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Alpine Vegetation Patterns on a Small Hillside Near Permafrost Lower Limit in the Qilian Mountians, Northwest China

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Abstract: Using sample plot and transect methods, alpine vegetation distribution features, such as types, heights and coverage etc., are investigated and 102 soil samples at 20cm depths are acquired for nutrients test on or near a small hillside, in the alpine meadow regions near permafrost lower limit, Qilian Mountains, Northwest China, to know about the responses of the vegetation pattern to its niches. The results show that, the vegetation types, vegetation coverage and soil nutrients contents at 20cm depth, such as C, N, P and K, are different at the different sampling points because of its different slope and aspect, on the small hillside. From the mountaintop to the valley of the hillside, where the ground changed from permafrost to seasonal frozen soil, the vegetation coverage, vegetation heights and the content of the soil nutrients components at 20cm depth reduced along with the hillside slope rising. The content of organic C, total N, ratio of C to N and ratio of C to P, are all negative linear with aspect of the sampling points on this small hillside. When the turfs of the alpine meadow were removed, the land surface was inhabited by some low-grade vegetations rapidly and the vegetation coverage and all the soil nutrients content at 20cm depth were much lower than those at the undisturbed area. The soil nutrients content at 20cm depths in these alpine meadow regions is very high. The atmospheric CO_2 concentration near land surfaces in these regions was also much higher than the global averaged value.

Key words: Alpine meadow, correlation, soil nutrients, turf, vegetation distribution

INTRODUCTION

Vegetation degradation in permafrost regions, where the vegetation is vulnerable, has been widely known (Tutubalina and Rees, 2001), due to the global warming and human activities. In the regions near the permafrost lower limit, the degradation and succession processes of the vegetation are more complex (Jiuyi *et al*., 1997). Vegetation distribution in alpine cultural landscapes is characterized by spatially inhomogeneous environmental conditions concerning climate, soils, geology as well as frequency and intensity of disturbance (Bianca *et al*., 2002). The physical environment is often regarded as one of the most important factors controlling the spatial heterogeneity of the landscape in mountain areas (Bolstad *et al*., 1998; Fischer, 1990; Tappeiner *et al*., 1998). The ecological space of a vegetation type corresponds to its fundamental niche; in contrast to the fundamental the realised niche is defined through interaction with other vegetation types; finally the geographic space of vegetation types or species is equal to its spatial distribution, caused by natural factors and human impact (Bianca *et al*., 2002).

Analyzing the habitat of a vegetation type means relating its geographic space to those environmental site factors that best represent the realised niche (Guisan *et al*., 1998). Since the realised niche and geographic space of a vegetation type in a high mountain environment is closely related to topographic relief (Allen *et al*., 1995), it is likely that landform parameters like elevation, slope or aspect are important input parameters for spatial analysis and modelling of vegetation distribution in mountain landscapes. In a complex system of site factors topography is the major (indirect) factor for vegetation distribution (Barrio *et al*., 1997; Gottifried *et al*., 1999). Thus, topography creates a patchwork-like pattern of small scale habitats and realised niches within the ecological space (Bianca *et al*., 2002). Besides natural environmental factors, the history of human impact in terms of agricultural land use and animal husbandry (Bianca *et al*., 2002), but also former and recent natural disturbance (avalanches, rockfall, mudslides, partly related to human impact, thus being only semi-natural disturbance factors) play a major role for the distribution of vegetation types (Tappeiner *et al*., 1998). Here we present the initial

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investigation results of the relationships between the distribution of alpine vegetation and its niches, such as topographic factors, soil nutrients and human disturbance, etc., near permafrost lower limit, in the Qilian Mountains, Northwest China.

MATERIALS AND METHODS

In Fig. 1 the research hillside (38°27′32″N, 99°33′22″E, Fig. 1c) covered with alpine meadow, with an altitude ranges from 3360 to 3440 m asl, lower limit of permafrost, lies in the midstream of Yeniugou river with a drainage area of about 4589 km^2 (Fig. 1b). The altitude of this watershed ranges from 2835 to 4891 m asl, with an averaged elevation value of 3929 m. The number of glacier is about 165 and about 89% drainage area is covered with permafrost in the Yeniugou river watershed, where the alpine meadow region, with a upper limit of 4000 m asl, is about 70% area of the watershed. Yeniugou river is the largest tributary of the Heihe river, which originates from the Qilian Mountains, Northeast of the Tibet Plateau (Fig. 1a), runs through the Hexi Corridor and scatters in the deserts, is one of the largest inland rivers in China, with a drainage area of 130,000 km^2.

