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A UNIQUE MOUNTAINOUS VERTICAL DISTRIBUTION PATTERNS AND RELATED ENVIRONMENTAL INTERPRETATION – A CASE STUDY ON THE NORTHERN SLOPE OF THE ILI RIVER VALLEY

ZHONG-PING TIAN[1,2], XIU-LING WANG[1], XIAO-YI ZHAO[1], LI ZHUANG[1*]

[1]*College of Life Sciences, Shihezi University, Shihezi 832003, P.R. China*
[2]*Key Laboratory of Species Diversity Application and Control in Xinjiang, College of Life Sciences, Xinjiang Normal University, Urumqi 830054, P.R. China*
**Corresponding author's email: zhuanglisunny@163.com; Tel: +86-13579767753*

Abstract

Patterns of plant diversity and soil factors along the altitude gradient on the northern slope of Ili River Valley were examined. Plant and environment characteristics were surveyed from 1000~2200 m. There were a total of 155 vascular plant, 133 herbage, 18 shrub, and 7 tree species in 44 sampled plots. The plant richness of vegetation types generally showed a special pattern along altitude, with a bimodal change of plant species number at 100m intervals of altitude samples. The two belts of higher plant richness were in transient areas between vegetation types, the first in areas from low-mountain desert to forest, and the other from dry grass to coniferous forest. Matching the change of richness of plant species to environmental factors along altitude by GAM model and relation analysis revealed that the environmental factors controlling species richness and their patterns were the combined effects of soil salt and nutrition. Water was more important at lower altitude, and temperature at higher altitude, the role of the inversion layer at high altitude coniferous forest species diversity appearing to rise. Soil nutrition and salt also showed a similar distribution pattern of diversity. Especially, diversity index and soil salinity showed a strong correlation. This study provides insights into plant diversity conservation of Ili River Valley in Tianshan Mountain.

Key words: Vertical distribution patterns, Species diversity, Environmental factors, Ili River valley.

Introduction

Studies on the relationship between vegetation and the environment have become an important field in vegetation ecology in recent years. As environmental factors influence the diversity of terrestrial plants and vegetation distribution (Zhang, 1993; Zhou & Wang, 1999; Hussain & Perveen, 2007; 2015), variations in species diversity along environmental gradients are important in biodiversity research. Consequently, investigating environmental factors such as elevation is essential for understanding gradient patterns of species diversity (Gaston, 2000; Lomolino, 2001; Whittaker *et al.*, 2001; Tang & Fang, 2004; Oommen & Shanker, 2005).

Significant local and global research has been conducted on distribution patterns of quadrat-based species diversity along elevation gradients (Carpenter, 2005, Sánchez-González & Lópe-Mata, 2005, Shen *et al.*, 2001, Fen *et al.*, 2006, Zhu *et al.*, 2008). These studies have determined that, in general, five species diversity distribution patterns exist along elevation gradients. Specifically, as elevation rises, diversity decreases before increasing, increases before decreasing (a unimodal curve), monotonously increases, monotonously decreases, or shows no obvious pattern at all (He & Chen, 1997a; Liu *et al.*, 2005a). The elevation-based distribution patterns of species diversity vary in different mountainous areas and with different life forms, and can be influenced by other factors such as local environmental conditions, relative mountain height, and prevailing geology and topography. Studies on elevation-based patterns of species diversity in different mountainous areas under different climatic conditions are necessary as they clarify local impacts and assist in establishing local protection measures for rare and vulnerable plants and eco-systems.

Currently, most studies on biodiversity in mountainous areas of China focus on subtropical evergreen broadleaved forest and warm temperate deciduous broadleaved forest (Ma *et al.*, 1995; Hao *et al.*, 2002; Fang *et al.*, 2004) rather than arid areas (Wang, 2002; Zhu *et al.*, 2008). The northern slope of the Ili is River Valley, located in the arid and semi-arid area of China with peaks high in the clouds and significant elevation gradients. Located in the western region of Xinjiang province, the Ili River Valley is situated inland at mid-latitude. It is surrounded by high mountains on the north, east, and south, and is open to the west in a U shape. As a result, warm humid air currents from the Atlantic Ocean, the Caspian Sea, and Lake Balkash rise along the valley, bringing with it a relatively humid continental and north temperate climate. With abundant precipitation and favorable natural conditions, the valley is known locally as "Jiangnan (vibrant place with a South China climate) beyond the Great Wall" (Zhang & Wang, 2009) except in winter. The special cold-lake effect plays a role at the bottom of the valley that is enclosed and semi-enclosed. In winters, cold currents from the mountains descend and build up at the bottom of the valley, making it the coldest place. Between elevations of 800~2000 m, a unique "inversion layer" zone exists (Liu *et al.*, 1993). What remains unclear, however, is whether vertical pattern on the northern slope of the Ili River Valley is similar to other arid mountain areas or to warm temperate deciduous broadleaved forests, or, alternate, whether it has its own distinctive distribution pattern. Several authors (Ma *et al.*, 1995; Hao *et al.*, 2002; Wang, 2002; Zhu *et al.*, 2008) have shown distinct plant species vertical distribution patterns, but little is understood in relation to the decisive factors behind the different patterns. Zhang *et al.* (2004) hypothesized that natural plant communities are formed as a consequence of the interactions between plants and the environment, and the spatial distribution patterns of plants are the result of the interactions and mutual development of plants and the environment. Many environmental factors influence community distribution, interactions of which are very complicated. Soil, for example, is not only a key environmental factor in plant survival but also an important component in forest eco-system studies. But while forest soil provides the necessary physical foundations for the existence and evolution of vegetation, soil formation and development are influenced by the occurrence and succession of forest vegetation (Song *et al.*, 2005). In terms of vegetative regeneration, recovery, and restoration, therefore, it is necessary to understand the chemical nature of soil at different elevations, the chemical nature of different soil types, and the relationship between vegetation and soil (You & Jiang, 2005).

