Assessing Community Distribution Characteristics and Succession Stages on Mountainous Areas Hosting Coming Winter Olympics Games

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Abstract

Background

The Yin Mountains located in China within the Chongli Country will be the core area of the 2022 Winter Olympic Games. It is necessary to survey the key factors limiting the vegetation communities' development so as to guide the vegetation restoration after major events in this region.

Methods

Two-way indicator species analysis (TWINSPAN) and market basket analysis (MBA) were used to classify the vegetation communities. Plant community and relationships among environmental variables were assessed through the detrended correspondence (DCA) and canonical correspondence (CCA) analyses.

Results

Soil moisture and organic matter were found the main factors limiting the development of shrub and herb communities. The distribution of different forest communities was mainly affected by geomorphological factors. In middle and high altitude areas, apart of arbor and shrub communities generally showed the process of transformation from the pioneer community to transitional community in the competition.

Conclusion

We concluded that providing the basis to understand the environmental factors that restrict the development of vegetation communities in the eastern Yin Mountains and its potential changes after human impacts, in this case, the Winter Olympic Games, could help to more efficient restoration plans.

1. Introduction

Climate and human activities play a key role in the growth of vegetation, especially in mountainous areas (Parmesan and Yohe 2003; Li et al. 2017). One of the largest human events with more environmental repercussions is the Winter Olympic Games. May (1995) showed some pioneer results related to the 1992 Winter Olympics and the difficulties to assess its potential direct adverse effects on the environment. This author emphasized on the assessment of secondary and longer-term impacts, which are difficult to be foreseen. Some common issues of these big events are related to floods and erosion, and the damage to young trees, natural flora and fauna due to skiing, which is not restricted to runs (Vanwynsberghe 2015). Therefore, an appropriate interpretation of the relationship between alpine vegetation types and the environment with human activities cannot be fully understood without considering other factors such as soils (Rodrigo-Comino et al. 2018), hillslope morphologies (Saco et al. 2007) and water availability (Brown et al. 2005).

Holistic studies considering all above-mentioned factors must be one of the main tasks of vegetation ecology scholars. According to, environmental heterogeneity is not only considered as one of the most important factors to control the species richness gradient (Stein et al. 2014; Khanalizadeh et al. 2020) but also closely related to the micro-climatic conditions induced by topography and the distribution of plant species (Scherrer and Körner 2011). Therefore, revealing the relationship between vegetation distribution and environmental factors could quantitatively explain the interaction between driving factors and environmental processes (Sohoulande Djebou et al. 2015). Moreover, this would allow finding the main factors restricting the development of different communities and leading to environmental changes.

Most of North China is located in the warm temperate semi-humid semi-arid monsoon climate region. However, the mountain vegetation, especially the alpine vegetation, is most affected by the coupling system of human impacts, changing climate conditions and topography (Anders et al. 2010; Geri et al. 2010). In addition to the difference among parent materials, the vegetation community changes sensitively with the modification of each limiting factor. Therefore, it is of great significance to decompose the complex coupling system into a single quantitative environmental factor to design efficient vegetation restoration and reconstruction in mountainous areas.

The Chongli District, Zhangjiakou region, with apparent ecosystem vulnerability and sensitivity, is located in a typical transition belt between semiarid and subhumid climate regions. The study area is the ecological barrier of 2022 Winter Olympic Games, which is not only related to the ecological service function of large-scale events and the vegetation restoration after the games but also the most important water supply and ecological service area in Hebei, Beijing and Tianjin. Therefore, the largest land retirement programme in the developing world (also called the Sloping Land Conversion Program and the Farm to Forest Program) was launched in 1999 and covered the middle and western developing regions of China (Zhou et al. 2021). Under the Grain to Green Program (GTGP) on a large scale in North China, the impacts of plantation and restoration have received more attention. On the one hand, plantations can enhance the soil and water conservation function of the soil surface and significantly improve soil quality (Martín-Peinado et al. 2016). However, on the other hand, due to specific tree species, soil texture, water and climate conditions, the effect of vegetation construction model in different regions is not the same and even shows a negative impact on the ecological environment (Cerdà 1998; Abbate et al. 2006). Some determinant problems are the soil water shortage and drying, the scarcity of surface herbs, and the formation of "green desert" landscape (Li 2019). Because the early contribution of the plantation to an ecosystem is not obvious, and even reduces the function of the ecosystem (Dislich et al. 2017), it is difficult to be listed as a suitable research object. But over time, plantation plays an increasingly important role in ecosystem services, especially the substantial global contribution of SOC sequestration to ecosystem carbon sink provided by planted forests (Wang and Huang 2020). In North China, after decades of closing mountains for forest cultivation and nature conservation, human disturbance is greatly reduced, and the artificial forest, the natural forest and the undergrowth vegetation are interacting, and the regeneration and succession are gradually completed in the process of mutual competition and integration.

Therefore, plantations such as *Larix gmelinii (Ruprecht) Kuzeneva* located in this study area should be included in the research scope, not only because of its wide distribution range and its influence on the ecosystem that cannot be ignored but also because of its the function of landscape construction in a mountainous area (Fang et al. 2020). However, this is poorly understood in the scientific literature. Now, paying attention to the organization of the Winter Olympic Games at 2022, recently, some authors highlight the relevance to demonstrate, for example, the construction of zero-carbon landscape in the ecological conservation area, which could achieve the regeneration of visual elements of plant zero-carbon landscapes, spatial emotions and ecological environments(Li et al. 2018).

Therefore, the main aim of this paper is to assess the difference between the impact of plantation and natural secondary forest on the ecosystem before the realization of the Winter Olympic Games. This would provide theoretical support for vegetation restoration and reconstruction in this large area considering the distribution range and characteristics of the plantations before any human disturbance. In this research, the plant communities of the Yin Mountains in North China were studied considering; i) the spatial distribution of Yin Mountains and vegetation communities in the region as a function of a set of measurable environmental variables; ii) the two-way indicator species analysis to assess the distribution characteristics and succession stages of communities in the whole ecosystem including the plantations were used; iii) the direct ordination method to observe the relationships between vegetation communities and measurable environmental variables (e.g. topography). Furthermore, as the host of the 2022 Winter Olympic Games, Chongli needs to have a further understanding of the floristic composition and ecological distribution of the plant community to avoid any uncontrolled impact (May 1995).

2. Materials And Methods

2.1. Study area

The study area (864.79 km^2) is located in the branch of Yin Mountain in North China, and its administrative division is subordinate to Chongli District, Zhangjiakou City, Hebei Province, China (40°47'54"–41°02'38"N, 115°13'42"–115°30'52"E). The landform of this area belongs to middle and high mountain landforms. The general altitude trend is high in the northeast and lowers in the southwest. Its altitude ranges from 820 to 2129 m a.s.l. (Du et al. 2019). The minimum altitude of the 91 samples was collected at 1220 m and the maximum one up to 2040 m (Fig. 1).

The Chongli mountain area is widely distributed occupying 80% of the county territory, and the forest coverage rate reaches 52.4%. The climate belongs to the East Asian continental monsoon climate and moderate temperate sub-arid zone. The annual average temperature is 3.7℃. The average temperature is in summer is 19℃ and in winter is -12 ℃ (Song et al. 2018). The snowfall is early and the snow is thick, and the with a long snow-storing period. The annual precipitation averages 483. 3 mm (Song et al. 2018). Therefore, due to its climatic and topographical conditions, the ecosystem of the study area includes mottled meadow ecosystems, deciduous broad-leaved and coniferous forests, alpine shrub and meadow ecosystems. In the mountainous area, forest soil types are mainly cinnamon soil and brown soil, and birch and larch trees, *Spiraea* and *Rosaceae* shrubs and herbaceous are the main vegetation species (Song et al. 2018).

2.2. Field sampling

A total of 91 Sample points considering different aspects following the strategy described by Lindsey (1956) were collected: on the sunny, shady, semi-sunny and semi-shady hillslopes. They were collected from 1220 to 2040 m a.s.l. (Table 1).

Table 1
Habitat and characteristics of 91 sampling points

Aspect	Direction	Quantity	Altitude (m)	Description
Sunny	45°~ 135°	34	1220 ~ 1950	It is mainly composed of shrubs and herbs, with a larger soil bulk density and more gravel content.
Shady	225°~ 315°	38	1290 ~ 2040	Shoulder and backslopes are mainly composed of trees and shrubs, and the footslope by shrubs and herbs. Soil bulk density is lower and is the surface layers wetter.
Semi-sunny and semi-shady	315°~ 45° and 135°~ 225°	19	1640 ~ 1920	Mainly distributed in the middle and high altitude areas, the footslope position is mainly composed by shrubs and herbs, and the backslopes and shoulders by trees and herbs.

The number of sampling points was determined according to the altitude range of the hillslope aspect, and distribution along the altitude contour line with a gradient of 50 m. The first field survey season was between August and September 2018, the second one from July to September 2019. It is important to highlight that the surveyed sampling points in 2018 were revisited during the second survey.

The optimum size selected to survey each particular vegetation type was estimated using the concepts of minimal area and species-area curves (Kent 2011). We selected 20 mx20 m sampling points dominated by trees and 10x10 m by shrubs and herbs. The specie coverage (%) is assessed as the vertical projection of all above-ground parts of a single species onto the ground, expressed as a percentage of the unit area of the species (Greig-Smith 1983). Additional recorded environmental factors include the location (longitude, latitude), altitude, aspect, inclination, and forest canopy. Moreover, five soil surface samples were randomly taken from each plot and transported to the laboratory. The soil organic matter content was measured by the potassium dichromate method (Walkley and Black 1934). The soil bulk density and porosity were measured by the core method (Margesin and Schinner 2005). Soil pH was measured in a suspension using an electronic pH-meter. The nomenclature and classifications of all plant species in this article are based on the handbook Flora of China edited by Lin (1991).

