

High mountain vegetation in temperate North China

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Abstract

Timberline vegetation on four mountains, Mt. Taibai, Mt. Wutai, Mt. Guandi and Mt. Xiaowutai, in temperate North China were investigated. Only the highest two mountains, Mt. Taibai and Mt. Wutai, in this region have a clear forest line, tree line and tree species line. All the timberlines are formed by larch trees. Herb plant communities show that the shady slope of Mt. Xiaowutai reaches the alpine timberline, whereas the timberline on Mt. Guandi is a topographical one. We therefore suggest that a climate-driven alpine timberline can only occur on mountains with elevations higher than 2900 m a.s.l. in the northern part of this region and 3400 m a.s.l. in the southern part. On Mt. Taibai and Mt. Wutai, herb species show clear vertical zones, including alpine meadow and subalpine meadow and forest understory. Topographical features, such as block fields and depressions, also have their effects on the plant communities near the timberline. In general, the timberline is species-poor compared to the whole mountain. Regional differences in species composition exist on the mountains. Our study implies that both climate and topography determine high mountain vegetation patterns in temperate North China. Future investigations on alpine vegetation dynamics should also focus on the effect of regional climate change on the local environment.

Keywords: Alpine timberline, North China, Plant community, Floristic composition

1. Introduction

Alpine timberlines located at the edge of forest tolerance to a cold climate, have been commonly regarded as sensitive to climate warming (KÖRNER 2003). A global monitoring network has been established since the beginning of this century (GRABHERR et al. 2001) to detect the changes in plant species diversity to climate warming (PAULI et al. 2012). In addition, shifting of the timberline position has been so far a hotspot in timberline research (LIANG et al. 2011).

To better understand whether timberline dynamics are caused by climate change and what kinds of dynamics will happen in the timberline under climate change, it is necessary to investigate the vegetation structure and plant species distribution around the timberline. This fundamental work on alpine timberline response to climate change, however, has commonly been overlooked in previous studies. The following two questions commonly dominate alpine timberline studies:

First, does the investigated site reach the climatic timberline? In previous studies, climate indexes as well as forest structure characteristics were used to determine the climate-driven alpine timberline. Climate indexes, however, were calculated from meteorological stations which were normally close to cities at the foot of the mountains, making the interpolated mountain climate full of uncertainties (BENISTON 1996). Forest structure, such as the abrupt transition from forest to grassland or shrubland, or gradual transition from continuous forest to patchy forest and isolated individual trees, were commonly regarded as identifying the

position of the timberline. However, this method sometimes can not distinguish a topography-determined timberline from a climate-determined timberline.

Next, will the alpine timberline move upward following climate warming? Previous work commonly predicts a linear upward movement of the timberline under future climate change. This could occur on mountains with an abrupt tree line, but a complicated landscape at a gradual timberline might buffer the effect of climate warming.

Different from its western part, the eastern part of China lacks high mountains. We urgently need knowledge, however, on whether the climate driven alpine timberline has been reached and how plant communities are distributed at high elevations. In this paper we aimed to answer the above-mentioned questions by systematically investigating floristic and geobotanical features of the alpine timberline in temperate North China.

2. Study area and Methods

2.1 Study area

The northern part of China comprises Northeast, North and Northwest China. In this paper we focus on North China, with the Loess Plateau in the west, the North China Plain in the east and the Inner Mongolia Plateau in the north. The climate is a continental monsoon climate with a mean annual precipitation of about 400 - 800 mm. For this study, we selected the four highest mountains in temperate eastern China. Located at the transition between the subtropical zone and the temperate zone lies Mt. Taibai (34°N, 108°E; 3667 m), the highest peak of the Qinling Mountain Range. It is also the second highest mountain in the eastern part of China, next to Mt. Yushan on the Island of Taiwan. Located at the center of the temperate forest zone, Mt. Guandi (38°N, 111.5°E; 2831 m), Mt. Wutai (39°N, 113.6°E; 3058 m), and Mt. Xiaowutai (40°N, 115°E; 2882 m) are the next three highest mountains (Figure 1).