To date, very few studies have been conducted on plant community types and their spatial distribution in the Ili River Valley. Detailed analysis on vegetation vertical spectrums was conducted in the Wild Fruit Forest in Xinjiang many years ago (Zhang, 1973), and preliminary studies on vertical distribution patterns of vegetation in the Ili River Valley have become available recently. Nevertheless, no reports on the vertical distribution of soil nutrients and soil salinity have yet been presented (Xu *et al.*, 2011; Tian *et al.*, 2013). Thus, we want to analyze distribution patterns of species diversity, soil nutrients, and salinity of the general plant community along elevation gradients and studied the relationship between vegetation and the local environment based on data collected from plant community quadrats and soil tests on the northern slope of the Ili River Valley from 2007. We hope this study not only provides an essential scientific basis for the protection and utilization of local vegetation and plant resources, but also further develops fundamental scientific theories relating to relationships between vegetation and valley environments within mountainous areas. In addition, our research serves as a case study and provides information for restoration of degraded vegetation and protection of endangered plant communities within mountainous areas.

Materials and Methods

Overview of the study area: Located in the West Tianshan Mountains in northern Xinjiang province, the north slope of the Ili River valley (i.e. the south slope of Keguqin Mountain) borders the Biezhentao Mountain to the west, the Borohoro to the east, the Junggar Basin to the north, and the Ili River Valley to the south. The Keguqin Mountain ranges from north-west-west to south-east-east and is more than 90 km long and 40 km wide. Located at 44°02′~44°30′N and 81°01′~82°02′E, the mountain covers an area of 3600 sqm. The average annual temperature is 2.8~9.2°C. The ≥10°C accumulative temperature is 1326 to 3300°C. Average yearly sunshine duration is 2898.4 hours and the frost-free period is 80-160 days. The ridge of the mountain has an elevation of about 4000 m and the peak is covered with snow all year round.

Study methods

1. Sample plot set-up and data acquisition

After an initial field investigation, representative plant communities on the northern slope of the Ili River Valley were selected for sample plot investigation and sampling. The study area included the ridge top to the desert steppe zone at the foot of the mountain, with the Wild Fruit Forest in between. With a total plot area of 100 × 100 m, three sample plots were established at every 100 m descending elevation. Consequently, a total of forty-four plots were established between 2200~1100 m on the northern slope of the Ili River Valley (Fig. 1). Because of the significant variation in species composition between the plant communities, three additional plots at 1900 m, five additional plots at 1,700 m, and one additional plot at 1600, 1400, and 1100 m were also established. One tree quadrat (20 × 20 m), one shrub quadrat (10 × 10 m), and three herb quadrats (1 × 1 m) were randomly sampled within each plot.

Within each quadrat, abundance, height, crown size, and coverage of trees and shrubs and the height and coverage of herbs were recorded. Eleven abiotic inorganic environmental factors were recorded and measured, including (1) topographical factors such as elevation (ELEV), (2) geological factors such as longitude (LONG) and latitude (LAT), and (3) edaphic factors such as organic matter (OM), available nitrogen (AN), available phosphorus (AP), available potassium (AK), pH value, electric conductivity (EC), gross salt (GS), and total salt (TS).

Three soil samples were collected randomly from each sample plot at depths of 0~10, 10~20, and 20~50 cm and returned to the lab for assay after being mixed evenly and air dried. Soil chemical parameters were determined using the following methods: potassium dichromate volumetric method-external heating for organic matter; perchloric acid-sulfuric acid digestion for total nitrogen; sodium bicarbonate leaching-Mo-Sb colorimetry for available phosphorus; ammonium acetate leaching-flame photometry for available potassium; electrometric titration for pH value; DDS-307 conductivity meter for electric conductivity; residue oven drying for gross salt and; standard curve conversion for total salt (Anon., 1983). Plant species were identified from the Flora of China, the Picture Flora of Senior Plants of China, and the Flora of Xinjiang.

2. Data processing and analysis

(1). Importance value calculation of species: Density (D), frequency (F), coverage (C) were measured and used to determine the relative abundance (RD), relative frequency (RF), and relative coverage (RC):

$$\text{Relative abundance} = \frac{\text{Abundance of a species}}{\text{Abundance of all species}} \times 100\%$$

$$\text{Relative height} = \frac{\text{Height of a species}}{\text{Height of all species}} \times 100\%$$

$$\text{Relative coverage} = \frac{\text{Coverage of a species}}{\text{Coverage of all species}} \times 100\%$$

Relative abundance, height, and coverage were then used to calculate the importance values (Ma *et al*., 1995, Huang *et al*., 1994) of the tree, shrub, and herb species:

$$\text{Importance value of trees and shrubs (\%)} = \frac{\text{Relative abundance + Relative height + Relative coverage}}{3}$$

$$\text{Importance value of herbs (\%)} = \frac{\text{Relative height + Relative coverage}}{2}$$

