicochemical properties of soil in the alluvial islands of Lijiang River basin. A field investigation of different vegetation gradient belts in three alluvial islands and an analysis of their soil samples is conducted. Results show that the composition of vegetation species on the three experimental plots is as follows: 6 families, 8 genera and 8 species on experimental plot (I); 8 families, 12 genera and 12 species on experimental plot (II); and 17 families, 18 genera and 18 species on experimental plot (III). Values of four plant-diversity indices, namely, Margalef richness index, Shannon-Wiener diversity index, Pielou evenness index and Simpson species dominance index, are substantially influenced by the vegetation gradient zone. Change in the gradient zone from gravel to bushes and trees, leads to decreased sand-grain content and increased silt and clay contents, and gravel content of surface soils significantly declines with change in gradient zones. Six types of chemical indicators of soil (organic matter, total nitrogen, available nitrogen, available phosphorus, total potassium, and available potassium) show significant differences with change in gradient zone. Significant correlations were found between plant diversity and physicochemical properties of the soil.

INTRODUCTION

Economic growth and development have caused Lijiang River basin to be seriously disturbed and damaged, leading to the exhaustion of water resources and the degradation of the vegetation ecosystem, as well as other environmental issues. These problems negatively affect the environment and economy (Li et al. 2013). Therefore, the degraded ecosystem in the lake-land ecotone of Lijiang River is highly important to be restored and rebuilt. Further damage to the local ecological environment should also be prevented. The alluvial island is a unique landform in the river; it has a relatively independent location, low human disturbance, and conditions that facilitate self-renewal and succession for its terrestrial vegetation. The vegetation composition in different alluvial islands usually reflects the composition of riverside vegetation in the same developmental stage. Therefore, this relationship plays an important role in understanding the vegetation composition on the alluvial island, which helps to carry out the artificial restoration of the riverside vegetation ecosystem.

Both local and foreign scholars have conducted many studies on the relationship between vegetation and physicochemical properties of the soil. Yang et al. (2012) examined the relationship between soil physicochemical properties in an alpine meadow, species diversity and biomass, and discovered that available nitrogen in soil has a substantial impact on both species diversity in all communities and the above-ground biomass. Zhen et al. (2009) conducted a correlation analysis of plant diversity in a desert area and soil physicochemical properties and determined the regression equation between the two. For lake-land ecotone, some scholars studied the hydro-fluctuation belt of the riverside and found that change in water level significantly influences plant-species composition, vegetation coverage and plant community succession (Riis et al. 2003, Leyer et al. 2005). Some other scholars studied plant communities and soil characteristics (Fang et al. 2011, Zhang et al. 2004, Zhang et al. 2012, Brettar et al. 2002, Zhang et al. 2014). They found that pH and heavy-metal content of soil vary with changes in water level, and that different vegetation communities have different tolerances and sensitivities with varied hydrological situations. Recently, some researchers have focused on the ecological restoration of water-land ecotone in Lijiang River. They studied the correlations between plant-root systems in water-land ecotone in Lijiang River and soil properties, soil nutrients, soil enzymes, vegetation distribution and other soil characteristics (Li et al. 2014, Li et al. 2013, Ren et al. 2014, Yang et al. 2015). The alluvial island is a common and special form of water-land ecotone in the karst area of the Lijiang River basin, but studies on the alluvial island in water-land ecotone are few.

Taking the alluvial island in Lijiang River bsin as the research object, this paper systematically explores vegetation composition in different vegetation zones on alluvial islands with different sizes, biodiversity characteristics and soil physicochemical properties. The mutual relationships between soil and vegetation were also investigated. The aim is to reveal the dynamic-change rule of vegetation on the alluvial islands and soil physicochemical properties, as well as relationships between the two, to provide scientific references for ecological restoration, vegetation breeding and cultivation in the water-land ecotone in the Lijiang River basin.