According to the measured data from 1959 to 2004 at the Yeniugou meteorological station (38°27′31.1″N, 99°32′23.2″E, 3320 m asl, sunny slope), 1.2 km far from the research hillside, the averaged annual precipitation, averaged annual air temperature and the mean annul pan evaporation (ϕ20) is about 403.2 mm, -3.1°C and 1275.9 mm, respectively. While the averaged annual sunshine hours and the averaged yearly air pressure is about 2701.7 h and 680.6 m b, respectively.

The research hillside shown in Fig. 1c, with an area of not more than 2 h m^{-2}, is shady or semi-shady. At this small hillside, the vegetation distribution varies largely along with small changes of hillside slope, aspect or/and elevation. In the mountaintop, where the altitude is of 3440 m asl, permafrost develops very well and the frozen polygon distributes widely. In the middle part of the hillside, the frost thawing heaving appears. While in the valley of the hillside (3360 m asl), seasonal frozen soil distributes.

The vegetation coverage, vegetation types, slope, aspect and soil nutrients at the 20 cm depth were investigated using sample plot techniques and transect methods (Fig. 1c). The size of each sample plot was about 5m¡Á5m. At each sample plot, 3 soil nutrient samples were collected in September, 2005. The soil nutrients content, such as organic C, total N, total P, etc., were all tested at the laboratory. The soil at the 20cm depth was loam soil.

The sample plots from No. I to No. IV, were used for contrasting the different vegetation distribution features

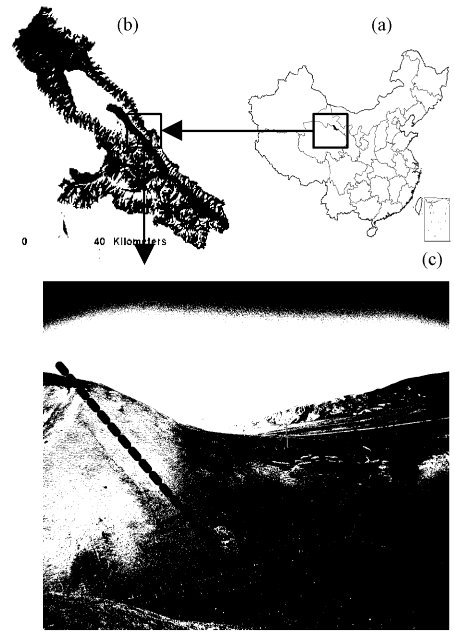
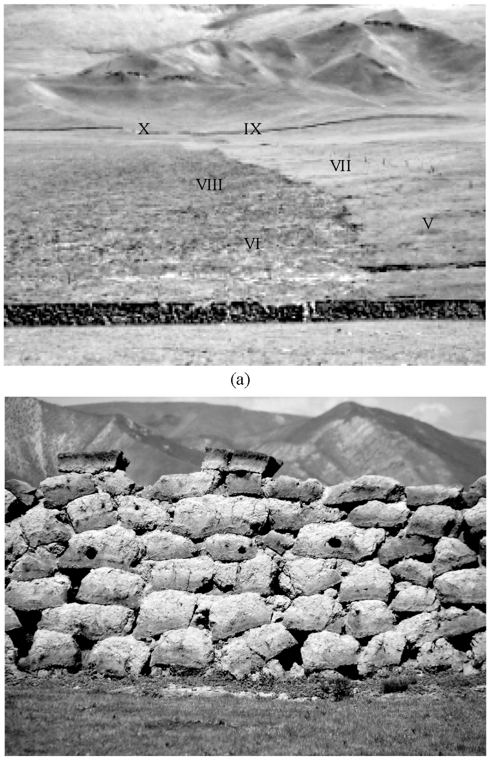