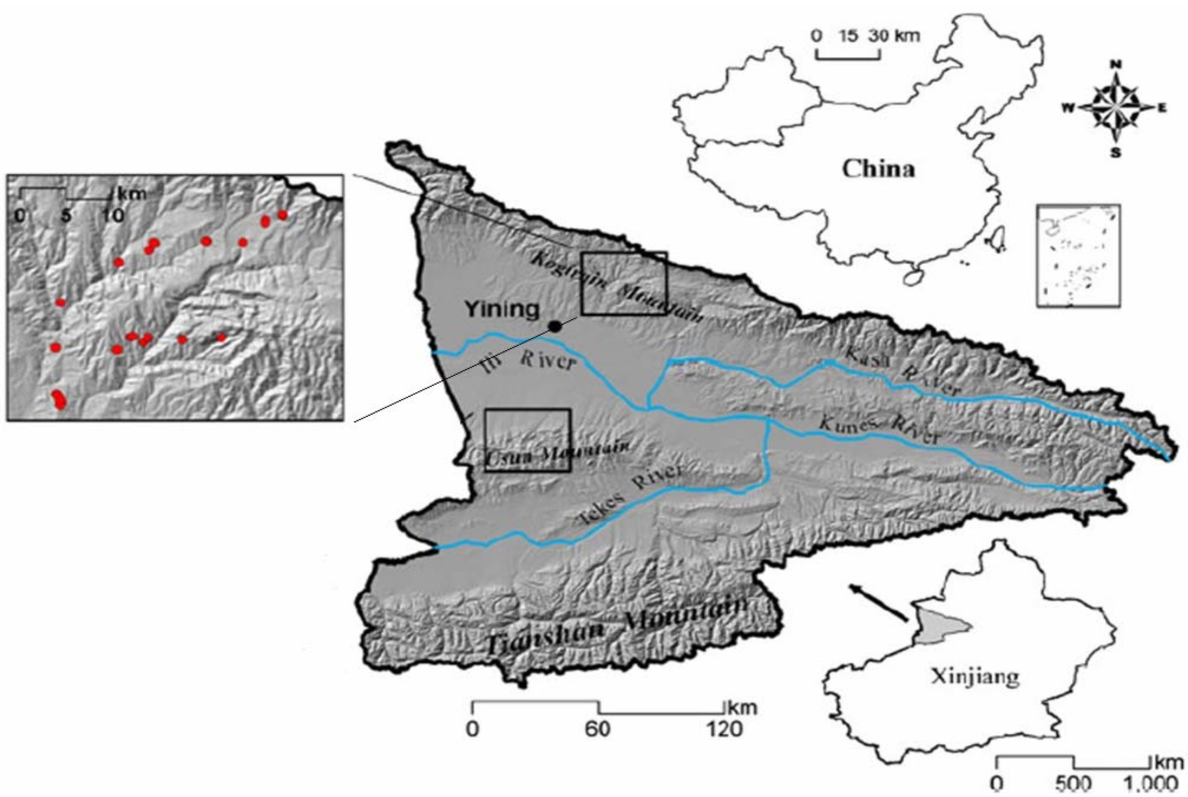

Fig. 1. Set samples of plant community on the northern slope of the Ili River Valley

(2). Calculation of community diversity

Richness index: (a) Patrick richness index: S = total number of species in the sample plot

Species diversity index: (b) Simpson index: D = $1-\sum_{i=1}^{S} pi^2$

(c) Shannon-Weiner diversity index: H = $-\sum_{i=1}^{S} pi\,Ln(pi)$

Evenness index: (d) Peilou evenness index: $E = \frac{H'}{Ln(S)}$

In the above diversity indicator formula, ***pi*** refers to the importance value of species *i* and S refers to the total number of species in the sample plot. When individuals in a community greatly differ in size, using the number of individual plants does not accurately reflect community diversity. Therefore, importance values are widely applied to replace number of plants in the calculation of plant species diversity (Ma *et al*., 1995; Huang *et al*., 1994).

(3) Data analysis: The distribution pattern of species diversity index with elevation was obtained by GAM model fit using the MGCV package program of R software (R Development Core Team, 2015). The GAM model is a semi-parametric expansion of a generalized linear model, assuming that the function can be added and the composition of the function is smooth, and establishes the relationship between the mathematical expectation of the response and predictor variables through connecting the functions. When the response variable follows binomial distribution, the general formula of the generalized additive model is:

G{E(Y)}=b0+f1(X1)+…+fm(Xm) (2)

where, E(Y) is the expected value; G{} is the contact function; b0 is the intercept; and f1…fm are smooth functions of environment variable X (smooth function is generally estimated by the cubic spline function (Cawsey *et al*., 2002)). In this GAM model, species diversity index was the dependent variable and elevation was the independent variable. Terrain factors such as aspect and slope generally affects species diversity on the landscape scale, and less obviously on the regional scale (Whittaker *et al*., 2001). Consequently, elevation is the main factor to be considered, which affects species diversity index, nutrients and salt content.

The correlation between variation in species diversity index, nutrients, and salinity with elevation was performed using SPSS 17.0 and figures were produced with Origin 8.0. The PCA analysis of edaphic factors was completed with analysis software of CANOCO Version 4.5 and drawing software of CANODRAW Version 4.0.