STUDY AREA

Lijiang River is the upper reach of Gui River in Xijiang River of the Pearl River system, which is located in northeast Guangxi. Lijiang River originates from the Maoer mountains at the border between Xing'an County and Ziyuan County in Guangxi Province and the south of Laoshanjie with an altitude of up to 1732 m. Lijiang River flows through five cities or counties (Xing'an, Lingchuan, Guilin, Yangshuo, Pingle). It is divided into upper, middle, and lower reaches according to precipitation, topography, and runoff characteristics. The part between Guilin and Yangshuo is the midstream. The main stream is 214 km in total length, and the total area of the basin is 12 285 km^2, accounting for 43.9% of the total area of Guilin. In Lijiang River basin, adequate light exists throughout the year, with an average temperature of 17.8-19.1°C, annual rainfall of 1814-1941 mm, and annual evaporation of 1377-1857 mm. Rain and heat occur approximately in the same period. Lijiang River basin has a subtropical humid monsoon climate and is abundant in annual runoff. However, this runoff is unevenly distributed throughout the year; flood season is from March to August (runoff in this period accounts for nearly 80% of the total annual runoff, whereas runoff in May and June accounts for 40% of the total) and dry season is from September to the following February (in the worst case, runoff in this period accounts for only 2% of the total annual runoff). Zonal vegetation in Lijiang River basin is evergreen broad-leafed forest. Trees are mainly *Pterocarya stenoptera*, *Cinnamomum burmanni* and *Cinnamomum camphora*; shrubs are mainly *Flueggea suffruticosa*, *Adina rubella* and *Vitexnegundo Linn*; and herbaceous plants are *Cynodon dactylon*, *Polygonum hydropiper* and *Humulus scandens* (Lour.) Merr (Li et al.2013).

MATERIALS AND METHODS

Sample setting: Experimental plots were located in the middle reaches of Lijiang River (river section from Guilin to Yangshuo with a length of 83 km). This study aimed to investigate and sample the vegetation, soil, and topography of the island (hereafter referred to as the alluvial island), which was gradually formed from sediment deposition in the basin. In the entire Lijiang River basin, three alluvial islands were selected as research points, each of which was established as a typical sample plot. The gravel belt, herbaceous plant belt, shrub-herbage belt and arbor-shrub-grass compound land are determined according to the compositional structure of vegetation on the sample plots and their distance from the riverbank. If a belt on the alluvial island was absent, it was recorded as zero. In the study area, three small sample plots were set at random on each sample band to investigate the plant diversity and sampling of soil physicochemical properties. The sample plot of the gravel band had an area of 10m × 10m; the sample plot of the herbaceous plant belt had an area of 1m × 1m; the sample plot of the shrub-herbage belt had an area of 5m × 5m; and the sample plot of the arbor-shrub-grass compound had an area of 10m × 10m. In the sample plot of shrub-herbage belt, three herbaceous samples of 1m × 1m were taken at random below the shrubwood; in the sample plot of the arbor-shrub-grass compound, three herbaceous samples of 1m × 1m were taken at random below the arboreal forest. Specific information is shown in Fig. 1 and Table 1.

Investigation and calculation of biodiversity: In September 2013, the investigation of the biodiversity of the selected sample plots was conducted and targeted at trees, shrubs and grasses in the sample plots. Indicators of trees in the study, mainly included species, number, height, crown width, diameters, height under branch and canopy density. Indicators of shrubs were mainly species, number, height, crown width, base diameter, coverage and biomass. Indicators of herbaceous plants were mainly the species, height, number, coverage and biomass. The biomass of shrubs in the sample plots was measured using the method of mean sample trees; for herbaceous biomass, herbaceous plants in the sample plot were all collected for measurement.

In the study of the biodiversity of plant communities on the alluvial islands, four commonly used models of species-diversity calculation were used: Margalef species richness (R), Shannon-Wiener diversity index (H), Simpson species dominance index (D) and the Pielou evenness index (E). The calculation formulae are as follows (Zhao 2011):

Margalef richness index (R):

$$R = \frac{S-1}{\ln N} \quad ...(1)$$

Shannon-Wiener diversity index (H):