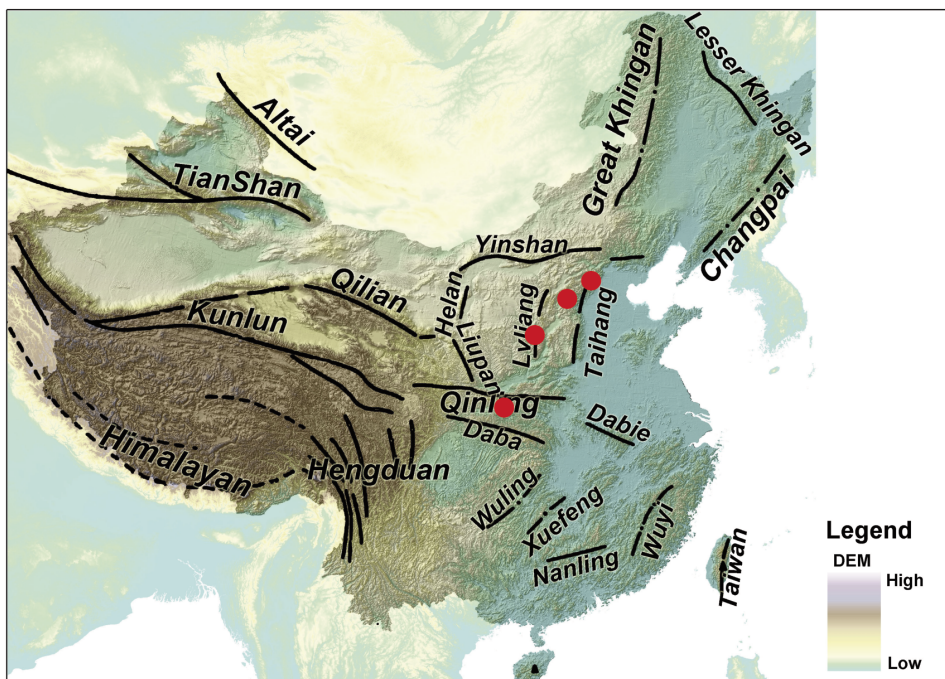


Fig. 1: Distribution of mountains in China. The red dots indicate the four investigated mountains, Mt. Xiaowutai, Mt. Wutai, Mt. Guandi and Mt. Taibai from northeast to southwest.

2.2 Methods

There are different definitions of ‘timberline’, but we regard it as the transition between the forest line (the upper line of continuous forest distribution) and the tree line (POTT et al. 1995). As for ‘tree line’, we define it as trees taller than 2 m (HOLTMEIER 2003).

Sample plots of plant communities were made from the upper edge of the continuous forest to the mountain top at every 10 m along an altitudinal gradient on the 4 mountains studied. At each altitude five samples were taken under different topographical conditions. Plot size for shrub-dominated communities was 2 m × 2 m, whereas that for meadow communities was 1 m × 1 m (MUELLER-DOMBOIS & ELLENBERG 2003). Total amounts of relevés are 129 and 154 on shady and sunny slopes of Mt. Taibai, respectively, and 280 and 75 on shady and sunny slopes of Mt. Wutai, respectively. 50 relevés were made on Mt. Guandi from the mountain top down on both sunny and shady slopes. On Mt. Xiaowutai only 11 relevés were made on the shady slope.

Two Way Indicator Species Analysis (TWINSPAN) was adopted to classify plant community types (HILL 1979). Only understory species were used for relevés in the forests.

3. Results

3.1 Floristic composition

There are 154 species recorded on Mt. Taibai. They belong to 34 families, 87 genera. The most common families are Poaceae, followed by Asteraceae, Ranunculaceae, Apiaceae, Rosaceae, Polygonaceae and Liliaceae. These 7 families contain 54% of the genera and 52% of the species recorded. The most common shrubs are *Salix cupularis* and *Rhododendron capitatum*.