2.3. Data analysis

Two-way indicator species analysis (TWINSPAN), a binary indicator species analysis similar to the multi-level dichotomy method is used to study ecological factors and species (Kooch et al. 2008). The advantage of this method is that the species classification can be completed at the same time as the sample plot classification. The TWINSPAN 2.3. for Windows (Hill and Hill 1979; Peeters and Gylstra 1997) was used to classify the vegetation data. The analysis using this method takes into account the following considerations: the maximum number of division levels was 3, the minimum group size for the division was 5 and the maximum number of indicators per division was 5.

The indicator species analysis (ISA) (Dufrêne and Legendre 1997), and the Monte Carlo methods were used to test the significance of the indicator value (IV) for each specie(Dai et al. 2006). The IV used by ISA allows the combination of the relative abundance (RA) and relative frequency (RF) information of the species in each group. The values of IV ranges from 0 (no indicator) to 100 (perfect indicator) (McCune and Mefford 1999).

After calculating the ISA, the market basket analysis (MBA) was carried out for all species about each community. The working principle of an MBA is to mine a data set, which is composed of a group of projects. In this case, it is the species and their respective communities. These populations correspond to the species found at each sampling point, and all populations can be analyzed to find a set of species frequently placed together in each community. The Apriori algorithm (Agrawal and Srikant 1994) of market basket analysis uses to be applied to analyze the existence of species combination in each habitat, and the results of the association rules of species A and B in community X were generated. When $\alpha = 0.05$, Fisher's exact test and Holm Bonferroni's correction are used to test the significance. In addition to indicating which species appear in which community, these rules also have three main parameters. First, the support (S) is the proportion of the whole data set, showing the probability of the species combination occurring in the community. Second, the confidence (C) is the value that allows indicating the probability of finding a habitat if a given species combination is found. Finally, the third one is the lift (L), which is a method to measure the correlation between the species group and the community (Leote et al. 2020). Because of ISA is only used for the species and their characteristics among the screening community, it does not have the relevant information between the characteristic species and the species and the community. As a result, the MBA is used to supplement ISA. Therefore, two species meeting MBA threshold (S = 0. 25, C = 0. 8) and IV maximum were selected in each community to name the whole community.

ISA analysis was performed using PC-ORD 5.0 (McCune and Mefford 1999). For the market basket analysis (MBA), the data were analysed using the R software v.3.6. 2 (R.C.Team 2018), and the package arules (Hahsler and Hornik 2007) also demonstrated how to use data sets to combine clustering and association rule mining.

Vegan package (Oksanen 2013) in R software v.3.6. 2 (R.C.Team 2018) was used to perform detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) of species and environmental data (Ter Braak 1986). Then, sorting is used to analyze the relationship between species composition and environmental factors. The prior DCA shows that the longest gradient length is 4.41 (Table 4), indicating that there is greater heterogeneity in the species composition data. Therefore, the CCA could be considered as a suitable method to determine the relationship between environmental variables and community distribution by correlating community differences with environmental variables (Lepš and Šmilauer 2003). Rarity is eliminated by using coverage of less than 5% or a frequency of less than 5% species (Zhang et al. 2001). The remaining 48 common species were used in both classification and ordination analyses, and to identify potential differences in the contribution of environmental variables among sampling points. The CCA axis was statistically evaluated by the Monte Carlo displacement test ($P = 0.001$).

Before performing the CCA analysis, a logarithmic conversion was performed based on the above-mentioned environmental variables that do not obey normal distribution such as altitude and inclination. According to the current inclination degree, the hillslope position of the experimental plot was divided into three different types by the method of value assignment, 1 for the shoulder, 2 for the backslope, and 3 for footslope position (Shao et al. 2012). For the aspect, we introduced two variables: northness and eastness. Northness will take values close to 1 if the aspect is generally northward and close to -1 if the aspect is southward, or close to 0 if the aspect is either east or west (Vogiatzakis et al. 2003).

3. Result

3.1. Community classification

Based on the flora composition of the study area, the TWINSPAN method divided 91 sampling points into eight groups, and the classification stopped at the third level (Fig. 3). Each group contained a sufficient number and variety of samples to make different vegetation communities considering their characteristics.

According to the analysis results of ISA and MBA, the original eight TWINSPAN groups were reduced to six community types. In ISA, the characteristic species (*Pteridium aquilinum (Linn.) Kuhn var. latiusculum (Desv.)Underw.ex Heller* and *Juncus effusus Linn.*) of groups 1 and 2 occupy the most important position in the IV ranking within the group, except for similar geographical coordinates and topographic factors. In the MBA, the support and confidence of *Pteridium aquilinum (Linn.) Kuhn var. latiusculum (Desv.)Underw.ex Heller* and *Juncus effusus Linn.* are greater than 0.5 and 0.9 respectively, so groups 1 and 2 were amalgamated. Similarly, groups 7 and 8 were assigned to the same group (i. e. *Larix-Carex* Community type). Information about indicator species and environmental variables for the six community types are included in Tables 2 and 3, respectively.

Table 2
Monte Carlo permutation test of significance of observed maximum indicator value (IV) for each species, based on 1000 randomizations.* MBA(market basket analysis) was used to select the species combined with the highest support degree to classify each vegetation community.

Community type	Characteristic species	Indicator Species Analysis				Market Basket Analysis		
		IV	IV from randomized groups			Support	Confidence	Lift
			Mean	Standard deviation	*p*			
Pteridium-Juncus						0.52	0.97	1.28
	Pteridium aquilinum (Linn.) Kuhn var. latiusculum (Desv.)Underw.ex Heller	41.02	25.20	5.2	0.001			
	Juncus effusus Linn.	45.95	26.10	5.53	0.001			
	Galium linearifolium Turcz.	57.14	12.50	5.36	0.001			
	Sanguisorba officinalis Linn.	49.27	21.60	5.17	0.001			
Armenia-Poa						0.29	1	1.17
	Poa annua Linn.	63.68	29.80	6.92	0.001			
	Armeniaca sibirica (Linn.) Lam.	23.10	24.10	6.22	0.001			
	Caragana acanthophylla Kom.	27.67	21.70	7.57	0.001			
Spiraea-Artemisia						0.53	1	1.06
	Spiraea fritschiana Schneid.	35.28	20.60	2.87	0.001			
	Artemisia carvifolia Buch.-Ham. ex Roxb.	37.05	22.00	2.28	0.001			
	Polygonum divaricatum Linn.	23.53	14.90	4.86	0.001			
Betula-						0.86	1	1

Potentilla								
	Betula platyphylla Suk.	35.38	*	*	*			
	Potentilla fruticosa Linn.	55.71	24.20	6.02	0.001			
	Epilobium angustifolium Linn.	95.93	23.30	8.24	0.001			
	Phaenosperma globosa Munro ex Benth.	35.37	14.30	6.56	0.001			
	Elymus dahuricus Turcz.	32.38	16.10	4.77	0.001			
Betula-Rosa						0.5	1	1
	Betula platyphylla Suk.	57.69	21.60	5.87	0.001			
	Rosa xanthina Lindl.	46.77	28.90	6.64	0.001			
	Corylus mandshurica Maxim.	41.67	13.30	5.54	0.001			
Larix-Caex						0.83	1	1
	Larix gmelinii (Ruprecht) Kuzeneva	88.68	26.70	8.73	0.001			
	Carex doniana Spreng.	44.78	21.40	4.79	0.001			
	Brachypodium sylvaticum (Huds.) Beauv.	25.65	23.30	6.44	0.001			
	Saussurea japonica (Thunb.) DC.	24.77	24.40	4.11	0.001			

***** The IV of *Betula platyphylla Suk.* is the highest in *Betula-Rosa* community, so mean, standard deviation and *p* values are not shown here.

Table 3
Mean and standard deviation (±) of environmental variables in the studied sampling points associated with every six community types.

	Community type					
	Pteridium-Juncus	*Armenia-Poa*	*Spiraea-Artemisia*	*Betula-Potentilla*	*Betula-Rosa*	*Larix-Carex*
Number of sampling points	21	7	34	7	16	6
Altitude(m)	1520 ~ 2040	1210 ~ 1400	1260 ~ 1900	1800 ~ 2000	1420 ~ 1950	1300 ~ 1900
Organic matter (%)	9.06 ± 1.47	3.82 ± 4.15	6.77 ± 2.45	8.02 ± 1.9	9.74 ± 2.08	6.04 ± 3.8
Slope(°)	27.19 ± 6.83	24.14 ± 15.6	25.97 ± 11.03	19.86 ± 5.52	24.5 ± 3.54	20 ± 6.36
Soil porosity (g/cm^3)	1.18 ± 0.13	1.15 ± 0.14	1 ± 0.2	0.82 ± 0.18	0.89 ± 0.12	0.99 ± 0.18
Soil bulk density (%)	40.75 ± 5.54	56.35 ± 5.75	58.56 ± 10.69	73.91 ± 6.37	64.18 ± 11.26	70.09 ± 11.85
Aspect	S ES	S	N S	E	N	N WN
pH	7.72 ± 0.66	7.7 ± 0.38	7.18 ± 0.3	7 ± 0.13	6.98 ± 0.29	7.14 ± 0.57

3.2. Vegetation grouping

Group 1-Group 2 (*Pteridium-Juncus* community type) includes a community with 27 species, mainly herbs, with a small number of shrubs. The characteristic species belonging to this community are *Pteridium aquilinum (Linn.) Kuhn var. latiusculum (Desv.)Underw.ex Heller, Juncus effusus Linn., ium linearifolium Turcz.*, etc. It is mainly distributed on the sunny hillslopes at high and middle altitudes, with steep slopes between 20° and 40°. The content of organic matter in soil was (9.06 ± 1.47%), which is second to *Betula-Rosa* community type. 12 sampling points (mainly below 1800 m) were affected by human activities such as Olympic venues, track and road construction, and the human activities decreased with the altitude.

Group 3 (*Armenia-Poa* community type) consists of only 7 sampling points and 9 common species. These sampling points are mainly found in low-altitude (1318.57 ± 57.03 m) and sunny hillslope areas, with a wide range of different inclinations (5 ~ 45°). The characteristic species are *Poa annua Linn., Caragana acanthophylla Kom., and Armenica sibirica (Linn.) Lam.* Mainly shrubs, which are resistant to drought, cold and barren. The soil organic matter content of this community is the lowest among all community types, only 3.82 ± 4.15%. All the 7 points were affected by human habitation (including abandoned farmland and grazing).