Results

Community types on the northern slope of the Ili River Valley: The 155 plant species sampled included 7 tree, 18 shrub, and 130 herb species (Table 1). In the desert steppe zones, 2 sample plots contained only herbaceous species. With a relatively simple composition, it included sub-elevation communities distributed in the Wild Fruit Forest, with *Corydalis ledebouraiana* the constructive species, *Achnatherum splendens* and *Erysimum diffusum* the dominant species, and *Sophora alopecuroides*, *Cynodon dactylon*, *Eremopyrum orientale,* and *Ajania fastigiata* the companion species. 11 sample plots were selected within the deciduous broadleaved forest zone. Within this zone, *Armeniaca vulgaris* was the constructive species, *Betula tianschanica*, *Acer buergerianum*, *Atraphaxis* and *Cynodon dactylon* were the dominant species, and *Sorbus tianschanica*, *Crataegus flava*, *Rosa albertii*, *Spiraea hypericifolia*, *Lonicera hispida*, *Spiraea tianschanica*, *Chenopodium glaucum*, *Phlomis pratensis*, and *Bromus japonicas* were the companion species. A total of 27 sample plots were selected in the mountainous steppe zone, with *Corydalis ledebouraiana* the constructive species, *Poa supina* and *Thymus altaicu*s were the dominant species, and *Achillea millefolium*, *Poa supine*, *Bromus japonicas*and *Thlaspi arvense* were the companion species. The herbs within the mountainous steppe covered the largest range of elevation. Four sample plots were selected in the coniferous forest but only one species, *Picea schrenkiana* was found.

Table 1. Vertical spectrum of vegetation on the northern slope of the Ili River Valley.

Elevation	Sample	Community	dominant species
>2100 m	P1-P4	Coniferous forest	*Picea schrenkiana*
1600~2100 m	P5-P31	Mountain grassland	*Thymus altaicus, Stipa capillata, Phlomis pratensis*
1200~1600 m	P32-P42	Deciduous broad-leaf forest	*Armeniaca vulgaris, Cerasus tianschanica* *Sorbus tianschanica, Crataegus chlorocarpa* *Rosa albertii, Spiraea hypericifolia*
<1200 m	P43-P44	Desert grassland	*Achnatherum splenden, Corydalis ledebouraiana*

Vertical distribution patterns in the mountainous areas on the northern slope of the Ili River Valley

1. Diversity index pattern in the mountainous area on the northern slope of the Ili River Valley: As elevation ascended, overall species richness, the Simpson and Shannon-Wiener diversity, and Pielou evenness indexes all increased, decreased, and then increased again (Fig. 2). Located below 1200 m, the desert steppe zone was composed of only herbaceous species, including *Achnatherum* spp., *Erysimum cheiranthoides* and *Corydalis ledebouraiana*. The 22°~30° gradient slope, receives significant sunshine but little rain. Low soil water content corresponded with low diversity indexes for all the desert steppe communities.

The deciduous broadleaved forest zone is located between 1200~1600 m, and includes the Wild Fruit Forest. Predominant plant species include *Armeniaca vulgaris*, *Acer buergerianum*, *Sorbus tianschanica*, *Crataegus flava*, *Rosa albertii*, *Spiraea hypericifolia* and *Lonicera hispida*. The slope gradients are relatively greater (23.56°~39°) and soil water content was relatively low. Peak values of all diversity indices were observed within this zone as it consists of deciduous broadleaved forest and is located in the middle of the mountainous area. The mountainous steppe is located between 1600~2100 m elevation. The majority of plants within this zone were herbaceous species such as *Corydalis ledebouraiana*, *Thymus altaicus*, *Poa supina*, *Festuca ovina*, *Stipa* sp., and *Chenopodium glaucum* with only a few scattered shrub and tree species The slope gradient ranged from 5.74°~23.56° and soil water content was relatively high. Due to the dominance of herb species, the mountainous steppe was the least diverse zone sampled.

Picea schrenkiana was the only community in the zone above 2100 m. While the highly dense *Picea schrenkiana* forest formed a dark, cold, and damp environment, thereby restraining the growth of most shrubs, many herb species grew in this zone and, as a result, all diversity indices increased elevation.

2. Elevation-based Pattern of Soil Nutrients in the Mountainous Area on the Northern Slope of the Ili River Valley: Organic matter is a major source of plant nutrients, and it directly influences the physical, chemical, and biological properties of forest soils. The organic matter content of the deciduous broadleaf forest ranged from 9.522-139.947g/kg for the coniferous forest soils. Available nitrogen refers to the amount of nitrogen that dissolves in water, which is directly absorbable and usable to plants. As with many nutrients, available nitrogen content has a decisive significance to the growth of plants. Available soil nitrogen ranged from 15.8~863.03 mg/kg, showing a general progressive increase as elevation increased (Fig. 3). Available phosphorus content also rose with elevation, although it was extremely low across the study area (2.1~22.58 mg/kg). In regards to plant growth, the sufficiency of potassium mainly depends on the level of available potassium in soil. Figure 2 demonstrates that readily available potassium content in this area ranged from 93~1,515mg/kg. Different from organic matter, available nitrogen, available phosphorus, and available potassium, readily available potassium content increased as the elevation increased and reached a peak value in the deciduous broadleaved forest zone (1,515 mg/kg).