Within the relevés recorded from 2780 - 3060 m a.s.l. on the shady slope and 2585 - 2910 m a.s.l. on the sunny slope of Mt. Wutai, there are a total of 160 plant species that belong to 33 families, 87 genera. The most commonly families are Poaceae with 21 species, Cyperaceae with 20 species and Compositae with 18 species. Species from these three families account for 36.9% of the total species recorded. Among the 87 genera, *Carex* is richest in species (15), followed by *Saussurea* (7), *Pedicularis* (6), *Gentiana* (5), *Ranunculus* (5), *Poa* (5), *Potentilla* (5), *Roegneria* (4), *Kobresia* (4), and *Festuca* (4). The above 10 genera account for 37.5% of the species. There are 58 genera having only 1 species. Shrubs, such as *Caragana jubata* and *Salix character*, are common.

There are 55 herb species recorded on Mt. Guandi. These species are habitat-selective: for example, the following species were restricted to the mountain top: *Bupleurum chinense*, *B. smithii*, *Delphinium grandiflorum*, *Artemisia subalata*, *Galium verum*, *Taraxacum platyepidum*, *Polygonum bistorta*, *Adenophora* sp., *Geranium sibiricum*, *Primula maximoviczii*, *Vicia* sp., *Roegneria kamoji*, *Papaver nudicaule*, *Rhodiola kirilowii*. They account for 27% of the total herb species. *Aconitum sinomonatanum*, *A. kusnezoffii*, *Cardamine tangtutorum*, *Thalictrum petaloideum* and *Saxifraga sibirica* are restricted to block fields. Two species, *Cardamine leucantha* and *Senecio nemorensis*, are limited to the forest understory. *Agrostis giganteum*, *Carex* sp., *Saussurea iodostegia*, *Viola biflora*, *Myosotis sylvatica*, *Epilobium angustifolium*, *Athyrium* sp., *Tilingia tachiroei* and *Rhodiola rosea* are found in various open habitats. The 8 shrub species recorded are *Caragana jubata*, *Saussurea alpina*, *Ribes mandschuricum*, *R. emodense* var. *verruculosum*, *Potentilla fruticosa*, *Rubus crataegifolius*, *Lonicera hispida*, and *L. caerulea* var. *edulis*.

Species composition at the forest upper edge of Mt. Xiaowutai is very similar to that of Mt. Wutai, which is not surprising since these two mountains are close together.

3.2 Forests

The forest line, tree line and tree species line are very clear on Mt. Taibai and Mt. Wutai (Table 1). On the sunny slope of Mt. Taibai in the south all these lines are about 600 m higher than on Mt. Wutai in the north. On the shady slope, the elevation difference can reach 800

Table 1: Elevation of upper forest boundaries on the four selected mountains in temperate North China

Sunny slope			Mt. Name	Shady slope		
Forest line	Tree line	Tree species line		Tree line	Tree line	Forest line
NA	NA	NA	Xiaowutai	2800	2750	2620
2610	2710	2800	Wutai	2990	2900	2810
NA	NA	NA	Guandi	NA	NA	2750
3425	3500	3700	Taibai	3560	3500	3410

– 900 m. The dominant species of the alpine timberline are *Larix chinensis* on Mt. Taibai and *L. principis-ruprechtii* on Mt. Wutai. On Mt. Guandi, only a forest line can be identified at an elevation of 2750 m a.s.l. on the shady slope. On Mt. Xiaowutai, the forest line, tree line and tree species line can be identified on the shady slope, but not on the sunny slope. *L. principis-ruprechtii* acts as the timberline species on both Mt. Guandi and Mt. Xiaowutai.