Group 4 (*Spiraea-Artemisia* community type) contains 34 sampling points, which are widely distributed on shady and sunny hillslopes between 1290 and 1901 m a.s.l., and when they are distributed on shady hillslopes, they use to occupy the footslopes. Their characteristic species are *Artemisia carvifolia Buch.-Ham. ex Roxb.*, *Spiraea fritschiana Schneid.*, *Polygonum divaricatum Linn.* and *Scutellaria baicalensis Georgi*, which are conditioned by warm and humid environments and well-developed soil. The inclination ranges from 7 to 46°. The soil color is slightly darker than that of the *Pteridium-Juncus* and *Armenia-Poa* communities. Soils are loamy, and the content of organic matter is in the middle of all community types (6.77 ± 2.45%). The soil and vegetation of this community could be classified as an intermediary type between the shrub grass and the arbor communities (transitional). 23 points (concentrated below 1700 m) were disturbed by human activities such as road construction and human settlements (mainly abandoned farmland).

Group 5 (*Betula-Potentilla* community type). This community contains only 7 sampling points, but they are all distributed on the semi-sunny or semi-shady hillslopes with altitudes up to1980 m. Its characteristic species are *Betula platyphylla Suk., Epilobium angustifolium Linn., Potentilla fruticosa Linn. and, Phaeosperma* and *Elymus dahuricus Turcz.*. It is relevant to highlight that *Betula platyphylla Suk.* is a pioneer tree species, and gradually was replaced by other tree species after planting. The soil is loamy, and the pH is neutral. The community is located at a high altitude in this area, which is not affected by human activities and other factors.

Group 6 (*Betula-Rosa* community type) has 16 sampling points. As in the *Betula-Potentilla* community, the pioneer and main tree species are the *Betula platyphylla Suk.*, but the difference is that most of the sampling points are distributed on shady hillslopes, the inclinations are about 25°, and the altitude range from 1423 to 1950 m a.s.l. In addition to *Betula platyphylla Suk.*, its characteristic species include *Rosa xanthina Lindl.* and *Corylus mandshurica Maxim.* The soils are similar to the *Betula-Potentilla* community, they are loamy. However, the soil organic matter content is the highest among all community types (9.74 ± 2.1%), and the soil texture is loose and neutral. Due to the influence of enclosure measures, the influence of human activities is not obvious. Only some afforestation activities were found around the area below 1600 m altitude (5 sampling points), such as road traces left by human transportation and trampling.

Group 7-Group 8 (*Larix-Carex* community type) is characterized by species such as *Larix* gmelinii (Ruprecht) Kuzeneva. Except for the footslope position of sample plot 65 on the semi-shady hillslope, other sampling points are distributed along the balckslopes of the shady faces. The altitude ranges from 1298 to 1900 m a.s.l. The inclination is not greater than 25°. Other characteristic species include some herbaceous plants such as *Carex doniana Spreng., Brachypodium sylvaticum (Huds.) Beauv., Saussurea japonica (Thunb.) DC., and Vicia sepium Linn. unijuga A. Br.*, and a few sampling points have a small number of shrubs. The soil is loose as the *Betula-Potentilla* and *Betula-Rosa* communities. The organic matter content changes significantly with altitude, in the low altitude range (1595.5 ± 263.61 m), the organic matter content fluctuated around 6.04. The pH value is neutral to weakly alkaline. 2 sampling points in lower altitude area (Below 1600 m) were seriously disturbed by the race track and road construction. While 3 sampling points in higher altitude area (1600 ~ 1900 m) had artificial footprints and planting pits, but the influence was not obvious.

3.3. Limitation of environmental factors on plant species

Table 4
Summary statistics for the two CCA (canonical correspondence analysis) ordinations and comparison of the results using DCA (detrended correspondence analysis).

Summary of ordination	Axis 1	Axis 2
CCA		
Eigenvalues	0.39	0.26
Cumulative percentage variance of species data (%)	5.81	9.64
Species- environment correlation	0.79	0.73
Test of significance of all canonical axes	F = 2.65	P = 0.001
DCA		
Eigenvalues	0.63	0.45
Cumulative percentage variance of species data (%)	9.31	15.86
Gradient length	4.41	3.60

In this study, the characteristic values of the first two coordination axes of DCA are 0.63 and 0.45, which are larger than the characteristic values of the first two coordination axes of CCA (0.39 and 0.26, respectively; Table 4). Therefore, TWINSPAN was used to organize and classify vegetation and sampling points, because the first step of the TWINSPAN method is to perform DCA (or CA) ordination. CCA is more beneficial to the ecological sense, and CCA can reflect the similarity of species composition and environmental factors at the same time, and even reflect the correlation between environmental factors and sampling points from the side. Therefore, we used CCA to explain the relationship between environmental factors and various species.

Figure 4 (above) shows the distribution pattern of species in this area by unconstrained ordination of IV indicators of species. Also, environmental factors are added to constrain the ordination of species (Fig. 4, below). By comparing the scoring order of species on DCA Axis 1 and CCA Axis 1, the species with the highest score (to the right) or the lowest (to the left) in the 2 figures register some differences. For example, the species ranked later are *Geum aleppicum Jacq.*, *Betula platyphylla Suk.* and *Phaenosperma globosa Munro ex Benth.*, etc. While the top-ranked species are *Hemistepta lyrata (Bunge) Bunge*, *Conyza canadensis (Linn.) Cronq.*, *Pogonatherum crinitum (Thunb.) Kunth*, etc. In summary, the potential influencing factors that affect the ranking and classification of axis 1 from DCA have a great correlation with the environmental factors that affect the ranking of axis 1 from CCA. While the performance on Axis 2 is not as obvious as Axis 1.

From Fig. 4 (below), we can see the correlation between species and environmental factors. The environmental factors that have a significantly positive correlation with axis 1 are soil bulk density ($r = 0.63$, $p < 0.05$) (Table 5) and hillslope position ($r = 0.46$, $p < 0.05$). The environmental factors that obtained a significant negative correlation with axis 1 are aspect ($r = -0.79$, $p < 0.01$) and soil porosity ($r= -0.73$, $p < 0.05$). Species with high positive scores on the first axis are *Hemistepta lyrata (Bunge) Bunge*, *Pogonatherum crinitum (Thunb.) Kunth*, *Conyza canadensis (Linn.) Cronq.*, *Sophora flavescens Alt.*, *Corylus mandshurica Maxim.*, *Armeniaca sibirica (Linn.) Lam.*, and *Galium linearifolium Turcz.* Some of these species, such as

Galium linearifolium Turcz., *Hemistepta lyrata (Bunge) Bunge*, and *Pogonatherum crinitum (Thunb.) Kunth* is the main species in the footslopes, widely distributed on the sunny hillslopes, while others such as *Conyza canadensis (Linn.) Cronq.* and *Armeniaca sibirica (Linn.) Lam.*, are usually associated with back- and footslope positions´ shrubland. Species with low scores on the first axis include *Serratula centauroides Linn.*, *Betula platyphylla Suk.*, *Geum aleppicum Jacq.*, *Polygonum divaricatum Linn.*, *Vicia sepium Linn. unijuga A. Br.*, *Kochia scoparia (Linn.) Schrad.* and *Larix gmelinii (Ruprecht) Kuzeneva*. Among them, *Betula platyphylla Suk.* and *Larix gmelinii (Ruprecht) Kuzeneva* are the main tree species on the shady and semi-shady hillslopes in the area, and most of them are pure forests, if on the same hillside, *Betula platyphylla Suk.* is generally distributed at the higher altitudes than *Larix gmelinii (Ruprecht) Kuzeneva*. While other species such as *Geum aleppicum Jacq.*, *Vicia sepium Linn. unijuga A. Br.* and *Kochia scoparia (Linn.) Schrad.* are undergrowth vegetation. These species ranked low on the first axis are widely distributed on the shady or semi-shady hillslope, with thick humus layers, shoulder position and loose soil, the soil porosity is above 66.7%, and the soil organic matter content is above 7.6%, which are significantly higher than the average values of 60.6% (soil porosity) and 7.2% (soil organic matter content) in all sampling points.

In the middle of the first axis, most species are related to shrubland or usually distributed in standing forest. For example, *Saussurea japonica (Thunb.) DC.*, *Lespedeza bicolor Turcz.*, *Potentilla fruticosa Linn.*, etc. It is difficult to observe any pattern of land directivity. In summary, the environmental factors that are most sensible with the distribution of plants on axis 1 are "aspect" and "hillslope position". The two ends of the axis represent the footslope position of the sunny hillslope and the footslope position of the shady hillslope, respectively. The underlying factor of this environmental difference is moisture, so, this distribution indicates that CCA axis 1 represents a moisture gradient.

The environmental factors with strong correlation with the axis 2 are altitude ($r = -0.79$, $p < 0.001$) and organic matter ($r = -0.52$, $p < 0.05$), and both are negatively correlated. Species with higher scores on the axis 2 include *Hemistepta lyrata (Bunge) Bunge*, *Thalictrum aquilegifolium Linn. var. sibiricum Regel et Tiling*, *Sphaerophysa salsula (Pall.) DC.* and *Brachypodium sylvaticum (Huds.) Beauv.* are widely distributed in low and middle altitude areas. They are present in shrub sampling points and standing forest sampling points, and have a negative correlation with the percentage of soil organic matter. The species with low scores on axis 2 are *Sonchus arvensis Linn*, *Asparagus cochinchinensis (Lour.) Merr.*, *Galium linearifolium Turcz.*, *Conyza canadensis (Linn.) Cronq.*, *Sophora flavescens Alt.* and *Potentilla chinensis Ser. fruticosa Linn.*, especially *Potentilla fruticosa Linn.* and *Sonchus arvensis Linn.*, are the main species in shrublands above 1700 m a.s.l., or there are a few under the standing forest in the high altitude area. This indicates that the CCA axis 2 represents an altitude gradient, and from the correlation of environmental factors, it can be noted that the organic matter content increases with increasing altitude.