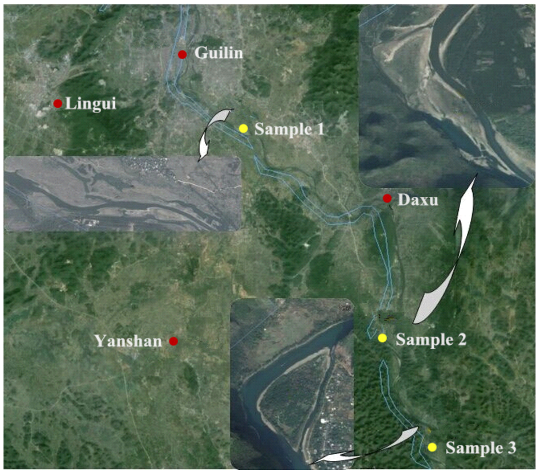

Fig. 1: Location of experiment sites in this study.

$$H = -\sum_{i=1}^{s}\left(\frac{N_i}{N}\right)\ln\left(\frac{N_i}{N}\right) \quad ...(2)$$

Simpson species dominance index (D):

$$D = 1 - \sum_{i=1}^{S} P_i^2 \quad ...(3)$$

Pielou evenness index (E): an auxiliary indicator in the community-species-diversity indices

$$E = \frac{H}{\ln S} \quad ...(4)$$

Where, S is the number of species in each community, N_i is an important value of the species at some level of the community, N is the sum of important values of all species at this level, and P_i is the proportion of the number of the species in the total number of individuals in the community.

Collection of soil samples and measurement of soil physicochemical properties: In September 2013, three alluvial islands in the experimental plot (river section from Guilin to Yangshuo) were selected as the research object. In each experimental plot, samples of soil with an interval of at least 5 m and with a depth of 0-20 cm from the surface (drilled with a soil auger) were selected according to different belts and then mixed to form a sample to be tested. This sample was taken back to the laboratory for natural drying. Given that the soil layer on the alluvial island in the Lijiang River basin was thin, soil with a thickness of 0-20 cm was taken as the study object.

After the soil samples were air dried, they were sieved through a 2 mm mesh. Some soil samples were used to measure the mechanical composition of soil. Other soil samples, which were used to measure soil nutrients, had to be ground so that they could be passed through a 0.25 mm sieve. Mechanical components of soil were divided according to the standards of the United States Department of Agriculture and were measured by a combination of sieving and hydrometer use. The other physicochemical analysis of the soil was made by the methods given by Lu (1999).

Data processing: Excel 2007 and SPSS20.0 software were used for statistical analyses, such as one-way ANOVA, correlation analysis (Pearson), and principal component analysis (PCA) (Du 2009). For all analyses, the testing standard of statistical significance was $P < 0.05$.

RESULTS AND ANALYSIS

Species composition and plant diversity: Vegetation species on the experimental plots are as follows: experimental plot (I) has 6 families, 8 genera and 8 species; experimental plot (II) has 8 families, 12 genera and 12 species; and experimental plot (III) has 17 families, 18 genera and 18 species (Table 2). Most plants were found to have one family, one genus, one species, and one life form. ****However, the extremely individual species such as Amaranthaceae, Compositae and Gramineae have many families, many genera, and many life forms****. Given that the alluvial islands in the Lijiang River are located in the karst region, soil here is thin with a high gravel content. Periodic flood erosion and sediment deposition also result in difficult plant growth and attachment. Typically, annual herbaceous plants are dominant, and the harsh environmental conditions restrict plant growth and development to some extent. This analysis is consistent with other relevant results of local and global studies (Sun et al. 2011, Wang et al. 2010, Wang et al. 2012).

The different experimental plots display differences in species composition. On experimental plot (I), annual herbaceous plants are dominant, and the dominant or constructive species are *Cynodon dactylon* (Linn.) Pers., *Cryptocor-yne sinensis* Merr., *Alternanthera philoxeroides* (Mart.) Griseb., *Celosia argentea* Linn, *Polygonum aviculare* Linn, and *Hydrocotyle sibthorpioides* Lam. On experimental plot (II), biennial or perennial herbaceous plants are dominant, and shrubs such as *Adina pilulifera* (Lam.) French ex Drake as dominant species appear. The dominant species or constructive species are as follows: *Lespedeza cuneata* (Dum.-Cours.) G. Don, *Polygonum hydropiper* Linn., *Eremochloa ophiuroides* (Munro) Hack, and *Adina pilulifera* (Lam.) French ex Drake. On experimental plot (III), biennial or perennial herbaceous plants and arbor species such as *Sapium sebiferum* (Linn.) Roxb., *Rosa multiflora* var. carnea, and *Celtis biondii* Pers. are dominant. Specifically, the dominant species or

Table 1: Basic situation of experimental sites in this study.

