Knowledge of Forest Management History as a Support Decision Tool for Management Plans of Forest Protected Areas

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Abstract

The paper deals with forest management history of Norway spruce dominated forest ecosystem in Central Europe. Until the early 18th century, the remnants of climax Norway spruce forests below the alpine tree line in study area was affected only by a locally conducted selection logging. By the end of the 18th century, these forests were utilized in two different ways based on available wood transport: (i) forests that allowed transport of harvested wood to the valleys by river drives were intensively harvested by clearcutting with no subsequent artificial restoration, leaving the stands to be spontaneously renewed by natural regeneration, whereas (ii) forests that did not allow river drives maintained their primeval character. In the subsequent years, the clear cuts often reached the alpine tree line, and, in combination with grazing and hay making, caused a downward shift of the tree line by up to 100 meters of altitude. Abandoning the no longer suitable clearcut harvests below the alpine tree line in the mid 19th century has the historical influence of forest harvests as one of the factors causing the alpine tree line altitudinal downward shift. Recently, a gradual upward shift of the alpine tree line ecotone is being observed in the study area under climate change. The results of this study suggest that research on forest management history can be consider as a decision-support tool for conservation management strategies for mountain forest habitats in protected areas.

Keywords: acidophilous spruce forests, conservation, forest management, Hruby Jesenik Mountains, Natura 2000.

Introduction

Linking of history and ecology is based on interdisciplinary approach (Russel 1997). Applying results of research on forest history to forest management is an example of this interdisciplinary approach into practice (Simon et al. 2014). Knowledge of forest management history helps us to objectively understand the current state of the forest ecosystem determined by the forest management and other human activities carried out in the past (Eastaugh and Hasenauer 2011). This knowledge can be applied as decision support tool for sustainable forest management strategy (Parviainen and Frank 2003) especially in European forests, which have been strongly influenced by forest management activities and land cover changes during last centuries (Petit et al. 2008, Pound 1979).

This article deals with forest management history of European Norway spruce dominated mountain forests below alpine tree line. The alpine tree line ecotone (ATLE) representing a transition zone between mountain forests ecosystems and alpine grasslands ecosystems. ATLE is considered as one of the most important ecological interfaces in the mountain landscapes around the world (Treml et al. 2010). The ATLE is formed by trees often occur in clonal groups (Laberge et al. 2000) surrounded by prostrate shrubs (Grau et al. 2012). An important strategy enabling trees to form and maintain stands in environments where seedling growth and survival are limited by cold is vegetative reproduction (Holtmeier 2009). Treeline ecotones in western North American mountains contain *Abies lasiocarpa*, *Picea engelmannii*, and shrubby *Chamaecyparis nootkatensis* (Arno and Hammerly 1984); those in central Kamchatka

include *Larix gmelinii* and *Pinus pumila* (Okitsu 1998) and those in the Carpathians in Europe have *Picea abies* and *Juniperus communis* ssp. *alpina* (Mihai et al. 2007).

In the temperate zone of Europe, forests with a natural dominance of Norway spruce (*Picea abies* L. Karst) below the ATLE are the predominant type of the natural potential vegetation in montane vegetation zones of the temperate Europe (Svoboda et al. 2010). Forest and conservation management strategy for these mountain spruce forests ecosystems is widely discussed under climate change impacts (Lindner et al. 2014, Yousefpour et al. 2013), in the frame of bark beetles as a driver for forest dynamics (Zeppenfeld et al. 2015) and of course in the context of ecosystem services of montane forests (Carnol et al.2014, Cudlin et al. 2013).

On a global scale, the most important factor determining the ATLE and spruce forests below the ATLEs (SFBA) is a temperature (Körner and Paulsen 2004). On a regional scale, the dynamics of the ATLE and SFBA is determined by a number of specific factors that may mutually interact: intense wind pressure (Holtmeier and Brol 2010), topography coupled with the dynamics of avalanches and local distribution of snow (Mellman-Brown 2005), vegetation structure (Treml and Chuman 2015). In the past, anthropogenic activities (grazing, haymaking and logging) have caused downward altitudinal shift of the ATLE (Holtmeier 1974). Today, there is in progress an opposite trend viz. upward forest shift of the ATLE and SFBA caused by the ongoing climate changes (Büntgen et al. 2007, Garamvoelgyi and Hufnagel 2013, Svajda et al. 2011, Vanoni et al. 2016). These climate-induced shifts of the vegetation can be locally modified by a variety of specific ecological factors, e.g. disturbances or different phenotypic plasticity and adaptability of dominant tree species in a specific forest ecosystem (Iverson and McKenzie 2013). But, in many mountain European areas, this climate-induced movement of the ATLE is based on anthropogenic activities in past, which included former agricultural activities in the ATLE and former forest management activities in the SFBA.

In the Hruby Jesenik Mountains (Czech Republic), a climate-induced upward shift of the ATLE and SFBA is currently inhibited by a competition between Norway spruce and Dwarf mountain pine (*Pinus mugo* Turra) (Senfelder et al. 2014). In the 19th and 20th centuries, the Dwarf mountain pine was artificially planted precisely to stabilize the ATLE against erosion (caused by grazing in the past) and to induce its upward altitudinal shift, as it has been earlier pushed to lower elevations by grazing. Below the ATLE, the forest vegetation of SFBA is formed by habitat type of Acidophilous spruce forests (Jirasek 1996). Today, these Acidophilous spruce forests are protected within the Natura 2000 European network (Natura 2000). A non-intervention management is applied in these forests to comply with the IUCN management category I, i.e. strict nature reserves (Dudley 2008). This management regime comes from current Management Plan (Kavalec 2012). The forest management strategy takes into account the targets defined by the Natura 2000 (maintenance and restoration of protected habitats on a specific site) but not forest history management (Machar et al. 2014).