3.4. Regional distribution characteristics of species community

In order to differentiate the community types obtained by the TWINSPAN method and compare the classification and ordination results among them, the final six community types were superimposed on the CCA sample ordination, and the final results are shown in Fig. 5.

As mentioned in Table 5, there are four main factors related to axis 1. The positive correlation includes soil bulk density ($r = 0.63$, $p < 0.05$) and hillslope position ($r = 0.46$, $p < 0.05$). Negative correlations include aspect ($r=-0.7875$, $p < 0.01$) and soil porosity ($r=-0.73$, $p < 0.05$). From Fig. 4, the distribution characteristics of the six communities can be distinguished. *Pteridium-Juncus* community with *Galium linearifolium Turcz.*, *Sanguisorba officinalis Linn.*, *Juncus effusus Linn.*, and *Pteridium aquilinum (Linn.) Kuhn var. latiusculum (Desv.)Underw.ex Heller* as the main characteristic species are concentrated in the lower right of the plot. However, *Armenia-Poa* community with *Poa annua Linn.*, *Caragana acanthophylla Kom.* and *Armeniaca sibirica (Linn.) Lam.* as the main characteristic species is concentrated in the shoulder of the plot. The main vegetation components of *Pteridium-Juncus* community and *Armenia-Poa* communities are shrubs and herbs, which are positively correlated with hillslope position and soil bulk density, and negatively correlated with aspect. Most of them are distributed in the footslope position of the sunny hillslope, and the soil is compacted. The difference among them is that the altitude and the percentage of soil organic matter in *Pteridium-Juncus* community are higher than that in *Armenia-Poa* community. *Spiraea-Artemisia* community, with *Artemisia carvifolia Buch.-Ham. ex Roxb.*, *Spiraea fritschiana Schneid.*, *Polygonum divaricatum Linn.* and *Scutellaria baicalensis Georgi* as the main species, is the same as *Pteridium-Juncus* community and *Armenia-Poa* community, both of which are shrub sampling points, but the community is widely distributed on two axes. *Betula platyphylla Suk.* is the main species in *Betula-Potentilla* community, and the undergrowth vegetation is mainly *Epilobium angustifolium Linn.*, *Potentilla fruticosa Linn.*, *Phaenosperma globosa Munro ex Benth.* and *Elymus dahuricus Turcz.*. It is distributed in the area with an altitude of more than 1800 m a.s.l., and mainly concentrated in the semi-shady hillslope, the average content percentage of soil organic matter in the community is the highest among all the six communities. As in *Betula-Potentilla* community, the main tree species of *Betula-Rosa* community are *Betula platyphylla Suk.*, but the undergrowth vegetation with *Rosa xanthina Lindl.* and *Corylus mandshurica Maxim.* as the main species are different. Furthermore, the obvious difference is that most of them gather on the shady hillslope below 1800 m a.s.l. The percentage of soil organic matter in this community is slightly lower than that in *Betula-Potentilla* community. The main tree species of *Larix-Carex* community is *Larix gmelinii (Ruprecht) Kuzeneva*, and the undergrowth is mainly *Carex doniana Spreng.*, *Brachypodium sylvaticum (Huds.) Beauv.*, and some other herbs. On-axis 1, it is mainly distributed on the left half or near the middle, while on axis 2, it is relatively scattered. The community is widely distributed considering the altitude, mainly in backslope of the shady hillslope, and only a few in the semi-shady hillslope, the percentage value of soil organic matter content and soil porosity is between shrubland and *Betula platyphylla Suk.* standing forest, so it is soil bulk density.

4. Discussions

In most of the vegetation studies in the mountainous area of northern Hebei Province (especially in Chongli area), the relationship between environmental variables and vegetation communities is described by the ecological characteristics of single or several types of vegetation, and there is no analysis of different topography variables in the unified magnitude and dimension. The difference of the methods used in this study is to quantify the different environmental variables (mainly topography) according to the basis, to determine the distribution patterns of the community by using the multivariate analysis techniques and to directly associate these distribution patterns with the quantitative environmental variables, to map the distribution of vegetation and population.

4.1. Zonal characteristics of six vegetation communities

The area in this study belongs to a typical warm temperate deciduous broad-leaved forest. The geographical composition of the flora shows an obvious transition pattern. In addition to the European Siberian species composition, it can also the flora of the Black Sea and Central Asian steppe flora (Committee 1995). Forest vegetation types are mainly natural secondary forest vegetation, followed by artificial forest one. According to TWINSPAN analysis and characteristic species screening, the six community types determined are abstract, and there is no fully determined species collocation and combination, just using these dominant indicator species and environmental factors to describe a community, and verify it with DCA and CCA methods respectively.

Betula platyphylla Suk. forest is the most extensive natural secondary forest, followed by mixed forests of *Betula platyphylla Suk.* and *Populus davidiana Dode* (Committee 1995). Both *Betula platyphylla Suk.* and *Populus davidiana Dode* belong to the pioneer tree species in the process of vegetation succession (Liu et al. 1998; Wang et al. 2019), and their ecological adaptability could be considered extremely strong. In particular, *Betula platyphylla Suk.* has obvious distribution characteristics in this area, as the most common warm temperate pioneer tree species in the middle and high altitude regions of the north. *Betula platyphylla Suk.* is only distributed at an altitude higher than 1500 m a.s.l. in this area. This could be because of its heliophilous and hydrophilous characteristics. Most of them are on the shoulder of the shady hillslope, and a small amount of them is distributed on the backslope. The soil moisture is significantly higher than that of the shrub grassland on the sunny hillslope, but it is significantly lower than that of the *Larix gmelinii (Ruprecht) Kuzeneva* plantation or the shrub grassland under the secondary forest of *Betula platyphylla Suk*. Due to the aspect factors and almost no human disturbance, the percentage of soil organic matter content is significantly higher than other forests or shrub grasslands, and it increases with the elevation. Therefore, the main limiting factor of *Betula platyphylla Suk.* distribution in this area is the mountain environment, including altitude, illumination, moisture content and soil organic matter content (Peterson 1998; Cumming 2002). One representative example is the research conducted by (Xu et al. 2015) in China, under humid alpine areas. These authors confirmed changes in leaf morphology, water viscosity and carboxylation efficiency with temperature, which, are subsequently affected by the altitude and aspect.

Among the six communities in TWINSPAN classification results, *Betula platyphylla Suk.* dominated communities accounted for two of them, which were *Betula-Potentilla* community and *Betula-Rosa* community respectively. The difference between the two communities was mainly manifested as undergrowth. The undergrowth of *Betula-Potentilla* community was subalpine shrubs and herbs dominated by *Epilobium angustifolium Linn.*, *Potentilla fruticosa Linn.*, *Elymus dahuricus Turcz.*, and other obvious pioneer species (Lin 1991). These pioneer species need not only a certain amount of light, but also suitable soil moisture, and also have obvious strong diffusion ability in a certain altitude range (Turrill 1953). Therefore, *Betula-Potentilla* community is located in a semi-shady slope with an altitude of more than 1800 m (It should be emphasized here that a few sampling points of *Betula-Potentilla* community are mixed forests of *Betula platyphylla Suk.* and *Larix gmelinii (Ruprecht) Kuzeneva*, which follow a rule that the proportion of *Betula platyphylla Suk.* is higher and higher with the increase of altitude, while that of *Larix gmelinii (Ruprecht) Kuzeneva* is the opposite). The undergrowth vegetation in *Betula-Rosa* community is composed of shrubs and herbs such as *Rosa xanthina Lindl.* and *Corylus mandshurica Maxim.* and other shade-resistant transitional vegetation in the back- and footslope positions. Furthermore, in addition to the pioneer or transitional species that are unique to *Betula-Potentilla* community or *Betula-Rosa* community, there are also a significant number of overlapping species in the two communities, such as *Phaenosperma globosa Munro ex Benth.*, *Carex doniana Spreng.* and some other herbaceous plants, they have a wide niche and can survive in complex and diverse environments (Dragon and Barrington 2009). Geographically, the community is widely distributed on altitude gradients (1400–2000 m), most of them appear on shady hillslopes, and there are also very few sampling points on semi-shady hillslopes, which are only distributed on the shoulder or in the backslopes. In summary, it can be seen that the undergrowth vegetation of *Betula-Rosa* community has partially or completely completed the conversion from pioneer species to transitional species. However, *Betula-Potentilla* community located in the high altitude area is still occupied by pioneer species.

Larix gmelinii (Ruprecht) Kuzeneva forest is the largest and most widely distributed plantation tree species in the region. Since 1979, the stand management and vegetation succession for 40 years up to the investigation date, as well as the closure management and protection from human interference have also lasted for more than 20 years (Committee 1995). The *Larix gmelinii (Ruprecht) Kuzeneva* community has developed into a near-natural state. Due to the high requirements of *Larix gmelinii (Ruprecht) Kuzeneva* on soil conditions, it not only needs a certain amount of soil water, but also needs good drainage, and is born in the deep and fertile soil layer (Leng et al. 2008). Therefore, after 20 years of natural succession, the *Larix gmelinii (Ruprecht) Kuzeneva* forest in *Larix-Carex* community has developed to appear only in the backslope of the shady hillslope, it is close to and under the *Betula platyphylla Suk.* forest. The reason is that the natural secondary forest (*Betula platyphylla Suk.*) in this area has been developing for a long time, the biodiversity is increasing, and the organic matter content and other nutrients in the soil are accumulating, which provide sufficient nutrients for the natural growth of *Larix gmelinii (Ruprecht) Kuzeneva* forest. From Table 3, it can be noted that the organic matter content of *Betula-Rosa* community and *Larix-Carex* community, especially the community dominated by *Betula platyphylla Suk.*, is significantly higher than that of other forests and shrub grassland. As we mentioned above, the growth of *Larix gmelinii (Ruprecht) Kuzeneva* needs wet soil with good drainage performance. However, in the mountainous area where the rainfall is concentrated in time and space, the position of footslope is easy to have poor drainage, high soil humidity, even waterlogging disaster, which affects the growth and development of deep root vegetation (Kastanek 1988; Berry et al. 2016). Therefore, the natural development of *Larix gmelinii (Ruprecht) Kuzeneva* forest in the backslope is promoted by the smooth drainage, appropriate humidity and nutrients, while the footslope position is occupied more by shrub grassland. Furthermore, due to its distribution characteristics on the hillslope, the sunlight is not as ample as that of shoulder positions. The undergrowth vegetation of *Larix gmelinii (Ruprecht) Kuzeneva* is dominated by herbaceous vegetation such as *Carex doniana Spreng.*, *Brachypodium sylvaticum (Huds.) Beauv.*, *Saussurea japonica (Thunb.) DC.* and *Vicia sepium Linn. unijuga A. Br.* Moreover, the shrub and herb coverage was significantly lower than *Betula platyphylla Suk.* community.