3.3 Alpine and subalpine meadows

Mt. Wutai

Four herb plant community types on the shady slope are distinguished. *Kobresia pygmaea* indicates the alpine *Kobresia* meadow, whereas the occurrence of *Cortusa matthioli* ssp. *pekinensis*, *Allium plurifoliatum* var. *stenodon* and *Cardamine tangutorum* indicate the sub-alpine and forest understories. On the second level of the classification, *Polemonium coeruleum* indicates the forest understory, whereas *Lagotis integrifolia*, *Papaver nudicaule* and *Rhodiola* indicate open habitat. *Trollius chinensis* differentiates the forest edge meadow from the subalpine scrub meadow (Figure 2).

The 75 relevés on the sunny slope were classified into four plant community types. The presence of *Cardamine tangutorum* identifies the forest understory. The light-preferring species *Thalictrum petaloideum*, *Polygonum viviparum* and *Leontopodium longifolium* indicate plant communities of open habitats. The second-level classification identifies forest-edge meadows with the presence of *Aster alpinus* and *Fragaria orientalis*, whereas *Astragalus moellendorffii*, *Kobresia bellardii*, *Bupleurum smithii* and *Gentiana macrophylla* indicate alpine and subalpine meadows. The third-level classification identifies subalpine meadows by the occurrence of *Elymus* sp., *Viola biflora*, *Poa sphondylodes*, and *P. sibirica*. Those relevés without the above species are commonly dominated by *Kobresia* species, implying alpine meadow (Figure 3).

Mt. Taibai

Five plant community types can be identified on the shady slope of Mt. Taibai. The first-level classification distinguishes forest understory from other plant community types by the understory indicators *Cardamine macrophylla*, *Carex scabrivostris* and *Polygonum sphaerostachyum*. Two groups are distinguished at the second-level classification with *Allium pratii*, *Polygonum sphaerostachyum* and *Pleurospermum giraldii* as indicator species. The third-level classification identifies the forest-edge meadow by *Aster alpinus*, *Gentiana tsinlingensis* and *Saussurea iodostegia*. Another group seems to be formed by marshy meadows

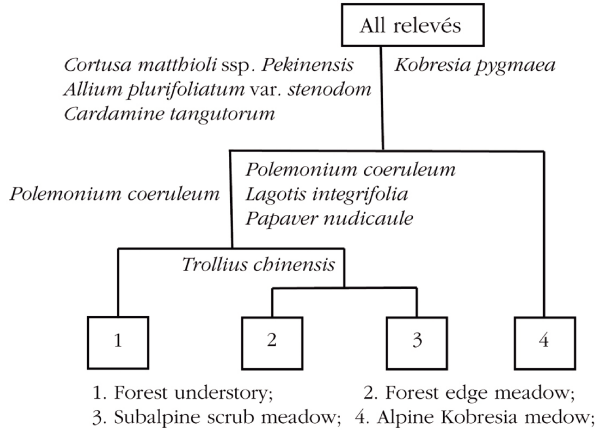


Fig. 2: Classification of herb plant communities on the shady slope of Mt. Wutai.

according to its habitat and species composition. *Kobresia graminifolia* and *Anemone taipaiensis* identify alpine meadow, whereas *Festuca ovina* and *Aster ovalifolius* identify subalpine meadow (Figure 4).

Similar plant communities were also found on the sunny slope of Mt. Taibai. At the first-level classification *Polygonum taipaiensis* and *Koeleria cristata* characterized two groups. The forest edge meadow was distinguished from the forest understory by *Cardamine macrophylla*. The second-level classification also identifies marshy meadows by *Deschampsia littoralis* and *Coluria purdumii*. The third-level classification separates subalpine and alpine meadows by *Pedicularis rhinanthoides* subsp. *labellata*, *Leontopodium calocephalum* var. *depauperatum*, and *Trollius farreri* (Figure 5).

