

Changes in the spruce forests of the Polish Tatra Mts. during the last 80 years

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Abstract: On the basis of the historical (dating from the 1920s) and contemporary phytosociological relevés, taken in the spruce forests of the Polish Tatra Mts., the changes were determined that took place in these forests. This area had been for centuries under the influence of human economic activities, mainly pasturing and wood extraction, and then protected in the Tatra National Park. These changes differ according to the altitudinal vegetation belts.

In the coniferous forests of the upper montane belt, the changes due to wind breaks or tree stand ageing did not lead to transition to other forest associations. A tendency can yet be noticed of losing a part of the species combinations characteristic for the associations or higher syntaxonomic units, which might be linked with the stopping of grazing in the forests and development of the undergrowth of tall herb character.

The association of the fir-and-spruce forests in the lower montane belt displayed much bigger changes. There was an increase of the role of species of the deciduous forests, while the role of the coniferous forest species was limited in the studied patches, which clearly indicates the evolution of the forests towards the beech woods, typical for the lower montane belt. This means a progressing limitation of the spruce forests in the limestone Tatras to the advantage of return of the beech woodsdominated there in older time.

Key words: spruce forests, Polish Tatra Mts., floristic changes during 80 years, vegetation typology

Introduction

Since the time the first descriptions of plant associations in the Tatra Mts. were elaborated, 80 years have passed. The period between these descriptions and the present day allows for the performance of the analysis of changes, which were taking place in forest associations. The aim of this study is to assess changes, which have occurred in the spruce forests of the Polish Tatras over the last eighty years. In the case of present elaboration the issue is not so much in how the concrete patches of vegetation change under the influence of the succession, degeneration or other similar phytocenotic processes, but in the changes of characteristics of association.

Tree stands with the domination of spruce (*Picea abies*) are in the Tatras a constant element of landscape. Spruce woods appear, as a rule, in the upper montane belt as natural zonal communities, forming

on the calcium-devoid substrate the association *Plagiothecio-Piceetum*, and on the carbonate substrate – the association *Polysticho-Piceetum*. Spruce is in the lower montane belt of the Tatra Mts. also the main species forming the stands of the mixed fir-and-spruce forests (*Galio-Piceetum*, *Abieti-Piceetum*), but, in fact, much more frequently constitutes monocultures on the habitats of the beech and mixed coniferous forests.

High share of spruce in the forest communities, as well as the current state of forests in the Tatra Mts., constitute the effect of many centuries of human economic activity in these areas. This activity involved pasturing in high mountain meadows and forest clearings, extraction of metal ores – mining and metallurgy, and exploitation of wood, as well as more intensive forest management, especially in the lower montane belt. High mountain pasturing brought about the lowering of the upper timberline and thin-

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ning out of the higher situated stands. Exploitation of wood for construction and burning purposes changed particularly the lower parts of the mountains, liquidating natural multi-species tree stands and introducing the spruce monocultures. In the 1920s, Szafer *et al.* (1923), analysing the vegetation of the Tatras stated that, for instance, that in the lower montane belt in the Chochołowska Valley there were no forest patch that would have natural character, nor any truly old tree. On the other hand, they thought the forests of the upper montane belt were natural, but strongly thinned due to felling and pasturing.

Establishment of the Tatra National Park in 1954 stopped the destructive human activity in mountain forests, although the consequences of this activity are still visible in the forests in the form of spruce monocultures in the lower montane belt and the blurring of the boundary between the lower and upper montane belt. Extending of protection over the Tatras allowed for the setting in motion of the natural processes of regeneration, maturing and ageing of the existing tree stands. The natural factors, which also nowadays exert influence on the increasingly old stands, are the mountain foehn-type wind (Polish “halny”) and the avalanches, leading to forest destruction and the subsequent pest invasions. The consequence thereof is constituted by the significant areas of the slopes devoid of forests or visible gaps in tree stands, especially of the upper montane belt, in the areas previously intensively exploited. Natural renewal of forests is also being observed. Thus, the spruce forests of the Tatras represent nowadays a mosaic of various ages, composed of old tree stands, regeneration phases, as well as freshly formed gaps (Holeksa, 1998, 2003; Holeksa & Zielonka, 2005). This is particularly visible in the upper montane belt. In the lower montane belt, on the other hand, a reconstruction of the stands is being conducted, with beech and fir planting under the canopy, meaning conscious and purposeful diminishing of the areas occupied by the spruce stands. All these processes lead to the transformation of the forest communities, changes in the species composition and the geobotanical character. The entirety of the respective processes can be tracked by comparing old documentation materials (the phytosociological relevés) with the current ones, taken in the same or similar locations.