Experimental plot	Longitude	Latitude	Altitude (m)	Grade (°)	Elevation differences (m)	Number of samples Gravel zone	Herb zone	Shrub-herbage	Trees-brushes -grasses
(I)	E110°19'29.02'	N25°13'35.05'	142	3	2.3	3	3	-	-
(II)	E110°25'35.5'	N25°07'05.65'	134	8	3.3	3	3	3	-
(III)	E110°25'58.95'	N25°03'46.68'	128	3	2.7	3	3	-	3

Table 3: Vegetation community biodiversity on different experimental plots.

Stage of succession		Margalef Richness index (*R*)	Shannon-Wiener index (*H*)	Simpson Dominance index (*D*)	Pielou Evenness index (*E*)	F test
Experimental plot (I)	Gravel zone	5.90±0.59a	1.17±0.23ab	0.59±0.09a	0.93±0.29a	**
	Herb zone	9.05±0.37b	1.40±0.31ab	0.67±0.12b	0.87±0.16ab	
Experimental plot (II)	Gravel zone	3.48±0.46a	0.66±0.24a	0.40±0.06a	0.95±0.18a	
	Herb zone	11.75±0.28c	1.77±0.36b	0.61±0.07ab	0.85±0.23b	
	Shrub–herbage	7.76±0.64ab	1.78±0.34b	0.64±0.10ab	0.91±0.15a	
Experimental plot (III)	Gravel zone	3.48±0.53a	0.66±0.27a	0.46±0.16a	0.95±0.19a	
	Herb zone	5.35±0.48a	1.50±0.25b	0.57±0.14ab	0.93±0.24a	
	Trees-brushes-grasses	10.20±0.62bc	2.44±0.31c	0.71±0.11b	0.90±0.27a	

Note: No significant difference with same letter; significant difference without same letter; P<0.05, the same below.

Table 4: Mechanical composition of soil on different experimental plots.

Experimental plots		Sand particle content	Silt content	Clay particle content	Gravel concentration (%)	F
Experimental plot (I)	Gravel zone	0.89±0.01 a	0.06±0.03a	0.06±0.00a	83.44±2.03a	**
	Herb zone	0.82±0.01a	0.10±0.01a	0.08±0.01a	69.67±3.47ab	
Experimental plot (II)	Gravel zone	0.87±0.01a	0.06±0.00a	0.08±0.00a	88.54±5.46a	
	Herb zone	0.82±0.01a	0.10±0.02a	0.09±0.01a	46.76±1.85b	
	Shrub-herbage	0.78±0.02 a	0.13±0.03a	0.10±0.03a	8.25±5.23c	
Experimental plot (III)	Gravel zone	0.88±0.00a	0.07±0.01a	0.06±0.01a	90.46±4.34a	
	Herb zone	0.82±0.02a	0.10±0.03a	0.08±0.01a	67.43±2.89ab	
	Trees-brushes-grasses	0.77±0.05a	0.13±0.04a	0.11±0.02a	7.93±3.87c	

constructive species are as follows: *Carex caespitosa* Linn., *Oxalis corymbosa* DC., *Polygonum hydropiper* Linn., *Cynodon dactylon* (Linn.) Pers., *Sapium sebiferum* (Linn.) Roxb., *Rosa multiflora* Thunb. var. carnea Thory, *Celtis sinensis* Pers., and *Vitex negundo* Linn. (Table 2).