As with the sunny hillslopes in most northern mountainous areas of China, except for a small area of artificially planted *Pinus tabuliformis Carr.* forest in some areas (due to serious human interference), most areas are natural shrubs or grasslands (Jintun et al. 2013; Wu et al. 2018), but the regional and soil texture make the vegetation composition significantly different. In the fooslope position of the shady hillslope in this area, there is also a distribution of shrub grassland (see Table 1 and Table 3). Therefore, shrub grassland was divided into three communities according to TWINSPAN vegetation classification. We found *Armenia-Poa* community in the low altitude area (1220–1380 m), with obvious inclination difference (5–45°), poor soil with more gravel, rare species composition and more bare land, among which *Poa annua Linn.*, *Caragana acanthophylla Kom.*, *Armeniaca sibirica (Linn.) Lam.* and other barren tolerant species are dominant. Because the distribution of this community is low in elevation and mostly in the footslope position, compared to other communities, the bad ecological environment is severely disturbed by construction activities such as large-scale events. (Gabarrón-Galeote et al. 2013). In addition, *Pteridium-Juncus* community is an alpine meadow community with *Gallium*, *Sanguisorba officinalis Linn.* and *Pteridium aquilinum (Linn.) Kuhn var. latiusculum (Desv.)Underw.ex Heller* as the main species were found in the middle and high altitude areas (1520–2040 m), and a small number of cold-resistant alpine shrubs such as *Potentilla fruticosa Lin.* and *Lespedeza bicolor Turcz.* appeared in some sampling points, and the content of soil organic matter and biodiversity increased with altitude. The community of *Spiraea-Artemisia* community is the most widely distributed and numerous shrub herbage sample plot in this area, and there is no special distribution rule from the data, but from the analysis results of TWINSPAN, *Artemisia carvifolia Buch.-Ham. ex Roxb.* and *Spiraea fritschiana Schneid.* are the characteristic species of this community. From the results of indicator specifications analysis, in addition to these two species, *Polygonum divaricatum Linn.* and *Scutellaria baicalensis Georgi* are also regarded as characteristic species of the community, but these species are all without major characteristics, that is, they can thrive in fertile soil and survive in poor soil (Lin 1991). In particular, *Artemisia carvifolia Buch.-Ham. ex Roxb.* can be seen from the DCA analysis (Fig. 4, above) that it is closest to the center of the figure, which shows that *Artemisia carvifolia Buch.-Ham. ex Roxb.* exists in most of the investigated sampling points, including some woodlands, but only in quantity difference. Therefore, logically speaking, *Spiraea-Artemisia* community is more like the remaining community of these grouping and classification methods, which has loose requirements for altitude, light, water and nutrients.

4.2. Limiting factors of six communities

Table 5
Correlation between the environmental factors of plant communities in the investigated area and the first two ordination axes of CCA (canonical correspondence analysis).

Environmental variables	Axis 1	Axis 2
Altitude	-0.24*	-0.79***
Organic matter	-0.42	-0.52*
Aspect	-0.79**	0.17
Soil porosity	-0.73*	0.40**
Soil bulk density	0.63*	-0.04
Slope position	0.46*	0.06
*P < 0. 05, **P < 0. 01, ***P < 0. 001		

Table 6
Correlation among six environmental variables in the study area.

	Altitude	Organic matter	Aspect	Soil porosity	Soil bulk density	Slope position
Altitude	1					
Organic matter	0.51**	1				
Aspect	-0.11	0.20	1			
Soil porosity	-0.04	-0.01	0.43**	1		
Soil bulk density	-0.26*	-0.29**	-0.35**	-0.62**	1	
Slope position	-0.11	-0.27**	-0.15	-0.12	0.16	1
*P < 0. 05, **P < 0. 01						

Although there is a certain degree of overlap in the ordination space among different groups, CCA confirmed the community types from TWINSPAN classification. CCA analysis of this area shows that the most significant correlation with the first axis of CCA is the slope direction (r = -0. 79, P < 0. 01), soil porosity (r= -0.73, P < 0.05) and soil bulk density (r = 0.63, P < 0.05) (Table 5). The correlation between environmental variables (Table 6) shows that soil porosity is positively correlated with aspect (r = 0.43, P < 0.01), and negatively correlated with soil bulk density (r=-0.62, P < 0.01). Therefore, the first axis of CCA is closely related to the aspect and soil porosity, and aspect directly affects the evaporation and conservation of moisture on the slope (Miller and Poole 1983), and the soil moisture can be controlled by the vegetation type on the soil surface (Moustafa and Zaghloul 1996). Therefore, the first axis of CCA represents the moisture gradient.

The second axis of CCA is closely related to the altitude and the percentage of organic matter content, and the positive correlation between the altitude and the percentage of organic matter content is significant ($r = 0.507$, $P < 0.01$). This is because the altitude affects the regional average temperature and precipitation in the mountain area (Dai and Huang 2006), promotes the accumulation of organic matter. In addition, the high altitude area is rarely visited, which greatly reduced the impact of human interference. Under various factors, the soil organic matter increases with elevation. Although there is a certain correlation between soil porosity and the second axis, it fails to pass the significant correlation test with altitude or organic matter content, so the second axis represents the altitude gradient.

To sum up, due to the topography limitations of different communities, various limiting factors restrict their development and diffusion. The first three communities (i.e. shrubland and grassland) are widely distributed in sunny and semi-sunny hillslopes under the influence of light factors and soil compactness, compared to forest stand, the requirement of soil water and nutrient is lower. Among them, *Armenia-Poa* community exists in the low altitude and low-slope position area, therefore, the spatial variation of soil moisture in different hillslope positions is the main factor limiting the development of the community (Yang et al. 2012). *Pteridium-Juncus* community is distributed in the middle and high altitude area, and the content of soil organic matter is also the main factor restricting its distribution. *Spiraea-Artemisia* community is the most widely distributed, and no obvious topographic factors are restricting the development of *Spiraea-Artemisia* community. The remaining three communities are all forest (including natural forest and artificial forest), and the limiting factors of the forest community are more strict than shrubland and grassland. First, all the three forest communities are distributed on the shady or semi-shady hillslopes, which have higher requirements for soil moisture and soil nutrients. At the same time, they have different requirements for altitude, aspect and soil porosity. For example, *Betula-Potentilla* community is a typical pioneer community, which only appears on the upslope position above 1800 m altitude, so its main topographic limiting factors are aspect, altitude and slope position. *Betula-Rosa* community is a typical transitional community, with a wide range of altitude distribution, and it appears on the shoulder and backslope position. Its limiting factors are the same as all other forest communities, with the only aspect. The last *Larix-Carex* community belongs to the artificial forest, and the main limiting factor is the slope position because the *Larix-Carex* community only "depends" on the slope position under the *Betula platyphylla Suk.* community, which has higher requirements on the original organic matter content of the soil, and even a small part of the *Larix gmelinii (Ruprecht) Kuzeneva* community and the *Betula platyphylla Suk.* community on the hillslope have the relationship between fusion and competition, and further from the mixed forest. In the mixed forest, *Betula platyphylla Suk.* is the main species in high altitude area, while *Larix gmelinii (Ruprecht) Kuzeneva* species are dominant in the low and medium altitude areas.

Different vegetation and communities have their fixed distribution areas, which can be directly seen from CCA species ordination of the study area (Fig. 4) and TWINSPAN classification results superimposed on CCA (Fig. 5). The variance of the two CCA axes was 15.9%, These low values can be attributed to high noise levels typical of species-abundance data (Ter Braak 1986). Furthermore, in order to test the significance of the environment variables, the eigenvalues of CCA and DCA are compared. The results show that the eigenvalues of the CCA axis are lower than those of DCA, indicating that important explanatory site variables were not fully included in the analysis. On this point, most scholars agree on the interpretation of Palmer (1993)and

(Vogiatzakis et al. 2003). CCA is an interpretative technology, which aims to separate subsets of environmental factors, to explain relevant gradients in several dimensions. Therefore, because it is a constrained ordination technology when additional environmental variables are used, the interpretable variables will increase.

4.3. Vegetation dynamics

It is generally believed that the mixed forest is superior to the single stand in terms of productivity, ecological function and stability (Xu et al. 2020; Zhou et al. 2020). In boreal forests, Shanin et al. (2014) showed that the tree species composition in the succession process of different stands depends on the site fertility and the initial proportion of tree species, and in the *Betula-Pinus* mixed forests, the proportion of *Pinus* trees increased in the poorer soils and decreased in the fertile ones. Taking into account the forest history in northern China, some scholars infer that the extension of *Betula* forests will increase but not the *Pinus* ones in the future scenarios (Wang et al. 2017). However, in the Chongli area, the composition of the two main tree species varies with the altitude. This could be mainly affected by the initial proportion of tree species and soil fertility at the initial stage of afforestation. As shown in Table 3, the content of organic matter closely related to soil nutrients reaches the highest value (9.7 ± 2.1%) below 1700 m, which greatly increases the survival rate of artificial afforestation. In addition, the current afforestation from low areas to the plateau and the principle of operability, the altitude of 1700 m became the dividing line of afforestation. Above this critical line, the initial density and survival rate of this plantation decreased with the increase of altitude. Therefore, in areas below 1700 m altitude, the *Larix gmelinii (Ruprecht) Kuzeneva* plantations would tend to migrate to the shoulders and squeeze the living space of *Betula platyphylla Suk.* natural forests, dominating in the mixed zone gradually. However, areas above 1700 m altitude, the opposite can occur. On the other hand, *Betula platyphylla Suk.* community below 1700 m altitude (here refers to *Betula-Rosa* community) not only faces an external competition but also undergrowth vegetation in the community changes. Teixeira et al. (2020) in the Atlantic forest demonstrated that forest age is the key factor of community succession, and the recovery rate of soil function is often faster than that of aboveground vegetation, because of the rapid recovery of soil function at the beginning of succession. This improves soil moisture and nutrient status and promotes the germination and growth of new species (Chua and Potts 2018; Qiu et al. 2018). This is consistent with the growth status of aboveground vegetation of *Betula-Rosa* community (the prediction of forest age by DBH and tree height) and soil nutrient status (mainly refers to the content of soil organic matter). There is an obvious transition of species such as *Rosa xanthina Lindl.* and *Corylus mandshurica Maxim.* and other shade-resistant transitional vegetation. Therefore, *Betula-Rosa* community prepared for the next succession stage under the coexistence of external pressure and internal driving force.