Fig. 1: Research sites map. a): presents the Yeniugou watershed in China, b): shows the research sites in the Yeniugou watershed and c): is the sketch map of the sampling points. In the c, the dashed line is the soil nutrients sampling line from mountaintop to hollow, the Roman numerals from I to IV present the vegetation sampling points on the hillside, while the Roman numerals from V to X show the sampling points at the two contrastive alpine meadow grounds and the turfs of one of them is removed

in the middle and lower part of the small hillside (Fig. 1c), where the vegetation coverage, heights and types were different, due to the different hillside slopes and aspects. The sample plots from No. V to No. X, lying in a flat grassland, 100m far from the research small hillside, were used to contrast the vegetation patterns in a natural and a disturbed alpine meadow ground (Fig. 1c and 2a). The turfs of the destroyed alpine meadow shown in Fig. 2a were used to build the enclosure shown in Fig. 2b, from the year 1970 to 1971.

For the sake of knowing about the variations of the vegetation distribution and soil nutrients near permafrost lower limit, from permafrost regions to seasonal frozen area, a sampling line (dashed line shown in Fig. 1c) with an averaged aspect about 82° was disposed. The distance between 2 sampling points was about 10 m and 36 total sampling points were deployed. At each sampling point, 2 soil samples at 20cm depths were acquired for nutrients



(a)
(b)

Fig. 2: The sample plots from No. V to No. X. a): is the contrasting photo between the natural and destroyed alpine meadow and the turves of the destroyed alpine meadow shown in a were used to build the enclosure shown in b, in the year from 1970 to 1971

test and vegetation type, height and coverage were also investigated. The hillside aspect of each sampling point was measured using Global Position System (GPS) and the side hill slope was also measured using compass.

RESULTS AND DISCUSSION

Vegetation patterns at the middle and lower parts of the small hillside: At the middle and lower part of the small hillside, the vegetation types and coverage are different largely at the different places (Table 1). At the sample plot I, *Carex moorcroftii Falc. ex Boott* is the dominant species and there are also some relatively high herb vegetation types, such as *Iris ensata Thunb.*, *Stellaria chamaejasme L.* and *Leontopodium nanum Hand.-Mazz.* etc. (Table 1). While at the sample plot II, there are only *Carex moorcroftii Falc. ex Boott* and some low-grade vegetation types. At the sample plot III, vegetation type is also versatile and many *Artemisia frigida Willd,* which is the dominant species with a total coverage of 14%, appear. At the sample plot IV, the *Carex moorcroftii Falc. ex Boott* is the dominant species which is similar to the sample plot I and II, while there are many *Leontopodium nanum Hand.-Mazz.* with a coverage of 22%, which is close to the coverage of the *Carex moorcroftii Falc. ex Boot* (Table 1). Different from at other sample plots, at the sample plot IV, *Stipa aliena Keng* appears with a coverage of 8%.

The height, size, number and coverage of a same vegetation species is different at the sample plot I~IV. For example, the height, size, number and coverage of *Iris ensata Thunb.*, *Stellaria chamaejasme L.*and *Leontopodium nanum Hand.-Mazz.*, which all appears at the sample plot I, III and IV, is different (Table 1).

The relationship between vegetation coverage and slope of the sample plot I to IV is negative, while with aspect of the sample plots, positive (Table 1), to some extent. That is to say, the vegetation coverage is negative linear with the ratio of hillside slope to aspect, to some extent, at the middle and lower parts of the small hillside, where the sunshine hours are more important than soil water content for vegetation growth.

Combing the measured data at the sample plot I to IV shown in Table 1 and 2, at the middle and lower parts of

Table 1: Vegetation types of the sample plots from No. I to No. VI on a small alpine meadow hillside, September 2005

				Iris ensata Thunb.			*Stellaria chamaejasme* L.			*LeontopdoiumnanumHand.-Mazz.*		
Sample Plots	Slope (°)	Aspect (°)	Coverage (%)	Vegeta. No.	Heigths (cm)	Coverage (%)	Vegeta. numbers	Heigths (cm)	Coverage (%)	Vegeta. numbers	Heigths (cm)	Coverage (%)
I	32	91	50	23	22	4	47	10	3	148	10	3
II	8	25	45									
III	16	127	48	38	22	8	18	18	4	210	12	8
VI	5	135	60	25	20	3	4	10	0.1	238	15	22