The object, area and methods of study

The study encompassed three types of spruce forests, existing in the Tatra Mts.:

- spruce forest of the upper montane belt on the siliceous substrate (*Plagiothecio-Piceetum*),

- spruce forest of the upper montane belt on the carbonate substrate (*Polysticho-Piceetum*),
- spruce-and-fir forests of the lower montane belt (*Galio-Piceetum*).

All of them belong to the class *Vaccinio-Piceetea*, order *Vaccinio-Piceetalia*, alliance *Piceion abietis*, sub-alliance *Vaccinio-Piceenion*.

Plagiothecio-Piceetum appears in the Western Carpathians on the siliceous substrate and is limited to the mountain ranges, which attain the altitude exceeding 1,150 m a.s.l., giving rise to the upper montane belt. *Polysticho-Piceetum* is encountered in Poland solely in the Tatras in the upper montane belt at the altitude of 1,150–1,500 m a.s.l., on the carbonate substrates (limestones, dolomites, chalk marls and other rocks with calcium carbonate content). *Galio-Piceetum*, the mixed spruce-and-fir forest of the lower montane belt of the Carpathians, classified as a separate unit by Matuszkiewicz (1977), singled out of the alliance of *Abieti-Piceenion*, is associated with quite fertile substrates, and appears in the Western Tatras on limestones and dolomites.

The study area encompasses the spruce forests of the valleys of Chochołowska, Starorobociańska, Kościeliska and Rybiego Potoku, situated within the boundaries of the Tatra National Park and protected since 1954. They are managed by the National Park (Kościeliska and Miętusia valleys, vicinity of the Giewont Mt., and Rybiego Potoku Valley) and by the Forest Community of Witów (valleys of Chochołowska and Starorobociańska), with sustainable forest economy being conducted in the framework of the national park, along with limited sheep pasturing over the clearings.

The basis for the study was constituted by the comparison of the phytosociological relevés originating from the publications of the 1920s with the contemporary relevés, taken by the present author in 2004 in the locations of the historical relevés or close to them, when precise location of the old relevés could not be established. In many places it turned out also impossible to repeat the phytosociological relevés because of the lack of forests, since old stands fell victim to numerous windbreaks, especially in the peak-adjacent parts of slopes, this being compounded by the bark beetle pest, particularly visible in the Rybiego Potoku Valley. Contemporary relevés were made in August, similarly as in the case of historical ones.

Historical materials, constituting the basis for comparison, originate from the publications of Szafer *et al.* (1923, 1927) and Pawłowski *et al.* (1928). All 45 historical phytosociological relevés were accounted for: 10 from *Plagiothecio-Piceetum*, 26 from *Polysticho-Piceetum*, and 9 from *Galio-Piceetum*. These were compared to 32 contemporary relevés, of which 12 represented *Plagiothecio-Piceetum*, 9 – *Polysticho-Piceetum*, and 11 – *Galio-Piceetum*. Changes

in the species composition and the phytosociological characteristics within the units considered were assessed.

Complete report on the study, along with the respective documentation, is provided in the publication of Kozłowska (2007). The present report gives the most important results, concerning the transformations to date of the Tatra Mts.' forests and the forecasted changes.