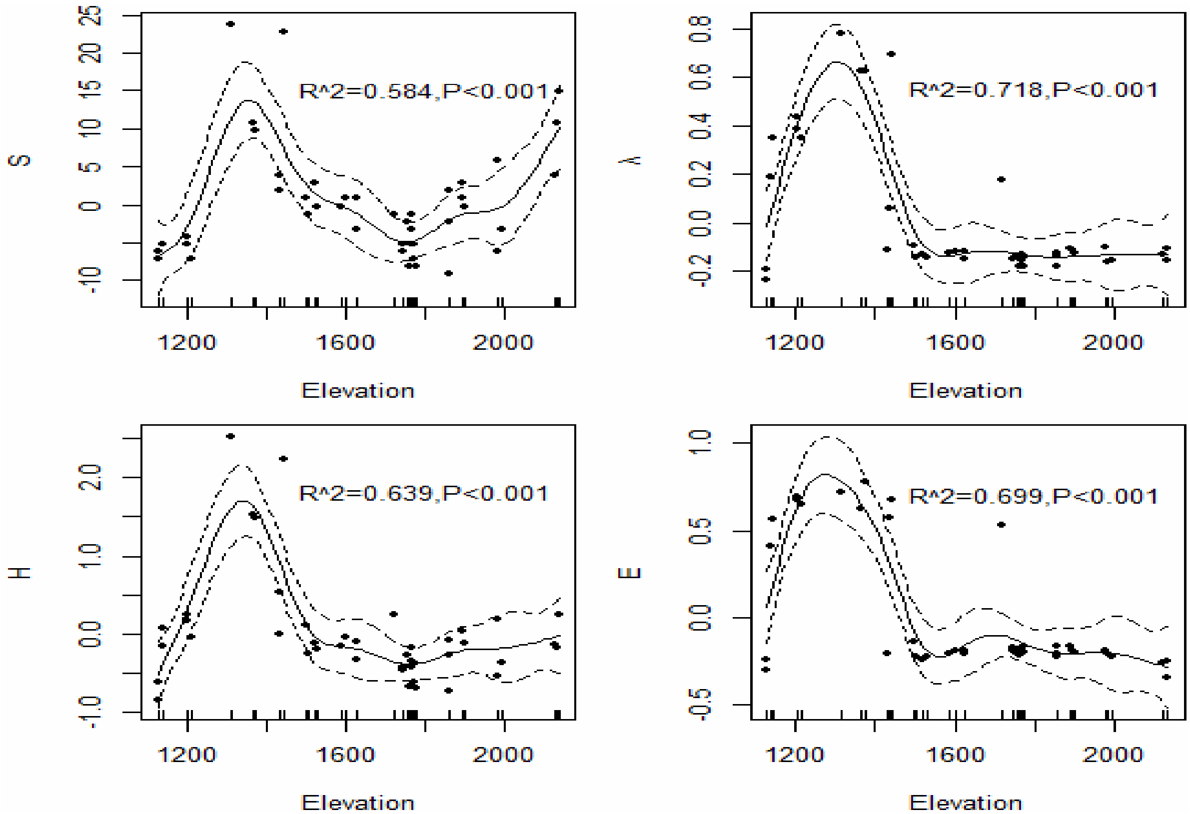

Fig. 2. Elevation-based pattern of species diversity on the northern slope of the Ili River Valley.

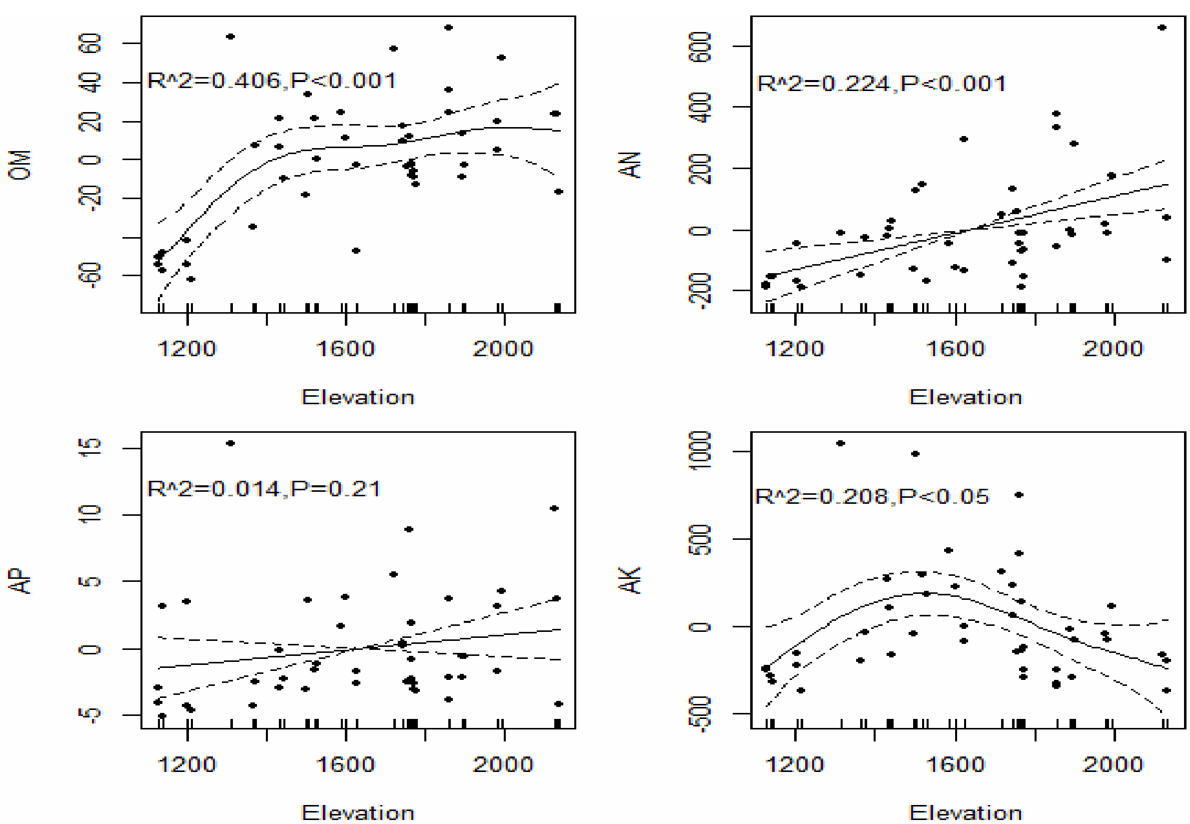

Fig. 3. Elevation-based pattern of soil nutrients on the northern slope of the Ili River Valley.