Table 1: Continued

	Artemisia frigida Willd.			*Kobresia capillifolia*	*Carex moorcroftii Falc. ex Boott*	*Stipa aliena Keng*	Other low vegetation
Sample Plots	Vegeta. numbers	Heigths (cm)	Coverage (%)	Coverage (%)	Coverage (%)	Coverage (%)	Coverage (%)
I				3	36		1
II				2	29		14
III	4500	5	14		12		2
VI					26	8	1

Table 2: Soil nutrients at the 20cm depth of the sample plots from No. I to No. VI on a small alpine meadow hillside, September 2005

Sample plots	Samples	Organic C ($g\ kg^{-1}$)	Total N ($g\ kg^{-1}$)	Total P ($g\ kg^{-1}$)	Total K ($g\ kg^{-1}$)	C:N	C:P	Available N ($mg\ g^{-1}$)	Extractable P ($mg\ g^{-1}$)	Available K ($mg\ g^{-1}$)
I	3	39.6	3.9	1.48	20.8	10.3	26.8	128.0	19.2	210
II	3	45.6	4.2	1.49	22.5	10.8	30.4	155.4	28.0	220
III	3	38.6	3.8	1.48	19.2	10.3	26.1	131.6	19.4	143
VI	3	38.1	3.6	1.48	20	10.6	24.2	158.5	19.4	333

Table 3: Vegetation types on a natural and a destroyed alpine meadow ground, September, 2005

Sample Plots	Coverage (%)	Sites state	*Kobresia capillifolia* Coverage (%)	*Anaphalis lactea maxim.* Coverage (%)	Other low vegetation Coverage (%)
VI	38	Turf moved			38
VIII	32	Turf moved			32
X	50	Turf moved			50
V	95	Undisturbed	90	4	1
VII	88	Undisturbed	81	6	1
IX	70	Undisturbed	40	28	2

the small hillside, the vegetation coverage is negative linear with the soil nutrients at the 20cm depth, such as organic C, total N, total P, total K, ratio of C to N and ratio of C to P, to some extent.

Though the soil nutrients are eroded by the rainfall easily at the small hillside, the nutrients content are, except lower than those in the secondary tropical dry forests in Mexico (Enrique and Julio, 2004), much higher than the reported data in other region in the literature, such as in the sandy land (Su *et al.*, 2005; Jia *et al.*, 2005) and forest (Aranda and Oyonarte, 2005) of the arid and semiarid regions, in the wet tropical forests (Barhbuiya *et al.*, 2004; Bijayalaxmi and yadava, 2006) and in the mountainous crop land in Japan (Saito *et al.*, 2006). Of course, this kind of contrast may not reasonable, due to the different environmental conditions. However, at least one thing could be say that the soil nutrients content are very high in the research regions.

Due to the high content of the organic C (Table 2) in the soil and global warming, the atmospheric CO_2 concentration near land surface is also very high, at or near the research site, where the permafrost degenerated severely. According to the measured data from 1959 to 2004, at the Yeniugou meteorological station, 1.2km far from the research hillside, the yearly averaged air temperature have risen about 1.0°C (Fig. 3). Using the data measured by an ENVIS System EERIL 3 (IMKO GmbH) at the same station, from September, 2004 to October 2005 (some data are absent), the averaged daily atmospheric CO_2 concentration (GMM222, Vaisala) at the 3.5m heights above ground is about 612PPM (Fig. 4), which is much higher than that of in warm regions and much higher than the global averaged value (about 379PPM). Though the accuracy of the GMM222 is relatively low (±20PPM), it is stable in a 2-year period and it can be removed, reattached or replaced at any time without the need for calibration and adjustment.