The growth potential of specific community vegetation is mainly limited by climate and other related environmental factors (Kucsicsa and Bălteanu 2020). However, in recent years, with the enhancement of human activities and land-use intensity, natural regeneration and soil properties are prevented (Stöhr 2007). The present upper forest limit is less than the potential limit (Holtmeier and Broll 2007). In the Chongli mountain area, the growth potential of *Armenia-Poa* community, which is dominated by low shrubs and herbs, is far from fulfilling its growth potential below 1500 m altitude. It is not only affected by land use and site conditions, but also by serious human disturbance. Therefore, barren tolerant herbaceous plants are dominant in the *Armenia-Poa* community, and a small amount of *Armeniaca sibirica (Linn.) Lam.* grows in some areas. Here, we mainly discuss the alpine meadow community with *Pteridium-Juncus* community type. We find that the transition species such as *Pteridium aquilinum (Linn.) Kuhn var. latiusculum (Desv.)Underw.ex Heller*, *Juncus effusus Linn.* and *Galium linearifolium Turcz.* are dominant in the community (van der Knaap and van Leeuwen 1995; Oh et al. 2010), and along the higher altitudes, the dominant status of these transitional species. This is very similar to the transitional type of arbor community (*Betula-Rosa* community) in this area, only existing in high altitude areas. From soil nutrients and physical properties, soil organic carbon increases with the increase of altitude, and bulk density of surface soil decreases with the increase in altitude. Both of these soil properties play an important role in driving the succession of vegetation communities. Therefore, we suppose that the community succession in this area occurs from the top to bottom in terms of soil and vegetation, which is not only determined by the perennial accumulation of soil organic carbon and the internal driving force of soil microbial community transformation on vegetation succession (Shao et al. 2019) but also the artificial disturbance of afforestation activities and land use patterns. This also plays an important role in the speed and direction of community succession.

To sum up, the succession law of *Betula-Rosa* community and *Pteridium-Juncus* community in high altitude area is earlier than that in low altitude area. We do not rule out that the influence of human factors is greater than that of climatic factors and biological factors in low altitude areas. The initial stage of artificial afforestation has made a great contribution to the vegetation restoration and biodiversity restoration in this area. However, the influence of artificial afforestation may hinder the succession speed and direction of original secondary communities in a certain altitude range, which is especially obvious in the mixed forest belt with medium altitude gradient. It would be necessary to repeat this assessment after the WOG to see if big events can modify this trend or not.

4.4. Uncertainty of the relationship between environment and vegetation

In this paper, in addition to the influence of topography and geomorphology on the distribution of ecosystem vegetation community, environmental variables (including rainfall, surface temperature, soil moisture) under the influence of climate should not be underestimated (Archibold 1995; Giaccone et al. 2019). The aspect is related to microclimate (aspect is indirectly related to solar radiation, solar radiation affects temperature and humidity), but there is no reliable precipitation and surface temperature data in the Chongli mountain area, so it is excluded that other climate data can be included in the ordination. However, further research on the influence of climate factors in the region will be carried out in the future.

In addition, although the inclination is measured and analyzed as a topographic factor, it has a low correlation with ordination axes. On the other hand, due to the time difference of weather, the soil moisture content of each plot cannot be quantified at the same time. Therefore, the two environmental factors are not considered in the model generation. Grazing also has a certain impact on the plant diversity and richness in mountain areas, but this area benefits from the policy of returning farmland to forest and grazing to grass (Pulido et al. 2018). The forest and grassland in the mountain area are in natural growth state in the past 20 years, so the threat of grazing on vegetation species can be ignored.

5. Conclusions And Final Remarks

This research considers the floristic composition of vegetation in Chongli Country, the core area of the 2022 Winter Olympics, which is affected by the change of topography and land uses for thousands of years. In the current stage, shrubs and herbaceous vegetation species in mid-to-high altitude areas generally show the process of transformation from a pioneer community to transitional community in the competition. On the other hand, *Larix gmelinii (Ruprecht) Kuzeneva* plantations and *Betula platyphylla Suk.* natural forests compete and integrate on the same slope, trending to form mixed forests. The natural forests above 1700 m altitude migrate downhill, while the plantations at 1400–1700 m altitude migrate uphill. However, in the low altitude area (below 1400 m) were considered as a vulnerable environmental environment, the plant diversity and vegetation coverage in this area exhibited significantly lower than those in other areas (Fig. 6), and the poor soil water conservation capacity is not enough to form a resistant vegetation community in the state of natural restoration. During the Winter Olympic Games, human disturbances (including venues, tracks and roads construction) will be further intensified. The resistance of vegetation restoration will not be limited to the low altitude areas below 1400 meters, and the vegetation communities in the middle and high altitude areas (above 1400 m) will be affected as well. How to strengthen the stress resistance of vegetation community, and how to build and restore the vegetation community quickly after the major event is the problems that we need to solve urgently.

In most of the vegetation studies in the Yin Mountains, especially in Chongli area, the relationship between topography variables and vegetation is mostly described qualitatively, lacking the basis of quantitative research. In this study, multivariate analysis techniques were used to determine the distribution patterns of the communities, and the results are associated with the measured environmental variables. Some important environmental factors that can be measured and plotted are determined by providing vegetation mapping units. Therefore, these data will be used as the first step to predict the distribution of vegetation communities in the Yin Mountains, and this methodology can also be used to map other mountain vegetation communities in Yin Mountains.

The managers of this area (especially Chongli City, the core area of the Winter Olympic Games) need to have a detailed understanding of the floristic composition and ecological distribution of the vegetation communities, which not only provides the basis for vegetation monitoring and mapping, but also helps to assess the impact of human disturbance (construction of venues, tracks and roads, etc.) on the vegetation communities, and provides instructive opinions for promoting the ecological restoration and construction after the Winter Olympic Games at 2022.

Annex I Names and abbreviations of the species

Number	Species	Abbreviation
1	*Ostryopsis davidiana Decaisne*	*Ostryops*
2	*Artemisia*	*Artemisi*
3	*Spiraea fritschiana Schneid.*	*Spiraea*
4	*Scutellaria baicalensis Georgi*	*Scutella*
5	*Carex doniana Spreng.*	*Carex sp*
6	*Aconitum barbatum Pers. var. puberulum Ledeb.*	*Aconitum*
7	*Saussurea japonica (Thunb.) DC.*	*Saussure*
8	*Armeniaca sibirica (Linn.) Lam.*	*Armeniac*
9	*Larix gmelinii (Ruprecht) Kuzeneva*	*Larix*
10	*Brachypodium sylvaticum (Huds.) Beauv.*	*Brachypo*
11	*Sphaerophysa salsula (Pall.) DC.*	*Sphaerop*
12	*Lespedeza bicolor Turcz.*	*Lespedez*
13	*Ulmus pumila Linn.*	*Ulmus*
14	*Imperata cylindrica (Linn.) Beauv.*	*Imperata*
15	*Betula platyphylla Suk.*	*Betula p*
16	*Phaenosperma globosa Munro ex Benth.*	*Phaenosp*
17	*Poa annua Linn.*	*Poa*
18	*Agrimonia pilosa Ledeb.*	*Agrimoni*
19	*Sanguisorba officinalis Linn.*	*Sanguiso*
20	*Vicia sepium Linn.*	*Vicia*
21	*Geranium wilfordii Maxim. wilfordii Maxim.*	*Geranium*
22	*Vicia sepium Linn. unijuga A. Br.*	*Vicia*
23	*Rosa xanthina Lindl.*	*Rosa*
24	*Kochia scoparia (Linn.) Schrad.*	*Kochia*
25	*Thalictrum aquilegifolium Linn. var. sibiricum Regel et Tiling*	*Thalictr*
26	*Potentilla chinensis Ser.*	*Potentil*
27	*Viola verecunda A. Gray*	*Viola*
28	*Serratula centauroides Linn.*	*Serratul*
29	*Corylus mandshurica Maxim.*	*Corylus*

Number	Species	Abbreviation
30	*Geum aleppicum Jacq.*	*Geum*
31	*Pteridium aquilinum (Linn.) Kuhn var. latiusculum (Desv.)Underw.ex Heller*	*Pteridiu*
32	*Polygonum divaricatum Linn.*	*Polygonu*
33	*Rubus corchorifolius L. f. corchorifolius L. f.*	*Rubus*
34	*Juncus effusus Linn.*	*Juncus*
35	*Populus davidiana Dode*	*Populus*
36	*Rubia cordifolia Linn. cordifolia Linn.*	*Rubia*
37	*Elymus dahuricus Turcz.*	*Elymus*
38	*Caragana acanthophylla Kom.*	*Caragana*
39	*Hemistepta lyrata (Bunge) Bunge*	*Hemistep*
40	*Potentilla fruticosa Linn.*	*Potentil*
41	*Epilobium angustifolium Linn.*	*Epilobiu*
42	*Heteropappus hispidus (Thunb.) Less.*	*Heteropa*
43	*Galium linearifolium Turcz.*	*Galium*
44	*Sophora flavescens Alt.*	*Sophora*
45	*Sonchus arvensis Linn.*	*Sonchus*
46	*Asparagus cochinchinensis (Lour.) Merr.*	*Asparagu*
47	*Conyza canadensis (Linn.) Cronq.*	*Conyza*
48	*Pogonatherum crinitum (Thunb.) Kunth*	*Pogonath*

List Of Abbreviations

TWINSPAN: Two-way indicator species analysis

MBA: Market basket analysis

DCA: Detrended correspondence analysis

CCA: Canonical correspondence analysis

GTGP: Grain to Green Program

SOC: Soil organic carbon

ISA: Indicator species analysis

IV: Indicator value

RA: Relative abundance

RF: Relative frequency

DBH: Diameter at breast height

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Authors' contributions

Hengshuo Zhang: Field investigation, Data Curation, Writing-Original draft preparation. Tonggang Zha and Yang Yu: Conceptualization, Writing and Supervision. Xiaodong Ji, Supervision. Jesús Rodrigo-Comino: Writing-Reviewing & Editing.