Changes in the upper montane belt spruce forests (*Plagiothecio-Piceetum*) in the Tatras

The currently observed spruce forests, belonging to *Plagiothecio-Piceetum* in the Tatras, represent the terminal stages of the stand development and constitute the evidence for the nature reserve type of management in the Tatra National Park, which leaves the upper montane belt forests to the natural processes of development and decline, and so they are often interspersed with gaps, due to windbreaks. Although they belong unambiguously to the class of *Vaccinio-Piceetum*, the share of species characteristic for this group decreased on the average from 8.4 per one historical relevé to 6.8 in the contemporary relevé. The average number of species found altogether in one relevé does not differ significantly between the historical and contemporary ones, being respectively equal 18.6 and 17.5. The changes observed consist, therefore, rather in the replacement of some species by the other ones (Fig. 1). Since there are numerous wind breaks and gaps, and the uptake of nutritive substances from the soil is less intensive than in the case of compact forest communities, soils are now

relatively more fertile and there are less species of strictly forest character. Tall herbs and bushes grow abundantly (e.g., rowans *Sorbus aucuparia* or raspberries *Rubus idaeus*), as well as photophilous species associated with small forest clearings and felling areas, such as *Senecio fuchsii*, *S. nemorensis*, *Solidago virgaurea*, and *Luzula luzuloides*. Thus, the analysed upper montane belt forests undergo the natural transformation processes of fluctuating character and are now in the ageing and decline phase.

The *Plagiothecio-Piceetum* community, as zonal for the upper montane belt on acid substrates, has persistent character and shall remain like this for the future. The changes in the species composition shall undergo natural transformations depending upon age and compactness of spruce stands. These changes, though, shall not result in the transformation into another type of forest.

Changes in the upper montane belt spruce forests *Polysticho-Piceetum* on limes in the Tatras

The changes, observed in the upper montane belt spruce woods growing on limestones in the Tatras over the period of last 80 years, have not been very significant, although clearly visible. The floristic diversity of this community increased only slightly from, on the average, 46.5 to 48.8 species in a phytosociological relevé. The membership in the syntaxonomic units of higher rank did not change, but the characteristics of the community weakened. This is clearly seen in Fig. 2. All the species considered characteristic for the community became increasingly rare – in the least degree this concerns *Polystichum lonchitis*. *Moneses uniflora* disappeared distinctly. Some orchids regressed (*Listera cordata*) or were not found at all (*Corallorhiza trifida*). There was a regression of the *Pirolaceae*, not only of *Moneses uniflora*, but also of *Pyrola minor* and *Orthilia secunda*. The same applies to the club-mosses: *Lycopodium annotinum* and *Huperzia selago*.

It is, on the other hand, telling that almost all species, whose frequencies increased, are tall herbs and grasses, or were the species with at least partly lignified twigs (scrubs, shrubs, deciduous trees). Among these, an especially significant group is constituted by the representatives of the class *Betulo-Adenostyletea* (see Fig. 2). Numerous other species belong to the class *Quercu-Fagetea* or are the common forest species.

The majority of the changes quoted here could be probably ascribed to the transformations that took place after the area had been protected in the Tatra National Park and pasturing was stopped. This made possible the development of species with large, soft

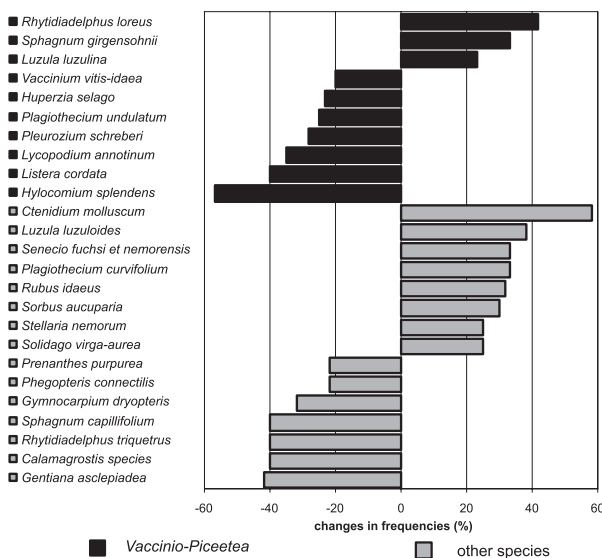


Fig. 1. Species of the association *Plagiothecio-Piceetum*, which changed their frequencies in the highest extent in the years 1923–2004 in the Tatra Mts.

leaves, until then subject to grazing by the sheep and cattle. Disappearance of the grazing factor was expressed as well through the decreased share of *Vaccinium vitis-idaea*, typical for the degenerate forests, and the expansion of *Vaccinium myrtillus*.