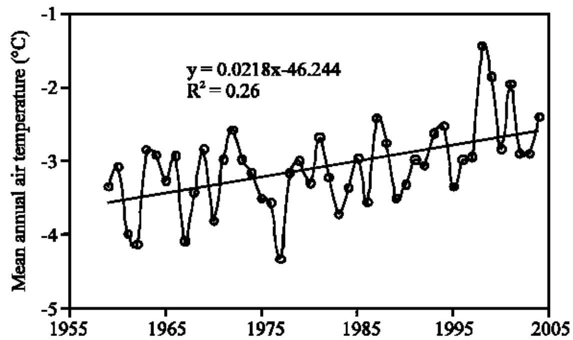


Fig. 3: Variation of the yearly averaged air temperature at the Yeniugou meteorological station, 1959-2004, 1.2 km far from the research site

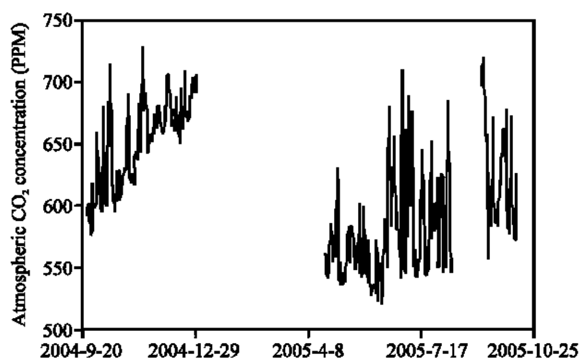


Fig. 4: Variation of the daily averaged atmospheric CO_2 concentration at the Yeniugou meteorological station, Sep 2004-Oct 2005, 3.5 m above the ground, 1.2 km far from the research site. The data were partly absent because the data logger card could not be read

Vegetation succession at the disturbed alpine meadow regions: From the photos shown in Fig. 2a, there are evidently two alpine meadow landscapes, where the topography, vegetation types and soil nutrients should

Table 4: Soil nutrients at the 20 cm depth on a natural (Sample plot V, VII and IX) and a destroyed (Sample plot VI, VIII and X) alpine meadow ground, September 2005

Sample plots	Samples	Organic C (g kg^{-1})	Total N (g kg^{-1})	Total P (g kg^{-1})	Total K (g kg^{-1})	C:N	C:P	Available N (mg g^{-1})	Extractable P (mg g^{-1})	Available K (mg g^{-1})
VI	3	31.9	3.0	1.29	20	10.6	24.7	128.7	13.1	210
VIII	3	35.1	3.1	1.35	20	11.3	26.0	139.0	22.6	240
X	3	30.2	2.8	1.34	20	10.6	22.5	141.7	10.9	210
V	3	62.1	5.2	1.79	20	12.0	34.7	227.5	31.3	270
VII	3	59.0	5.2	1.43	20	11.4	41.3	163.0	33.5	230
IX	3	42.7	3.8	1.33	20	11.2	32.1	181.9	17.1	320

Table 5: Vertical soil nutrient gradients from mountaintop to the hollow of a small hillside near permafrost lower limit, September 2005