Results show that on different experimental plots of the alluvial islands studied, differences exist in biological diversity. First, on the same experimental plot, with the gradient zone extending from the gravel zone to the zones of trees, shrubs and herbages, Margalef richness index and Shannon-Wiener diversity index significantly increase, whereas Simpson species dominance index does not significantly change. Second, for different gradient zones on experimental plots (I) and (II), Simpson species dominance indices are significantly different; for different gradient zones on experimental plot (II), Simpson species dominance indices are not significantly different. Third, for the same gradient zones on the alluvial islands on different experimental plots, Margalef richness indices, Shannon-Wiener diversity indices and Simpson species dominance indices show significant changes. Fourth and last, for different gradient zones on different experimental plots, Pielou evenness indices show no significant differences. The above results differ in some respects from the results of Li et al. (2013) and Wang et al. (2007), which may be related to the special environments of the alluvial islands.

Physical properties of the soil on different experimental plots: The mechanical components of topsoil on the alluvial islands of the Lijiang River basin are mainly sand grains, accounting for more than 80% of the total components; silt and clay contents are lower, accounting for approximately 10% (Table 4). For different gradient zones on the same experimental plot, contents of sand, silt and clay are not significantly different, but with the transition of the gradient zone from the gravel belt to the zone of trees, shrubs and grasses, gravel content decreases, and silt and clay contents increase. On experimental plot (III), soil and sand contents of the zone of trees, shrubs and grasses decrease by 12.5%, compared with the gravel zone; however, silt and clay contents increase by 46.15% and 45.45%, respectively. For the same gradient zone on different experimental plots, no significant difference exists in the content of mechanical components of soil. Studies have shown that gravel contents of topsoil on different experimental plots significantly decrease with change in gradient zone. On experimental plot (I), gravel content of grass zone decrease by 16.50% compared with that in the gravel zone. On experimental plot (II), gravel content of shrub zone decrease by 90.68% compared with that in the gravel zone. On experimental plot (III), gravel contents of the zone of trees, shrubs and grasses decrease by 91.23%, compared with that in gravel zone. With increased gradient zone, the physical conditions of soil become more suitable for vegetation growth. Considering that the mechanical composition of soil is greatly influenced by water erosion, a large number of fine-grained materials such as silt and clay are washed away by the river water. A lower relative elevation belt corresponds with greater impact. As a result, silt and clay contents decrease, and gravel content increases. With increased relative elevation, species diversity and other indicators increase, plant community structure becomes more complex, the mechanical composition of soil improves, and silt and clay contents increase. This result is similar to other relevant research findings (Yang et al. 2009, Liu et al. 2005, Wang et al. 2004, Ye et al. 2010).

Chemical properties of soil on different experimental plots: Studies have shown that different vegetation gradient zones in the alluvial islands of the Lijiang River basin have a large impact on six types of soil indicators: OM, TN, AN, AP, TK and RAK (Table 5).

On experimental plot (I), contents of OM, AN and RAK in herbaceous plants are significantly higher than those in gravel zone ($P<0.05$). On experimental plot (II), contents of OM and TN in herbaceous plant, shrub and tree zones are significantly higher than those in gravel zone ($P<0.05$). AN increases from gravel zone to shrub and grass zones. On experimental plot (III), contents of OM, TN and AN in shrub and grass zones are significantly higher than those in herbaceous plant and gravel zones ($P<0.05$). Contents of AP, TK and RAK decrease from gravel zone to shrub and grass zones.

In the gravel zones of different experimental plots, various indicators of soil chemical properties show no significant difference. In shrub, grass and tree zones, contents of all indicators except pH are relatively higher than that of other gradient zones, but the difference if insignificant. With gradually increased gradient zone and increased biodiversity, various chemical indicators of soil have effectively improved and soil fertility has significantly improved and become more suitable for vegetation growth and development.

Correlation between plant diversity and soil physicochemical properties: After the Pearson correlation analysis of plant-diversity indicators and the physicochemical property indicators of soil on different experimental plots, the following research results are obtained. First, Margalef richness indicator (R) is extremely significantly negatively correlated with contents of sand, gravel and TK ($P<0.01$) but significantly positively correlated with contents of TN, AN, underground biomass, clay and OM contents ($P<0.05$). Second, Shannon-Wiener diversity index (H) is extremely significantly negatively correlated with contents of sand, gravel, AP and TK ($P<0.01$) but extremely significantly positively correlated with contents of silt and clay ($P<0.01$), as well as AN and above-ground biomass ($P<0.05$). Third, the Simpson species dominance index (D) is extremely significantly positively correlated with contents of gravel, TP, and RAK ($P<0.01$), as well as with sand content ($P<0.05$), but is significantly negatively correlated with silt content ($P<0.05$). Fourth, Pielou evenness index (E) is significantly positively correlated only with total-potassium content ($P<0.05$). Thus, changes in soil physicochemical properties on the alluvial islands easily affect the plant-diversity characteristics. Pearson correlation analysis shows that on the alluvial islands of Lijiang River, the plant diversity and the physicochemical properties of soil are closely related. Changes in soil physicochemical properties on the alluvial islands significantly affect the vegetation growth and development and vice versa.