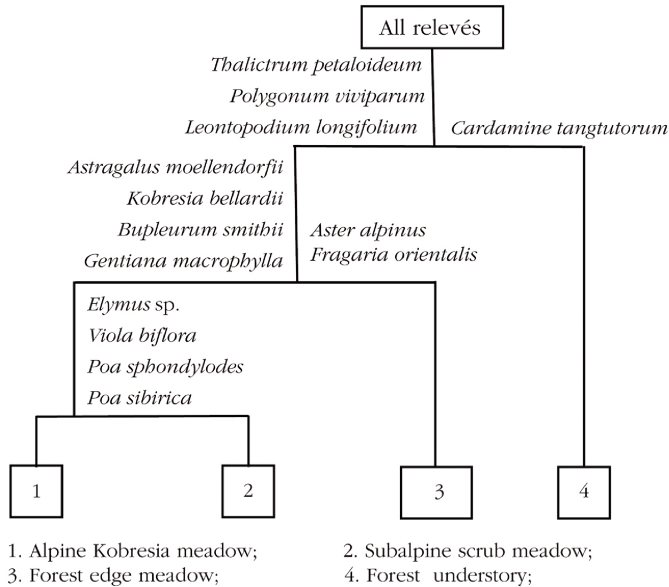


Fig. 3: Classification of herb plant communities on the sunny slope of Mt. Wutai.

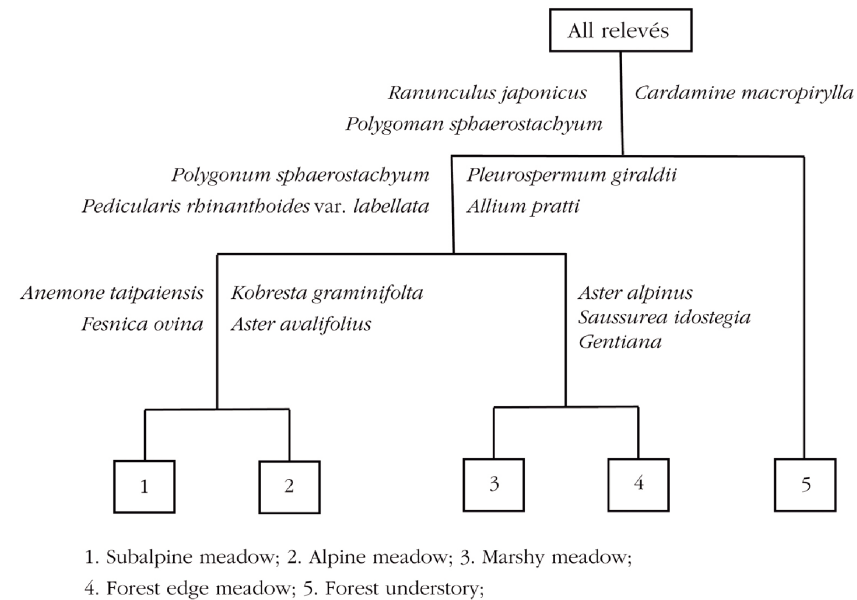


Fig. 4: Classification of herb plant communities on the sunny slope of Mt. Taibai.