Sampling point No.	Soil Samples	Slope (°)	Aspect (°)	Distance between sampling points (m)	Dominant species	Vegetation coverage (%)	Vegetation heights (cm)	Organic C (g kg^{-1})
1	2	3	70		*Kobresia capillifolia*	50	8	41.0
2	2	4	71	9	*Kobresia capillifolia*	70	12	51.5
3	2	6	79	8.6	Kobresia capillifolia	48	10	50.8
4	2	7	62	9.6	*Kobresia capillifolia*	55	15	57.7
5	2	8	57	10.3	*Kobresia capillifolia*	50	13	50.4
6	2	25	52	10	*Kobresia capillifolia*	65	10	60.2
7	2	22	52	10	*Kobresia capillifolia*	70	10	70.6
8	2	18	72	10	*Kobresia capillifolia*	80	14	58.5
9	2	11	74	10	*Kobresia capillifolia*	50	5	44.1
10	2	25	75	10	*Kobresia capillifolia*	40	4	39.3
11	2	35	99	10	*Kobresia capillifolia; Iris ensata Thunb.*	45	6	43.7
12	2	37	106	10	*Kobresia capillifolia*	40	5	22.1
13	2	50	90	10	*Kobresia capillifolia*	45	6	40.7
14	2	47	78	10	*Kobresia capillifolia*	40	4	36.7
15	2	51	78	10	*Kobresia capillifolia*	40	3	27.1
16	2	43	78	10	*Kobresia capillifolia; Stipa aliena Keng*	35	7	26.0
17	2	53	79	10	*Kobresia capillifolia*	25	4	23.0
18	2	55	68	10	*Kobresia capillifolia*	35	4	23.5
19	2	52	71	10	*Kobresia capillifolia*	30	5	25.6
20	2	53	67	10	*Kobresia capillifolia*	35	3	31.6
21	2	50	64	10	*Kobresia capillifolia*	20	4	28.6
22	2	42	81	10	*Kobresia capillifolia*	45	8	29.7
23	2	40	75	10	*Kobresia capillifolia; Stellaria chamæjasme L.*	55	7	29.9
24	2	37	87	10	Carex moorcroftii Falc. ex Boott	45	5	29.8
25	2	30	88	10	Carex moorcroftii Falc. ex Boott	38	5	31.2
26	2	26	97	10	Carex moorcroftii Falc. ex Boott	40	6	26.7
27	2	25	110	10	*Carex moorcroftii Falc. ex Boott*	40	3	26.8
28	2	18	101	10	*Carex moorcroftii Falc. ex Boott; Leontopdoium nanum Hand.-Mazz.*	60	9	33.8
29	2	13	102	10	*Carex moorcroftii Falc. ex Boott*	50	5	32.9
30	2	7	101	10	*Carex moorcroftii Falc. ex Boott; Leontopdoium nanum Hand.-Mazz.*	60	6	40.6
31	2	10	89	10	*Carex moorcroftii Falc. ex Boott*	70	8	39.0
32	2	6	89	10	*Carex moorcroftii Falc. ex Boott; Stipa aliena Keng*	12	25.5	
33	2	5	85	10	*Carex moorcroftii Falc. ex Boott*	85	6	41.2
34	2	3	101	10	*Carex moorcroftii Falc. ex Boott*	95	8	51.0
35	2	1	92	10	*Carex moorcroftii Falc. ex Boott*	98	15	19.9
36	2	-1	97	10	*Carex moorcroftii Falc. ex Boott*	80	4	24.6
mean		25.5	81.6			52	7	37.1

Table 5: Continued

Sample plots	Total N (g kg^{-1})	Total P (g kg^{-1})	Total K (g kg^{-1})	C:N	C:P	Available N (mg g^{-1})	Extractable P (mg g^{-1})	Available K (mg g^{-1})
1	3.8	1.26	22.5	10.9	32.6	79.2	22.4	150
2	4.8	1.36	25.0	10.6	37.9	178.9	22.6	140
3	4.7	1.42	25.0	10.9	35.8	223.7	17.1	160
4	4.7	1.26	25.0	12.4	45.8	186.8	29.9	200
5	4.3	1.27	25.0	11.8	39.7	195.7	22.4	150
6	5.0	1.5	22.5	12.0	40.1	206.0	27.1	240
7	6.0	1.73	25.0	11.7	40.8	267.7	32.1	300
8	5.4	1.84	25.0	10.8	31.8	223.2	32.7	210
9	3.9	1.35	25.0	11.4	32.6	134.7	16.9	130
10	3.9	1.3	25.0	10.0	30.2	123.9	12.3	190