Analysis of main components based on plant diversity and soil physicochemical properties: After an analysis of the main components of different experimental plots based on four plant-diversity indicators and 14 soil physicochemical property indicators, results show that the contribution rates of main components 1, 2, 3 and 4 are 38.87%, 21.79%, 10.88% and 8.72%, respectively. The cumulative contribution rate reaches 80.26%, reflecting the vast majority of information on the alluvial islands. Thus, these four main components can be used as bases to analyze main components in the evaluation of the growth characteristics of vegetation on the islands. In the main component 1, contents of sand, silt, clay and gravel, as well as the weight coefficients of the Shannon-Wiener diversity index and the Margalef rich-

Table 2: Species in the vegetation community of the different experimental plots.

Family	Genus	Species	Important value: Experimental plot (I) Gravel zone	Experimental plot (I) Herb zone	Experimental plot (II) Gravel zone	Experimental plot (II) Herb zone	Experimental plot (II) Shrub -herbage	Experimental plot (III) Gravel zone	Experimental plot (III) Herb zone -grasses	Experimental plot (III) Trees -brushes
Cyperaceae	*Carex*	*Carex polycephala* var. simplex	-	0.06	0.49	0.04	-	0.84	0.41	0.36
Umbelliferae	*Hydrocotyle*	*Hydrocotyle sibthorpioides*	0.12	-	-	0.04	-	-	-	-
Oxalidaceae	*Oxalis*	*Oxalis corymbosa*	-	-	-	-	-	-	-	0.28
Malvaceae	*Sida*	*Sida rhombifolia* L.	-	-	-	-	-	-	-	0.06
Amaranthaceae	*Celosia*	*Celosia argentea* L.	0.35	0.48	-	0.4	0.47	-	0.12	-
	Alternanthera	*Alternanthera philoxeroides* (Mart.) Griseb.	0.36	-	-	0.12		-	-	-
Leguminosae	*Lespedeza*	*Lespedeza cuneata* (Dum.Cour.) G.Don	-	-	-	-	0.30	-	-	-
Polygonaceae	*Polygonum*	*Polygonum hydropiper*	-	0.29	-	0.16	0.20	-	0.4	-
		Polygonum aviculare	0.27	0.16	-	0.19	-	-	-	-
Compositae	*Xanthium*	*Xanthium sibiricum*	-	-	-	-	-	-	-	0.12
	Artemisia	*Artemisia argyi*	-	-	-	-	0.09	-	-	-
Gramineae	*Cynodon*	*Cynodon dactylon*	0.7	0.57	-	0.63	0.60	-	0.71	0.25
	Eremochloa	*Eremochloa ophiuroides*	-	-	-	-	0.12	-		0.36
Rubiaceae	*Adina*	*Adina rubella*	-	-	-	-	0.39	-	0.47	-
Plantaginaceae	*Plantago*	*Plantago asiatica*	-	-	-	-	-	-	-	0.06
Violaceae	*Viola L.*	*Viola inconspicua*	-	-	-	-	-	-	-	0.06
Labiatae	*Salvia*	*Lysimachia fortunei*	-	-	-	-	-	-	-	0.28
Verbenaceae	*Vitex*	*Vitex negundo* Linn	-	-	-	-	-	-	-	0.32
Commelinaceae	*Murdannia*	*Murdanni atriquetra*	-	-	-	-	-	-	-	0.06
Apocynaceae	*Nerium*	*Nerium indicum* Mill	-	-	-	-	-	-	-	0.06
Araceae	*Cryptocoryne*	*Cryptocoryne sinensis*	0.52	-	0.85	0.22	-	0.5	-	-
Euphorbiaceae	*Sapium*	*Sapium sebiferum*	-	-	-	-	-	-	-	0.54
Rosaceae	*Rosa*	*Rosa multiflora* var. carnea	-	-	-	-	-	-	-	0.48
Ulmaceae	*Celtis*	*Celtis biondii*	-	-	-	-	-	-	-	0.65

Table 5: Comparison of soil chemical properties on different experimental plots.