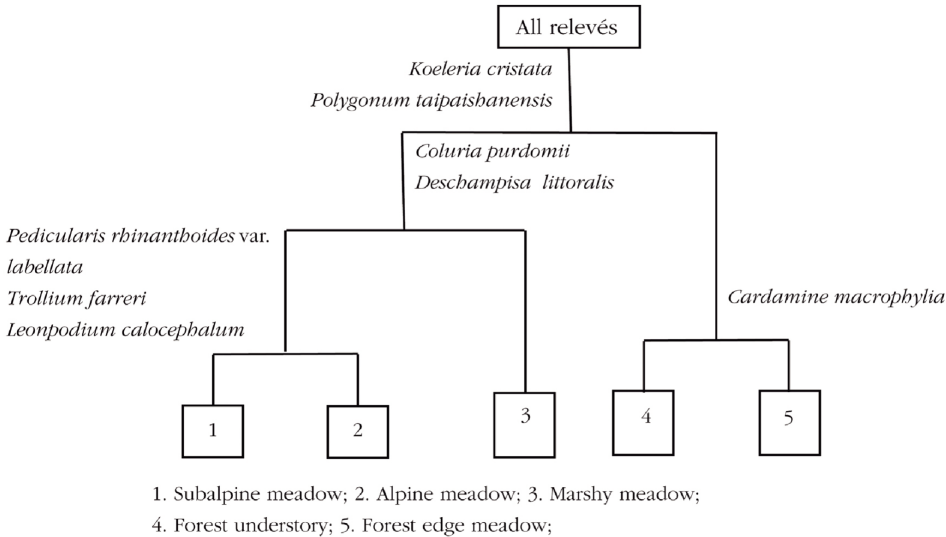


Fig. 5: Classification of herb plant communities on the sunny slope of Mt. Taibai.

Mt. Guandi

The same method applied to Mt. Guandi yielded very different plant community types. The first-level classification identifies scrubby meadow from 2810 m a.s.l. to the top of the mountains with the occurrence of *Caragana jubata*. The indicator species are *Cardamine tangtutorum*, *Poa sphondelodes*, *Rhodiola kirilowi*. Two plant communities are distinguished at the second level, with *Agrostis gigantea*, *Cardamine leucantha*, *Cortusa matthioli* indicating a plant community on thick soil, and *Tilingia tachiroei* and *Rhodiola dumulosa* indicating a plant community on thin soil.

Mt. Xiaowutai

On Mt. Xiaowutai, *Kobresia*-dominated meadows only occur above an elevation of 2600 m a.s.l., with for example *Kobresia bellardii*, *Saussurea iodostegia*, *Astragalus moellendorffii* and *Polygonum viviparum*. There is an evident transition from meadow to forest understory. At the elevation of 2860 m a.s.l. *Kobresia bellardii*, *Saussurea iodostegia* and *Libanotis condensate* dominate, and *Kobresia* has a relative frequency of 20%. At 2700 m a.s.l. *Libanotis condensate* and *Saussurea iodostegia* dominate, with a relative frequency of *Kobresia bellardii* decreasing to 5%, but those of *Saussurea iodostegia* and *Libanotis condensate* do not show an evident change. Under the forest at an elevation of 2520 m a.s.l., *Carex lanceolata* dominates with relative frequency of 30%, and *Athyrium sinense* appears.

Table 2: Transitional appearance of plant species on the timberline in Mt. Xiaowutai

Elevation (m a.s.l.)	Number of species	Species with the highest frequency	Maximal frequency (%)
2860	17	<i>Kobresia bellardii</i>	20
2830	20	<i>Cerastium arvense</i>	16
2800	24	<i>Astragalus moellendorffii</i>	12
2750	19	<i>Carex stenophylloides</i>	18
2710	21	<i>Libanotis condensate</i>	16
2690	19	<i>Libanotis condensate</i>	14
2670	18	<i>Saussurea iodostegia</i>	14
2650	19	<i>Libanotis condensate</i>	16
2620	22	<i>Libanotis condensate</i>	18
2600	17	<i>Carex lanceolata</i>	28
2560	17	<i>Carex lanceolata</i>	24
2520	15	<i>Carex lanceolata</i>	30

4. Discussion and conclusions

Our results show that only those high mountains with elevation of >2900 m a.s.l. can develop full alpine timberlines in the north of our study area. The timberline position rises up to 3400 m a.s.l. in the south of the temperate zone. Using these criteria, we concluded that there are only two mountains, Mt. Taibai in the south and Mt. Wutai in the north, which are high enough to reach the alpine timberline. On Mt. Xiaowutai, only the shady slope has developed an alpine timberline. Mt. Guandi is close to the alpine timberline but does not reach it. The other mountains in temperate North China are not high enough for a climate driven timberline. Our study also shows that forest structure alone can not provide evidence for the existence of an alpine timberline. The species composition of meadows clearly shows the difference between the alpine zone dominated by *Kobresia* species and the subalpine zone dominated by forbs and legumes. CUI (1983) identified the alpine timberline in this region by using special alpine geomorphological phenomena. Our results show patterns of the alpine timberline that are quite consistent with the alpine timberlines indicated by geomorphological phenomena. This implies that the high mountains vegetation is strongly associated with geomorphological conditions.