Table 5: Continued

Sample plots	Total N ($g\ kg^{-1}$)	Total P ($g\ kg^{-1}$)	Total K ($g\ kg^{-1}$)	C:N	C:P	Available N ($mg\ g^{-1}$)	Extractable P ($mg\ g^{-1}$)	Available K ($mg\ g^{-1}$)
11	4.0	1.39	25.0	10.9	31.4	146.2	16.9	140
12	2.6	1.28	17.5	8.6	17.3	75.9	5.6	140
13	3.6	1.62	17.5	11.2	25.2	151.6	22.2	170
14	3.4	1.35	20.0	10.7	27.2	131.6	11.5	140
15	2.6	1.25	17.5	10.4	21.7	94.5	12.7	160
16	2.5	1.32	17.5	10.6	19.7	92.6	10.0	120
17	2.1	1.23	15.0	10.9	18.7	68.7	7.6	170
18	2.2	1.23	20.0	10.6	19.1	58.8	7.8	160
19	2.0	1.15	20.0	12.7	22.3	44.7	9.8	150
20	1.9	1.25	17.5	16.7	25.3	75.2	6.4	140
21	2.4	1.25	20.0	11.7	22.9	102.8	7.6	160
22	2.7	1.32	20.0	11.1	22.5	105.8	10.6	170
23	2.7	1.36	20.0	11.2	22.0	90.2	10.2	130
24	2.8	1.37	20.0	10.6	21.8	69.5	8.2	190
25	2.7	1.38	22.5	11.4	22.6	114.8	14.7	230
26	2.3	1.21	20.0	11.9	22.1	92.4	23.2	180
27	2.5	1.35	22.5	10.6	19.8	112.6	8.0	170
28	3.1	1.35	22.5	10.8	25.0	133.7	16.3	260
29	3.1	1.64	22.5	10.5	20.0	141.4	19.0	240
30	3.6	1.44	22.5	11.2	28.2	167.7	16.3	460
31	3.6	1.48	22.5	10.9	26.4	164.6	15.5	300
32	2.2	1.32	20.0	11.6	19.3	89.8	10.4	270
33	3.7	1.62	22.5	11.2	25.4	175.8	26.9	500
34	4.4	1.69	22.5	11.5	30.2	189.2	24.6	580
35	1.7	1.45	22.5	11.6	13.7	79.1	21.4	230
36	2.1	1.52	22.5	11.8	16.2	91.2	13.9	230
mean	3.3	1.39	21.6	11.3	26.5	130.0	16.5	213

(a)

(b)

Fig. 5: Vegetation types at the two disturbed sample plots. a): Presented vegetation types at the sample plot VI, VIII and X, where the turfs were removed for build enclosure in the year from 1970 to 1971 and b), showed the vegetation types near Yeniugou meteorological station, where the turfs were removed for laying water pipe, in May to August, 2004, 1.1 km far from the point shown in Fig. 5a

be similar in the early years. The turfs of the left part (Fig. 2a) where sample plot VI, VIII and X lay in, were removed in the year from 1970 to 1971 to build enclosure shown in Fig. 2b. After that, 35 years have passed and the vegetation cover and soil nutrients of the disturbed grassland have changed largely (Table 3 and 4).

The vegetation types at the turf removed sample plots (No. VI, VIII and X) are some low-grade vegetations (Fig. 5a) and the vegetation coverage (Table 3) and all the soil nutrients content at 20 cm depth (Table 4) are much lower than those at the undisturbed sample plot (No. V, VII and IX).

After the turfs are removed, the low-grade vegetation types at the disturbed sample plot (No. VI, VIII and X) breed rapidly. After that, nevertheless, the vegetation succession processes are very slow, which could be inferred from the contrasting results of Fig. 5a to 5b, where the vegetation types are similar. The photos shown