Stage of succession		pH	Organic matter (g/kg)	Total nitrogen (g/kg)	Alkaline-N (mg/kg)	Total phosphorus (g/kg)	Available phosphate (mg/kg)	Total potassium (g/kg)	Rapidly available potassium (mg/kg)	F
Experimental plot (I)	Gravel zone	6.87±0.24a	12.79±1.33a	1.04±0.16a	69.09±13.26a	0.54±0.07a	28.55±0.84bc	24.21±2.31a	61.50±6.17b	**
	Herb zone	6.93±0.11a	19.54±1.79b	1.08±0.23a	92.89±21.03b	0.64±0.02a	35.71±0.56c	23.51±4.26a	110.17±9.73a	
Experimental plot (II)	Gravel zone	7.86±0.15a	12.66±1.56a	1.06±0.14a	47.58±17.34a	0.48±0.01a	31.90±0.14bc	22.63±3.79ab	63.75±4.19b	
	Herb zone	7.28±0.62a	23.45±1.98b	1.37±0.13b	58.07±23.24a	0.49±0.04a	27.45±0.15bc	20.11±2.41b	67.75±7.34b	
	Shrub-herbage	7.14±0.53a	22.03±1.79b	1.46±0.10b	76.49±43.07ab	0.56±0.03a	28.40±0.23bc	21.78±1.76ab	68.50±6.18b	
Experimental plot (III)	Gravel zone	7.14±0.18a	9.03±1.38a	1.01±0.21a	51.49±18.16a	0.56±0.03a	28.40±0.26bc	21.78±2.13ab	68.50±6.37b	
	Herb zone	6.85±0.16a	13.39±1.26a	1.28±0.25a	69.68±13.29a	0.63±0.01a	25.25±0.42b	21.54±2.34ab	48.00±2.43c	
	Tree-brush-grass	7.12±0.34a	20.56±1.87b	1.57±0.19b	94.31±43.29b	0.79±0.05a	21.24±0.31a	19.76±4.17b	46.63±3.21c	

Table 6: Principal component analysis of diversity and soil physicochemical properties on different experimental plots.

	Margalef Richness index (*R*)	Shannon-Wiener index (*H*)	Simpson Dominance index (*D*)	Pielou Evenness index (*E*)
Sand grain	-0.557**	-0.834**	0.411*	0.196
Particles	0.613**	0.817**	-0.436*	-0.341
Clay particles	0.390*	0.618**	-0.335	-0.237
Gravel concentration (%)	-0.592**	-0.871**	0.527**	0.042
pH	-0.066	-0.180	0.255	0.120
Organic matter (g/kg)	0.436*	0.242	-0.062	0.056
Total nitrogen (g/kg)	0.574**	0.267	0.145	-0.116
Alkaline-N (mg/kg)	0.755**	0.458*	0.109	-0.132
Total phosphorus (g/kg)	-0.022	-0.332	0.501**	0.181
Available phosphate (mg/kg)	-0.257	-0.544**	0.545**	0.155
Total potassium (g/kg)	-0.524**	-0.641**	0.317	0.399*
Rapidly available potassium (mg/kg)	0.081	-0.275	0.545**	0.109
Above-ground biomass (g)	0.262	0.404*	-0.095	-0.035
Underground biomass (g)	0.660**	0.373	0.268	-0.277

Notes: ** indicates 0.01 level (double-sided) significant correlation, * indicates 0.05 level (double-sided) significant correlation.

Table 7: Principal component analysis based on plant diversity and soil physicochemical properties.