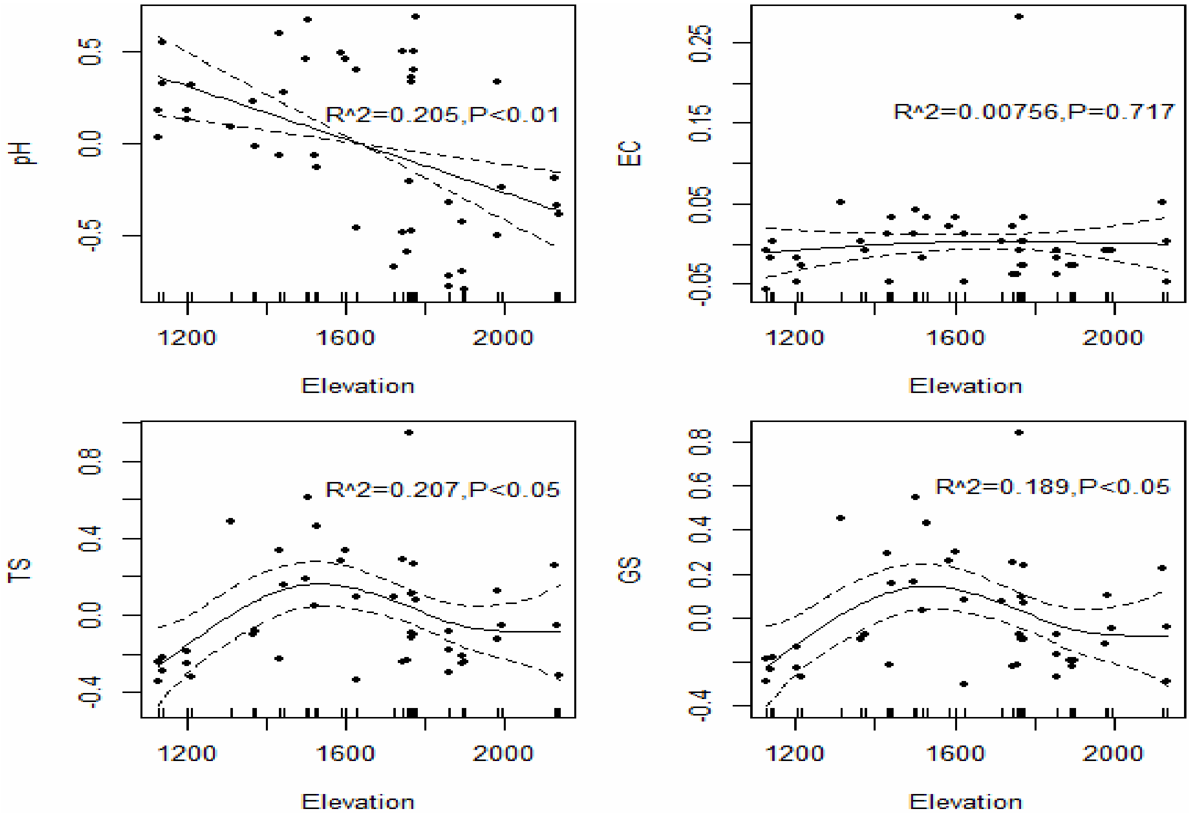

Fig. 4. Elevation-based pattern of soil salinity in the mountainous area on the northern slope of the Ili River Valley.

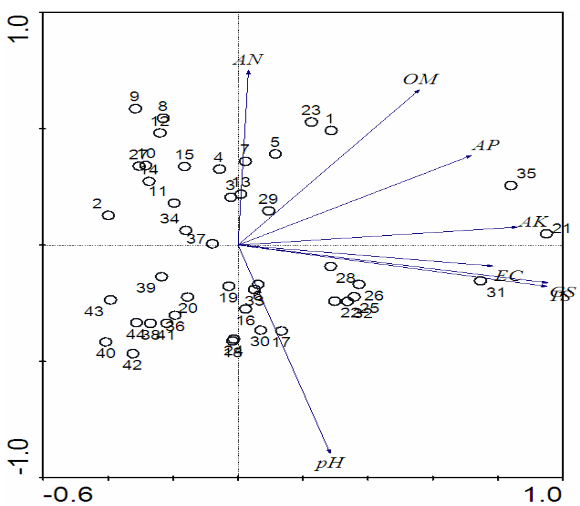

Fig. 5 Principal components of edaphic factors in sample plots under elevation variations.