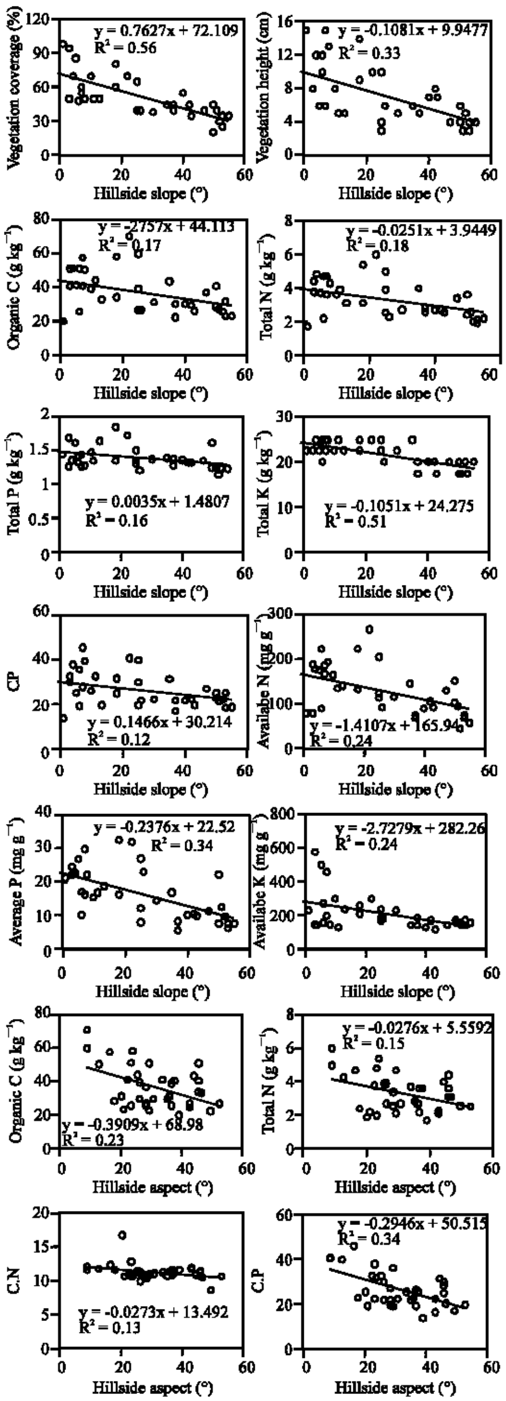


Fig. 6: Effects of micro-topography to vegetation patterns and soil nutrients at 20 cm depths on a small hillside near permafrost lower limit and all the correlations passed the F-test when $\alpha = 0.05$

in Fig. 5b presented the vegetation types on another small hillside, where the turfs were removed too, for laying water pipe, from May to August, 2004.

With even topography, the soil nutrients contents at the sample plots V to X, especially at the undisturbed plots, were little erosion and were higher than those at the sample plots I to IV (Fig. 1c).

Vegetation patterns and soil nutrients variation from mountaintop to the valley of the small hillside: At the higher parts of the research small hillside, the dominant vegetation species is *Kobresia capillifolia*. While at the lower part, *Carex moorcroftii Falc. ex Boott* is the dominant species (Table 5).

On the small hillside, the vegetation coverage and vegetation heights reduce along with the hillside slope rising (Fig. 6), according to the data shown in Table 5. The content of the soil nutrients components at 20cm depth, such as organic C, total N, total P, total K, ratio of C to P, available N, available P and available K, is negative linear with the hillside slope (Fig. 6). Among these correlations, the vegetation coverage and content of total K are more sensitive to the varieties of the slope of sampling points (Fig. 6).

The organic C, total N, ratio of C to N and ratio of C to P, are all negative linear with aspect of the sampling points (Fig. 6) on this small hillside. The ratio of C to P is more sensitive to the changes of the hillside aspect (Fig. 6).

All the correlations shown in Fig. 6 pass the F-test when $\alpha = 0.05$, while other correlations that are not shown in Fig. 6, such as relationship between the slope and ratio of C to N at the sampling points, relationship between aspect and total P, etc., do not pass the F-test when $\alpha = 0.05$.

CONCLUSION

On a small alpine meadow hillside near permafrost lower limit, the vegetation types, vegetation coverage and soil nutrients at 20 cm depth, such as C, N, P and K, etc., are different at the different sample plots due to its different slope and aspect.

At the different sample plots of the hillside, the size and amount of a same vegetation type is also different. From the mountaintop to the valley of the hillside, where the ground changes from permafrost to seasonal frozen soil, the vegetation coverage and vegetation heights reduce along with the hillside slope rising. The content of the soil nutrients components at 20 cm depth, such as organic C, total N, total P, total K, ratio of C to P, available N, available P and available K, is negative linear with the slope of the sampling points. Among these correlations, the vegetation coverage and content of total K are more sensitive to the varieties of the slope.

The organic C, total N, ratio of C to N and ratio of C to P, are all negative linear with aspect of the sampling points on this small hillside. The ratio of C to P is more sensitive to the changes of the hillside aspect.

When the turfs of the alpine meadow are removed, the land surface are inhabited by some low-grade vegetations rapidly and the vegetation coverage and all the soil nutrients content at 20cm depth are much lower than those at the undisturbed sample plots. However, the vegetation succession processes at the turfs removed grassland is very slow.

The content of the soil nutrients at 20cm depths, such as organic C, total N, etc., in these alpine meadow regions, are very high. The atmospheric CO_2 concentration near land surfaces in these regions is also much higher than the global averaged value.

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