The species of mosses and liverworts underwent changes as well, frequencies of some of them increased, while of the other ones – decreased. Yet, their ecological requirements are less known, and so it is hard to unequivocally explain the loss of some species and expansion of the others. Still, the general role of the moss-like species in the upper montane belt spruce forests growing on lime has not changed.

The most difficult to explain is the disappearance of the characteristic species of the *Polysticho-Piceetum*. Perhaps the basis of the characteristics of these association is constituted, side by side with the properties of the habitat, also by the ancient way of forest use, marked with grazing. To what extent this created an opportunity for the *Pirolaceae* species and for some of the orchids – it is hard to unequivocally assess. This issue requires a deeper study.

In the Tatras, the association *Polysticho-Piceetum* is a persistent, zonal forest type, linked with the upper montane belt and the calcareous substrate, and as such does not undergo changes into another forest

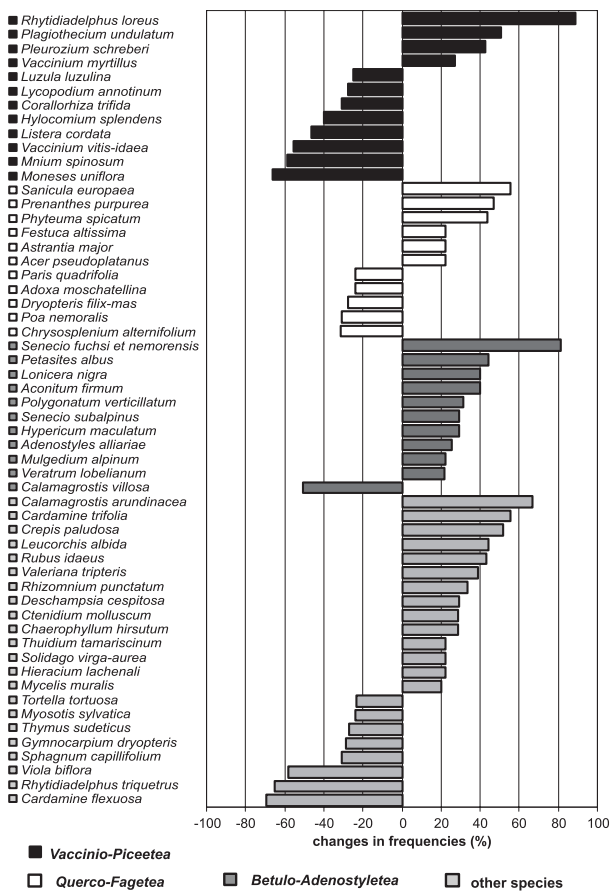


Fig. 2. Species of the association *Polysticho-Piceetum*, which changed their frequencies in the highest extent in the years 1923–2004 in the Tatra Mts.

type. The transformations that it actually goes through, have in their majority the character of natural fluctuation, associated with the development phases of the tree stands in conditions of the protection status of the national park.

Changes in the lower montane belt mixed forest *Galio rotundifolii-Piceetum* in the Tatras

After eighty years since the historical relevés had been taken in the lower montane belt mixed spruce-and-fir forest in the Tatras, the following changes could be noted (Fig. 3):

- the renewal of the deciduous tree species (*Fagus sylvatica*, *Acer pseudoplatanus*),
- the increase of the number of bushes (*Daphne mezereum*, *Lonicera nigra*, *Salix caprea*, *Rubus idaeus*),
- the increase of the quantity of high herbs, grasses and sedges,