OM: Organic matter; TN: Total nitrogen; AP: Available phosphorus; AK: Available potassium; EC: Electricity conductivity; GS: Gather salt; TS: Total salt

3. Elevation-based pattern of soil salinity in the mountainous area on the northern slope of the Ili River Valley: From Fig. 4 demonstrates that pH at all elevations is relatively neutral 6.51~7.99. As a key indicator of soil salinity, soil conductivity ranged from 0.06~0.4ms/cm, showing only a small variation as elevation increased. Total salt content in the soil ranged from 0.375~1.665g/kg and increased as elevation ascended, reaching a peak value at elevations between1400~1600m. Gross salt content in the soil ranged from 0.353~1.506mg/kg. Similar to the tendency of total salt, it increased as elevation increased and reached a peak value in the deciduous broadleaved forest zone between elevations of 1400~1600m.

Principal components of edaphic factors in sample plots under elevation variations: In the first principal component, the soil salinity parameters (total salt, gross salt, and conductivity), and total P and K had their greatest influence on the first principal component (Table 2 and Fig. 5). For the second principal component, available nitrogen and organic matter in soil both had high positive values, while soil pH had a high negative value. Additionally, organic matter in soil is closely related to productiveness and fertility. Analysis also showed that soil pH, which is closely related to soil salinity, showed significant negative correlation with nutrient levels.

Correlations among species diversity index, soil nutrient, and soil salinity: The species richness was positively correlated with the Simpson (r = 0.534), Shannon-Wiener (r = 0.851), and Pielou evenness indices (r = 0.310); and negatively correlatedwith gross salt and total salt in soil (r = -0.343; r = -0.341) (Fig. 6). In terms of the index Simpson, it showed a strong significant correlation with the Shannon-Wiener index (r = 0.864) and a significant positive correlation with the Pielou evenness index (r= 0.938); however, it also showed a strong significant negative correlation with soil pH value (r = -0.465).

Table 2. Principal components of edaphic factors in sample plots under elevation variations.

Component	Component score coefficient of environment variance								Cumulative %
	TS	GS	EC	AK	AP	AN	pH	OM	
1	0.969	0.969	0.850	0.833	0.702	-0.022	0.303	0.481	51.422
2	-0.127	-0.110	-0.087	0.124	0.447	0.832	-0.809	0.711	77.716

The Shannon-Wiener index showed a significant positive correlation with the Pielou evenness index (r = 0.714) and a significant negative correlation with soil conductivity (r = -0.367). The Pielou evenness index showed a strong negative correlation with soil conductivity (r = -0.477). Organic matter had a very significant positive correlation with available nitrogen (r = 0.473), available phosphorus (r = 0.571), and available potassium (r = 0.487). Available phosphorus had a strong significant positive correlation with available potassium (r = 0.623). Soil pH value had a significant positive correlation with gross salt (r = 0.382) and a very significant positive correlation with gross salt (r = 0.391). Soil conductivity showed significant positive correlation with gross salt (r = 0.843) and a very significant positive correlation with total salt (r = 0.845). Gross salt had a very significant positive correlation with total salt (r = 0.999).

Discussion

Plant community diversity pattern on the northern slope of the Ili River Valley: The diverse ecological and environmental conditions of mountainous areas make them a germplasm bank for the survival, reproduction, and preservation of many rare or endangered species (Whittaker *et al.*, 2001; Theurillat & Schliissel, 2000; Oommen & Shanker, 2005). Previous studies on biodiversity in mountainous areas have found five distribution patterns of species diversity variations as elevation increases: diversity decreases before increasing, increases before decreasing (a unimodal curve), monotonously increases, monotonously decreases, or shows no obvious pattern (He & Chen, 1997b; Liu *et al.*, 2005b). However, the species richness pattern we observed does not fit any of these patterns. For both diversity indices and the evenness index we found that as elevation increased species richness first increased, then decreased, and finally increased again. Previous research has stated that wild *Malus sieversii* deep in Tianshan formed large scale forests with light green rounded crowns, forming a distinctive contrast to the dark coniferous forest of *Picea schrenkiana* (Zhang, 1973). The structure of this mountainous vegetation vertical spectrum lacked a xeromorphic vegetation zone and a highly mesophytic deciduous broadleaved forest zone, which is exceptional in desert mountainous vertical spectrum structures. In the present study, however, a unique vegetation vertical distribution pattern was observed. A similar vertical pattern was observed from vegetation in the middle part of Tianshan, which was regarded as a unimodal distribution pattern (Sang, 2009). Conversely, however, the present paper demonstrated a rather unique vertical distribution pattern in the arid area which was closely related to the unique local climate and environmental factors.

Only available potassium showed a consistent pattern with species diversity. Research has indicated that a small amount of highly competitive species exist under rich resource habitat conditions, while a great number of species are able to grow in soil with only moderately rich resources (Tilman, 1982); therefore, species diversity at such elevation gradients as seen from our study should be relatively high. The diversity pattern and soil nutrient pattern shown in this study area were consistent with the above opinion.

Diversity patterns of vegetation communities on the northern slope of the Ili River Valley and relationship with the environment: Species diversity distribution patterns are related to factors such as climate and community productivity (Odland & Birks, 1999), and are influenced by vegetation evolution to a certain extent (Ricklefs, 2004) The study area is located in the arid and semi-arid area of China, while the Ili River Valley is situated inland at mid-latitude. With high mountains surrounding it on the north, east, and south, the valley is open to the west in a U shape. As a result, warm humid air from the Atlantic Ocean, the Caspian Sea, and Lake Balkash rises along the valley, bringing a relatively continental and north temperate climate to the region (Zhang & Wang, 2009). The special cold-lake effect plays a role at the enclosed and semi-enclosed valley base. In winters, cold currents from the mountains descend and build up at the bottom of the valley, making it the coldest place. As elevation increases from 800 to 2000m, a unique "inversion layer" zone is formed (Liu *et al.*, 1993). Under these unique geological conditions, species richness peaked in the deciduous broadleaved forest zone and was lowest in desert steppe zone and mountainous steppe zone as elevation varied. Such results are consistent with the "middle expansion hypothesis", which states species richness is greatest at moderate elevation gradients. Due to the inversion layer, however, species richness increased again at 2000m. Many studies have demonstrated that low temperature at high elevation restrains species survival but the inversion layer found in this study appears to be an exception. It is likely, therefore, that temperature played an important role as the study site and inversion layer exist on the northern slope of West Tianshan. Interestingly, the area investigated by Sang (2009) was also on the northern slope of Middle Tianshan, in which similar vertical distribution patterns were observed. Further research is required, to determine whether such patterns are a common feature on northern slopes of arid mountainous areas or site specific.