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Figures

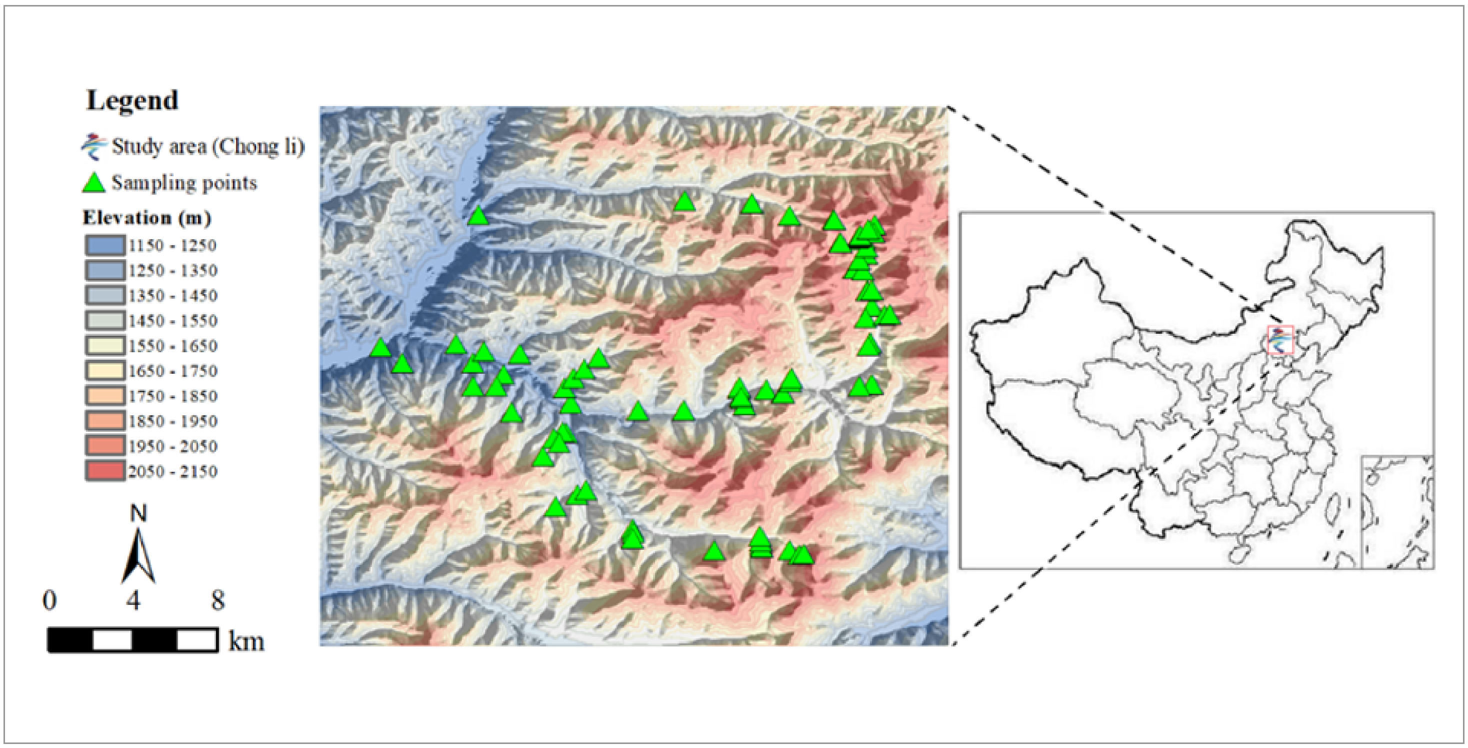

Figure 1

Study area and sampling points

Figure 2

Field sampling points. 1: sampling point of Betula platyphylla Suk. forest; 2: sampling point of Larix gmelinii (Ruprecht) Kuzeneva plantation; 3 and 4: sampling points of shrubs and herbs.

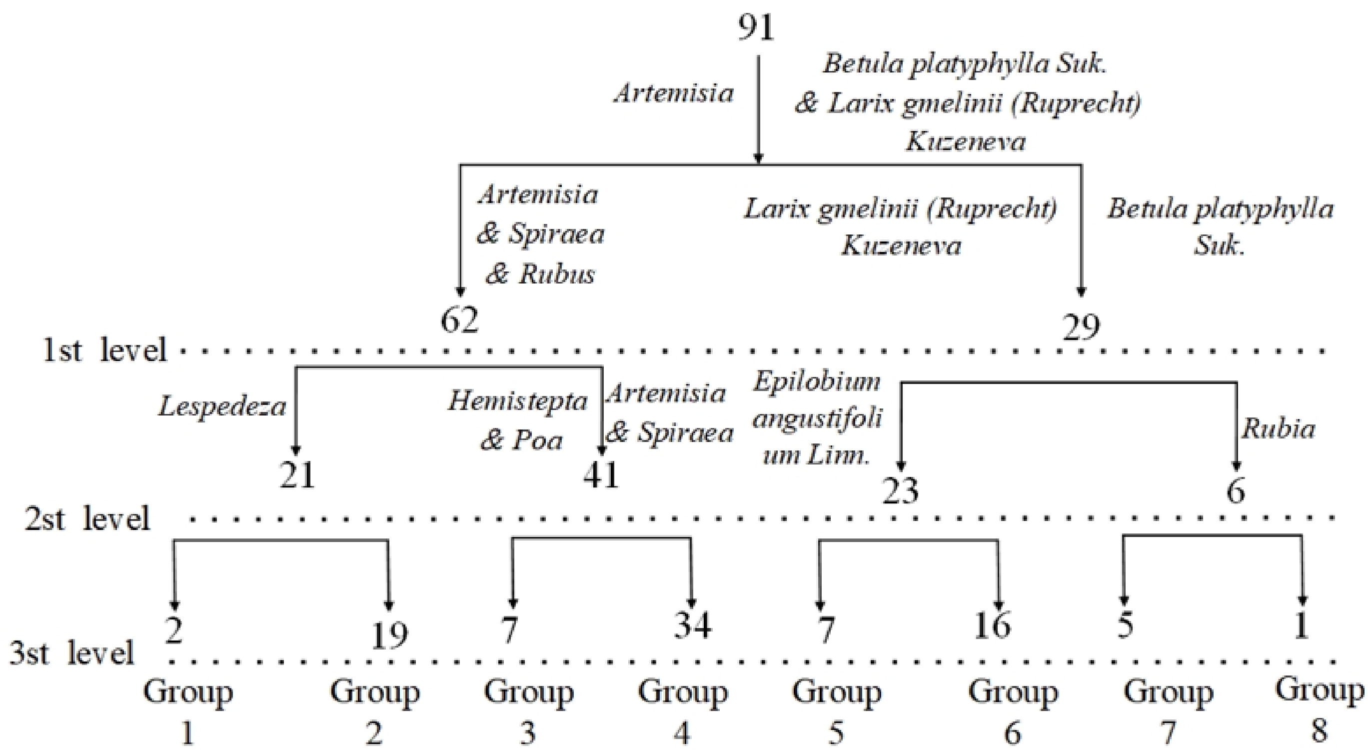

Figure 3

Dendrogram derived from the TWINSPAN (two-way indicator species analysis) of the vegetation data collected at the study sites.