Factors	Components			
	1	2	3	4
Sand grain	-.892	-.004	.312	-.052
Particles	.900	.063	-.306	.097
Clay particles	.773	.107	-.291	.033
Gravel concentration	-.900	.088	.161	.054
pH	-.035	-.226	.543	.414
Organic matter	.337	.544	.320	-.540
Total nitrogen	.371	.553	.530	-.362
Alkaline-N	.604	.694	.278	-.099
Total phosphorus	-.296	.865	-.169	-.011
Available phosphate	-.556	.670	-.275	.135
Total potassium	-.746	.421	-.431	-.170
Rapidly available potassium	-.268	.863	-.266	.012
Above-ground biomass	.555	.249	-.498	.389
Underground biomass	.578	.401	.175	.541
Margalef Richness index (*R*)	.757	.348	.308	.010
Shannon-Wiener index (H)	.913	-.101	-.106	-.196
Simpson Dominance index (D)	-.446	.541	.335	.538
Pielou Evenness index (E)	-.305	.019	-.206	-.359
Eigenvalue	6.997	3.922	1.959	1.569
Percent (%)	38.871	21.790	10.884	8.717
Cumulative (%)	38.871	60.662	71.545	80.262

ness index, are relatively high. Thus, these indicators can reflect information on the change characteristics of vegetation on the alluvial island. In the main component 2, the weight coefficients of AN, TP, AP and RAK are relatively high, indicating that these indicators can reflect information on change characteristics of vegetation on the islands. In main component 3, the weight coefficients of pH, TN and above-ground biomass are relatively high, indicating that these indicators can reflect information on change characteristics of vegetation on the islands. In main component 4, the weight coefficients of OM, underground biomass and Simpson species dominance index are relatively high, indicating that these indicators can reflect information on change characteristics of vegetation on the islands.

CONCLUSIONS

Based on the study on the types of typical vegetation in different gradient zones on different alluvial islands of Lijiang River basin, physicochemical properties of the islands' soil, and the correlation between vegetation and soil properties, the following conclusions are drawn.

1. Vegetation composition on different experimental plots has the following rule: plant species become increasingly rich and varies from 6 families, 8 genera and 8 species on experimental plot (I) to 8 families, 12 genera, and 12 species on experimental plot (II) to 17 families, 18 genera, and to 18 species on experimental plot (III).
2. Different experimental plots follow the same rule: With increased relative elevation, the values for Margalef richness index, Shannon-Wiener diversity index, and Simpson species dominance index increase.
3. In different gradient zones on the same experimental plot, the contents of sand, silt and clay show no significant change; however, with a change in the gradient zone from gravel zone to tree, shrub and grass zones, sand content decreases, whereas silt and clay content increases. Gravel content of the topsoil significantly decreases with change in gradient zone. On experimental plot (I), contents of OM, AN and RAK in herbaceous plant zone are significantly larger than those in gravel zone; on experimental plot (II), contents of OM and TN in herbaceous

plant zone and shrub and grass zones are significantly higher than those in gravel zone, and AN increases from gravel zone to shrub and grass zones; on experimental plot (III), contents of OM, TN and AN are significantly higher than those in herbaceous plant and gravel zones, and contents of AP, TK and RAK decrease from gravel zone to tree, shrub and grass zones.

4. Margalef richness index (R) is extremely significantly negatively correlated with contents of sand, gravel and TK; extremely significantly positively correlated with contents of TN, AN and underground biomass; and significantly positively correlated with clay and OM contents. Shannon-Wiener diversity index (H) is extremely significantly negatively correlated with contents of sand, gravel, AP and TK; extremely significantly positively correlated with silt and clay contents; and it is significantly positively correlated with contents of AN and above-ground biomass. Simpson species dominance index (D) is extremely significantly positively correlated with contents of gravel, TP and RAK; significantly positively correlated with sand content; and significantly negatively correlated with silt content. The Pielou evenness index (E) is only significantly positively correlated with total-potassium content. Analysis of the main components shows that contents of sand, silt, clay and gravel, AN, TP, AP and RAK, as well as indices of Shannon-Wiener diversity and Margalef richness, are the main indicators that can reflect information on change in the characteristics of the vegetation on the alluvial islands.

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