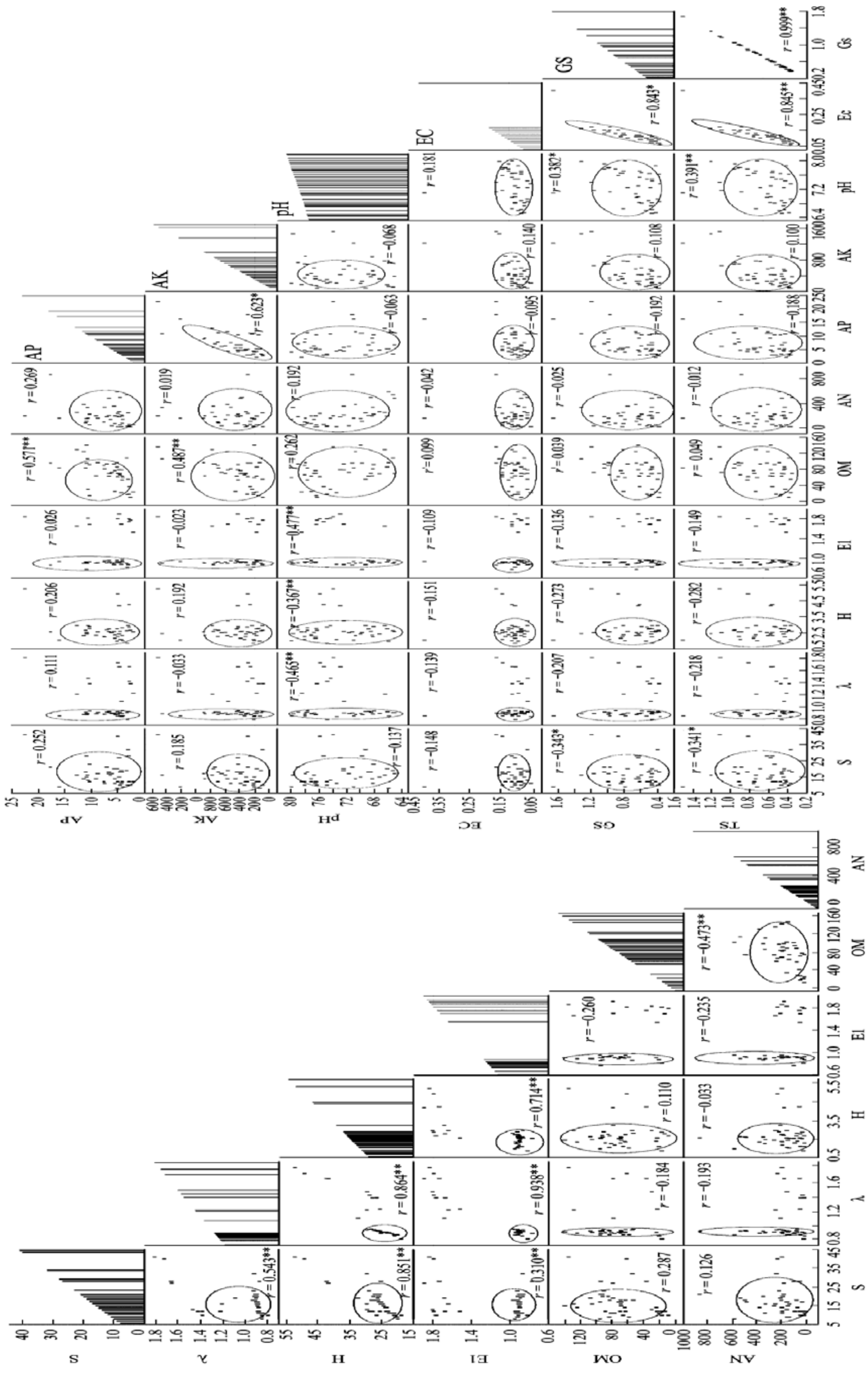

Fig. 6. Strong correlation among species diversity, soil nutrients and soil salinity.
S: Species diversity ; λ: Simpson index; H: Shannon-Wiener index; E1: Pielou evenness index; OM: Organic matter; TN: Total nitrogen; AP: Available phosphorus; AK: Available potassium; EC: Electricity conductivity; GS: Gather salt; TS: Total salt

Conclusions

This is more a summary than a conclusion: Both species richness and the two α diversity indices and evenness index first increased, then decreased, and finally increased again, presenting a rather unique vertical distribution pattern, which was closely related to the unique local climate and environmental factors.

Under the unique geological conditions, species richness peaked in the deciduous broadleaved forest zone and was lowest in desert steppe zone and mountainous steppe zone as elevation varied, which are resulted from the inversion layer.

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