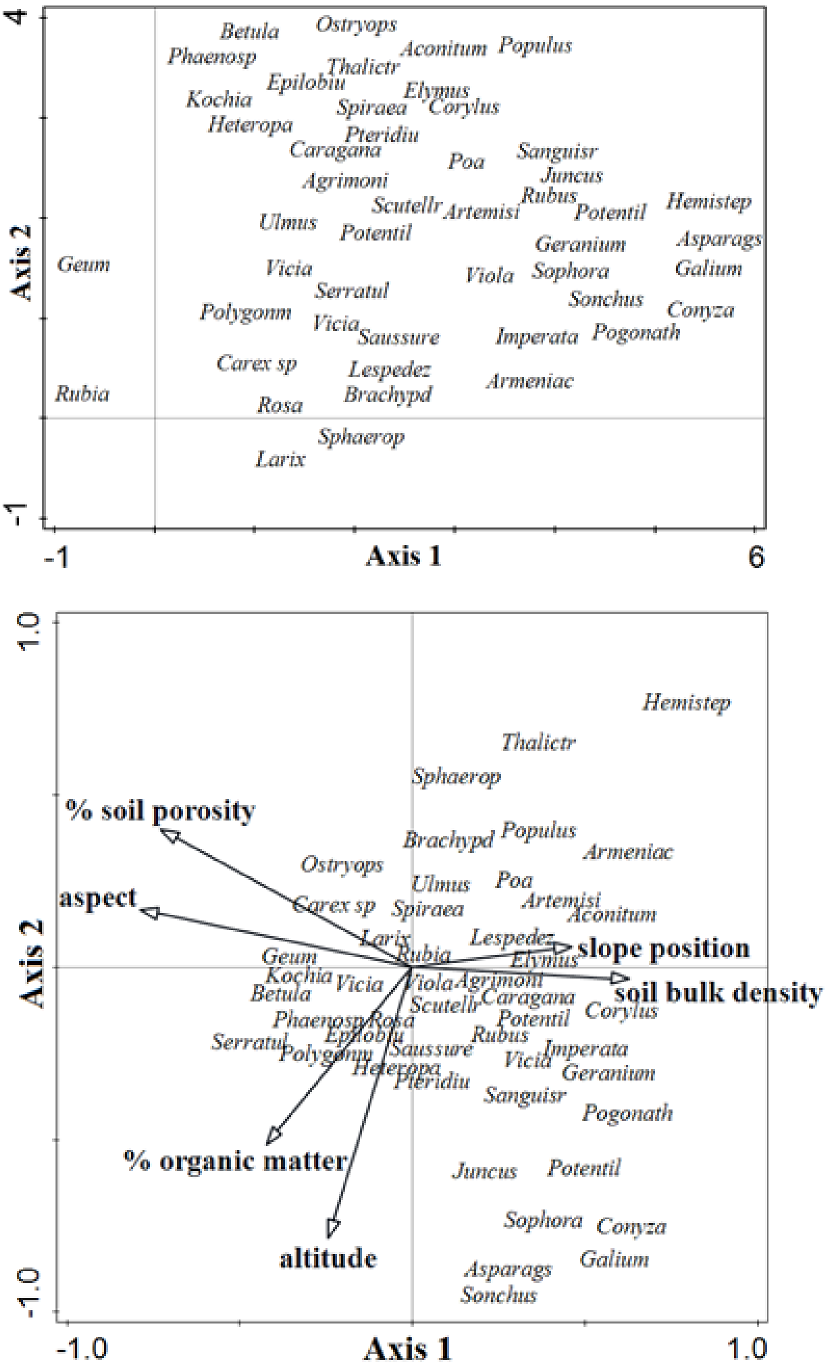

Figure 4

DCA (detrended correspondence analysis, above) and CCA (canonical correspondence analysis, below) species ordination. The length of the vector is proportional to its importance and the angle between two vectors reflects the degree of correlation between variables. The angle between a vector and each axis is related to its correlation with the axis. For species abbreviations, see Appendix I.

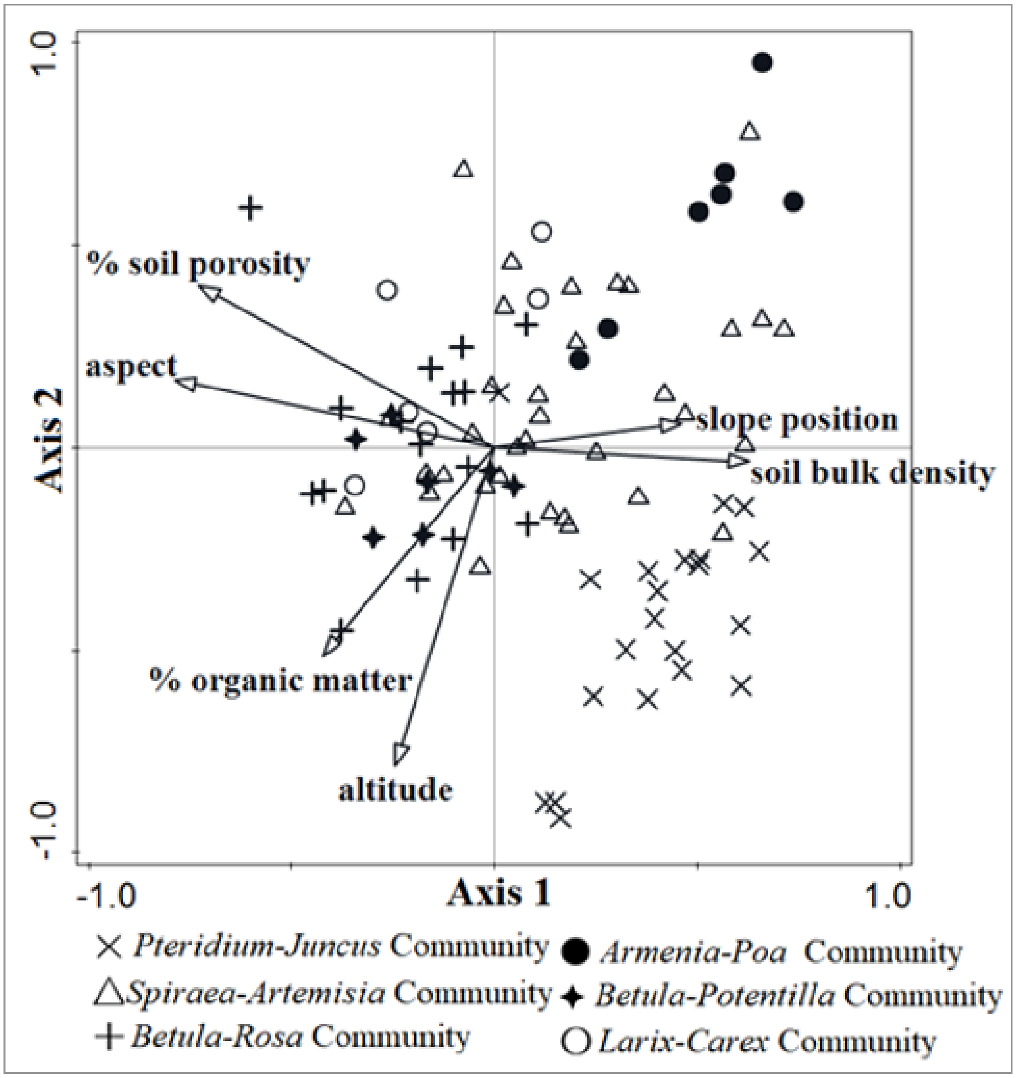

Figure 5

CCA (canonical correspondence analysis) sampling points ordination of the study area with the community types derived from TWINSPAN (two-way indicator species analysis) superimposed. The vectors represent environmental variables. The length of the vector is proportional to its importance and the angle between two vectors reflects the degree of correlation between variables. The angle between a vector and each axis is related to its correlation with the axis. For species abbreviations, see Appendix I.

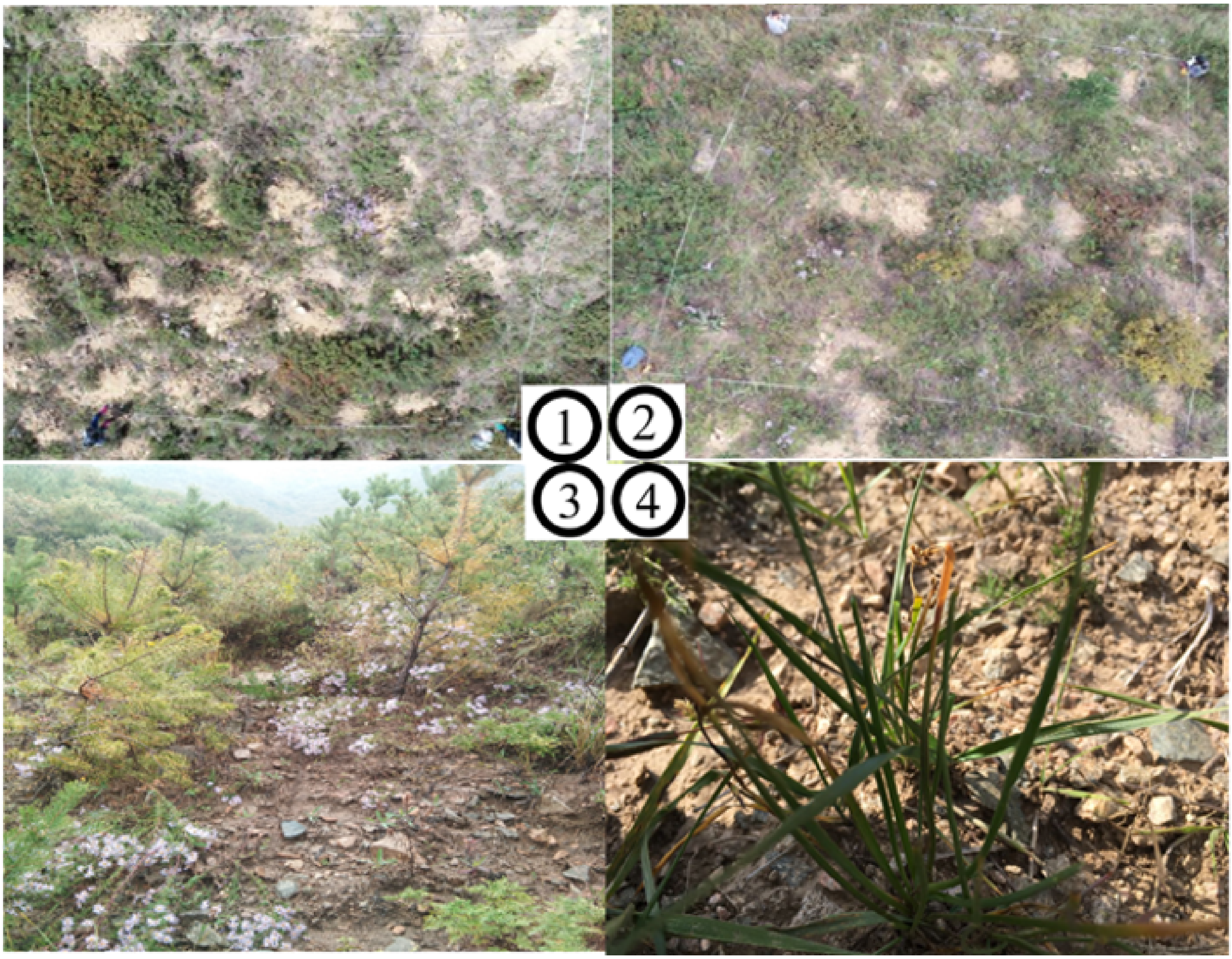

Figure 6

Large number of bare ground and soil surface gravels on the slopes of shrub and herb sampling points below 1400 m (1 and 2 are aerial photos, and 3 and 4 are close shots).