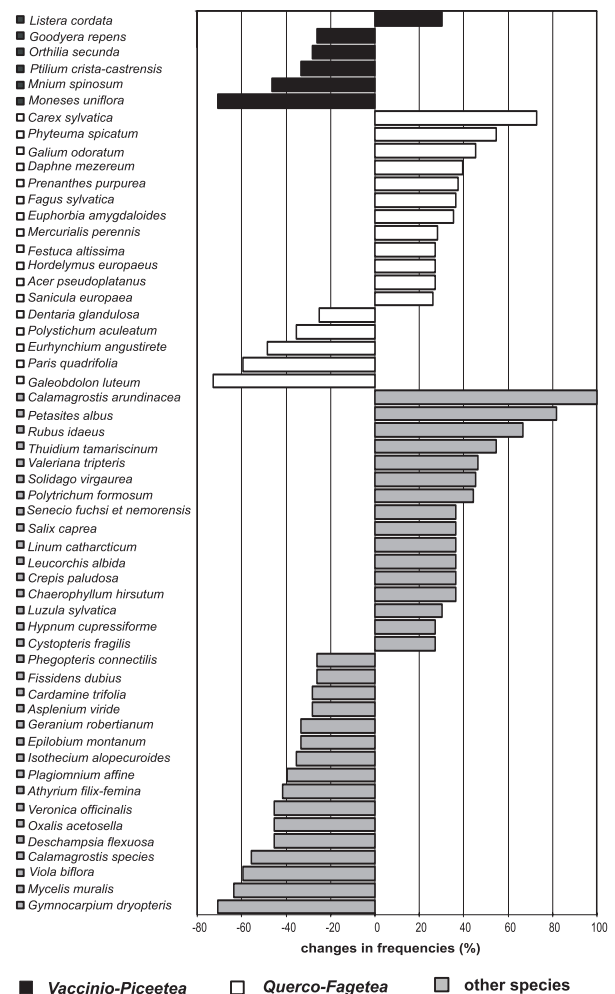


Fig. 3. Species of the association *Galio-Piceetum*, which changed their frequencies in the highest extent in the years 1923–2004 in the Tatra Mts.

- the distinct increase of the number and frequency of species from the class of *Querc-Fagetea* (the coverage of these species remained on a similar level).

The average number of species in a relevé increased from 41.7 to 44.5, what evidenced bigger floristic richness of the contemporary lower montane belt spruce-and-fir forests.

All these features are the evidence of transformation of the forests, taking under protection after the periods of intensive grazing and intensive management for timber production. This transformation tends towards the restoration of the state from before the spruce stands had been introduced. There are more of deciduous trees, and the tall herb and grassy undergrowth, not grazed by the sheep and cattle, developed. A renewal of club-mosse, and of some orchids was observed. At the same time, the shares of some species decreased, which, as of now, does not find an unequivocal explanation. These might perhaps be natural fluctuations, linked, in particular, with the inter-species interactions. It is also possible that some regressing species are of pioneering and photophilous character and can not vegetate under tall herbs. Yet another explanation might be a change in the nutritional preferences of the herbivorous animals, with replacement of the influence, exerted by sheep and cattle, by the fallow-deer. This issue requires a further study. On the basis of comparison of the current state with that from before 80 years ago, one can conclude that the process, which takes clearly place in the lower montane belt spruce-and-fir forests, is an example of regeneration of deciduous forest associations from the class *Querc-Fagetea*. This is seen through the ratio of the syntaxonomic group value “D” (Tüxen & Ellenberg, 1937) of the species from the classes of *Vaccinio-Piceetea* and *Querc-Fagetea* (Table 1) – 80 years ago the spruce forest species dominated over those characteristic for mixed and deciduous woods. Nowadays, the syntaxonomic group value of the species from the class *Querc-Fagetea* dominates over that for *Vaccinio-Piceetea*, which means that the process of transformation of the spruce forest into deciduous

Table 1. Changes in the shares of two syngenetic groups of species (*Vaccinio-Piceetea* and *Querc-Fagetea*) on the basis of syntaxonomic group values „D” in *Galio-Piceetum* in the Tatra Mts.

State	Historical		Contemporary	
Syntaxonomic unit	<i>Vaccinio-Piceetea</i>	<i>Querc-Fagetea</i>	<i>Vaccinio-Piceetea</i>	<i>Querc-Fagetea</i>
Syntaxonomic group value	165.7	139.4	171.1	201.6

one was registered. In the future, one might expect the transformation of the lower montane belt spruce forests of the region into beech woods. The return of the deciduous forest is insofar more feasible that the limestone rocks are situated shallowly in the bedrock and even long-term maintenance of spruce monocultures could not change the character of the bedrock, i.e. to make it persistently acid. Hence, the relatively quick return of the beech forest with compact undergrowth, composed of tall herbs, is quite probable.