Timberlines in temperate North China constitute a transitional landscape. In this study we found that the alpine timberlines in temperate northern China are mostly gradual ones. The complicated environmental conditions might account for this. Huge areas of block field on all four mountains create various microhabitats for plant species, for example, different soil

depths, different light supplies, different water supplies, and so on. Our study shows that herb species well indicate the environmental conditions at the alpine timberline in temperate northern China. They well distinguish the effects from light and temperature. And the occurrence of some *Kobresia* species well indicates the position of the alpine timberline.

Due to the effect of environmental conditions, the distribution of herb species also shows gradual transitions. For example, subalpine meadowss and alpine meadow commonly mix on Mt. Taibai and Mt. Wutai, most likely due to the effects of topography-created microhabitats.

Our study shows that mountain tops are relatively poor in plant species, particularly above the forest line. For example, only 154 species occur above the forest line at 3400 m a.s.l. on Mt. Taibai, which account for only 8.4% of the total number of species on this mountain.

Although the timberline tree species are different on Mt. Taibai (*Larix chinensis*) as compared to the other mountains (*Larix principis-ruprechtii*), they both belong to the genus *Larix*. The shrub species are also quite different on these mountains: *Rhododendron* spp. in the south and *Caragana jubata* in the north. As for herb species, Mt. Wutai, Mt. Xiaowutai and Mt. Guandi show a similar species composition and great difference exist between these three mountains and Mt. Taibai, implying different floristic developments .

References

- BENISTON, M. & FOX, D.G. (1996): Impacts of climate change on mountain regions. In: WAESON, R.T. et.al. (eds). *Climate Change 1995. Impacts Adaptations and Mitigations of Climate Change: Scientific-Technical Analyses*. Cambridge University Press, Cambridge. 191-213.
- CUI, H.T. (1983): On the classification of the alpine zone and the subalpine zone. – *Chinese Science Bulletin* (8): 494-497.
- GRABHERR, G., GOTTFRIED, M. & PAULI, H. (2001): Long-term monitoring of mountain peaks in the Alps. In: BURGA, C.A. & KRATOCHWIL, A. (ed.), *Biomonitoring: General and Applied Aspects on Regional and Global Scales. Tasks for Vegetation Science*, Kluwer, Dordrecht: 153-177.
- HILL, M.O. (1979): TWINSPAN: A FORTRAN Programme for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Cornell University, Ithaca, New York.
- HOLTMEIER, F.-K. (2003): *Mountain Timberline: Ecology Patchinees and Dynamics*. Kluwer Academic Publishers, Dordrecht, Boston, London
- KÖRNER, CH. (1999): *Alpine Plant Life: Functional Plant Ecology of High Mountain Ecosystems*. Springer Verlag, Berlin, Heidelberg
- LIANG, E.Y., WANG, Y.F., ECKSTEIN, D. & LUO, T.X. (2011): Little change in the fir tree-line position on the southeastern Tibetan Plateau after 200 years of warming. – *New Phytologist* **190**: 760-769.
- MUELLER-DOMBOIS, D. & ELLENBERG, H. (2003): *Aims and Methods of Vegetation Ecology*. The Blackburn Press
- PAULI, H., GOTTFRIED, M. & DULLINGER, S. (2012): Recent Plant Diversity Changes on Europe's Mountain Summits. – *Science* **336**: 353-355
- POTT, R., HÜPPE, J., REMY, D. et al. (1995): Paläoökologische Untersuchungen zu holozänen Waldgrenzschwankungen im oberen Fimbartal (Val Fenga, Silvretta, Ostschweiz). – *Phytocoenologia* **25**(3): 363-398

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