In general terms, it seems likely that *Galio rotundifolii-Piceetum* on the lime substrate disappears from the Tatras. The reasons stem from the natural processes of regeneration of phytocoenoses after the introduction of the protective regulations of the Tatra National Park and the withdrawal of the intensive sheep grazing.

Changes in the spruce forests of the Tatras

Analysis carried out with the help of the DCA, regarding the entirety of the phytosociological material from the spruce forests of the Tatras (Fig. 4), revealed the following phenomena:

There are clear differences between the historical and contemporary relevés, visible on the basis of positioning along the axis 2 of the phytosociological relevés, taken in two different terms; this applies to each of the forest types considered.

The contemporary forest types distinctly differ from each other in terms of habitats, which can be observed on the basis of their location along the axis

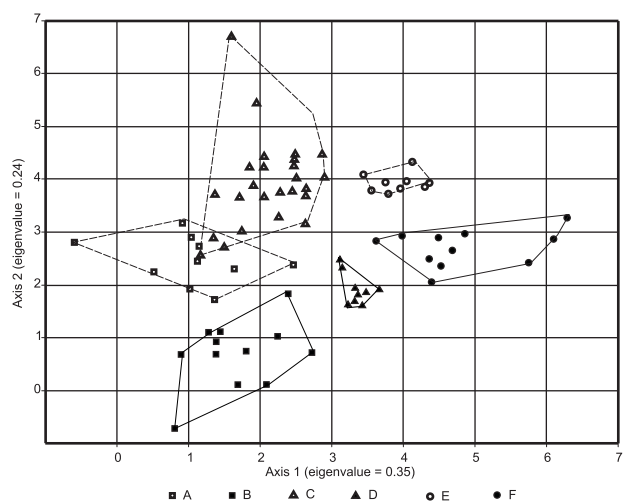


Fig. 4. Ordering diagram of the phytosociological relevés of spruce forests from the Tatra Mts. in the setting of the first two axes of DCA

Explanations: A – *Plagiothecio-Piceetum* historical, B – *Plagiothecio-Piceetum* contemporary, C – *Polysticho-Piceetum* historical, D – *Polysticho-Piceetum* contemporary, E – *Galio-Piceetum* historical, F – *Galio-Piceetum* contemporary

1, while the upper montane belt forests, observed 80 years ago do overlap as to their ranges of variability, which constitutes the evidence for the existence at that time of an impact factor, that in a way covered up the differences related to abiotic conditions. This factor was most probably constituted by sheep grazing, common at that time in the areas surrounding forest clearings.

During the last eighty years changes took place in the spruce forests of the Tatras, whose intensity depended upon the altitude. In the upper montane belt, the forests controlled by the location and properties of the substrate, remain stable. It means that their role as dominating zonal associations on acidiphilous or calcareous substrate has not changed in the landscape. The changes that have been taking place in them, arising due to wind breaks or ageing of the tree stands, do not lead to the transition to other forest associations. Anthropogenic or natural degeneration of forest patches have a local character and do not change a role of forests in the mountain landscape. There is, on the other hand, a distinct tendency of disappearance of species forming the characteristic species combinations, that is manifested by the lowering of the latter or even disappearance of some species characteristic for the associations, or for higher syntaxonomic units. A spectacular phenomenon of this kind is the disappearance of the species of *Pirolaceae*, which has not been explained until now.

The spruce-and-fir forests of the lower montane belt in the Tatra Mts. display much bigger changes. The *Galio-Piceetum*, representing the more fertile forms of the associations from this group, shows the symptoms of a distinct recession, the role of the species of the deciduous woods being on the increase, while the role of the conifer forest species decreases in the patches considered, which clearly indicates the evolution of the patches towards the beech woods.

Summary of results

The transformation of the forests subjected to protection in the Tatra National Park leads to the restoration of forest types and bear less traces of human influence.

This transformation consists in changes in the species composition of forest communities, disappearance of some rare and valuable species, and regression of a number of species characteristic for the

syntaxonomic units, to which the respective forests belong.

The contemporary human activity supports only the natural directions of changes, both in the forests of the Tatra National Park and of the Forest Community of Witów.

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