The main objective of this paper is to highlight the importance of knowledge on forest management history to forest management plan in forested protected areas (including to the Natura 2000 system) based on the case study from Central Europe. Presented results of forest management history are related to the montane Acidophilous spruce forest habitats below the ATLE in the Hruby Jesenik Mountains (Czech Republic) in the National Nature Reserve Praded, which is the site under Natura 2000 system. Management plan of this protected area is based on two common hypotheses: (1) current state of naturalness of forest ecosystem reflects the intensity of timber logging in the past and (2) the former ATLE in local scale is today unknown and thus there is very difficult to manage the forest stands (e.g. as we do not know the former ATLE, we do not know where exactly we should remove non-native trees such as Dwarf mountain pine from the former alpine grasslands etc.). Authors tested both of hypotheses by research of unpublished historical source.

Material and Methods

Study area

The study area – National Nature Reserve Praded (NNR P) – is located in the Hruby Jesenik Mountains (HJM) in the northeastern part of the Czech Republic (Figure 1). The local bedrock geology consists of acidic crystalline rocks (gneisses, mica schists, and flysches). The surface forms have been modeled by mountain glaciers in the glacial period (Demek and Mackovčin 2006). The soils are shallow and very stony, mostly Cambic Podzols with high content of skeletal material. The forests below the ATLE in NNR P predominantly consists of Acidophilous spruce forests ecosystems in climatic conditions of the spruce forest vegetation zone (Vahalik and Mikita 2011). This forest habitat in the study area extends up to the natural tree line, an ecotonal belt formed by sparse Norway spruce clonal groups. Around the highest peak in the study area (Praded, 1491 m a. s. l.), the ATLE transition into alpine grassland habitats is observed (Jenik 1961). NNR P has a total area of 2,031.4 ha. NNR P is the Site of Community Importance Praded (Czech national code CZ0714077, see Machar 2012).

Acidophilous spruce forests below the ATLE in the study area consist of a mosaic of two distinct types of vegetation: (i) allochtonous even-aged forests, originating from past clear-cut forests and (ii) autochtonous un-

even-aged forests dominated by autochtonous spruce. According to the international Natura 2000 typology of habitats, the forests are classified by the code 9410 (Miko 2012). According to the Czech national classification of biotopes, the study site belongs to the forest habitat code L9.1 (Chytry et al. 2010).

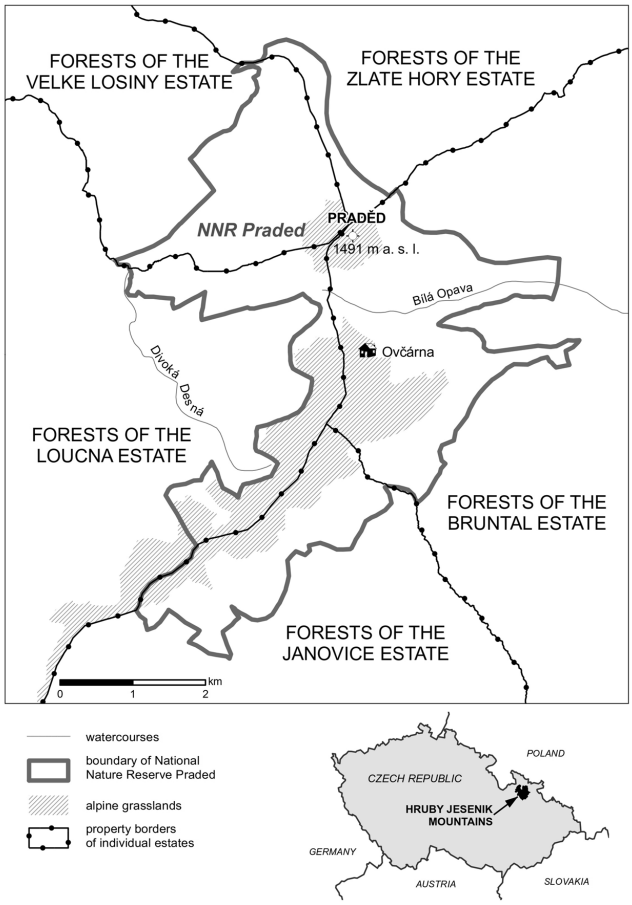

Figure 1. Location of the study area, NNR P and Hruby Jesenik Mountains, in the Czech Republic and reconstruction of historical borders of former estates in the study area

Data sources and analysis of forest management history in the study area

Until 1620, there are no specific known historical documents that would map the historical development of the forests in NNR P study area. To study the historical development between the years of 1621 and 1947, we used preserved original written records from forest inventory books and accounting books of the forest owners. This archival documentation (written in German language) is deposited in the State Regional Archive in Opava (the "Bruntal Estate" collection), in the State Regional Archive in Janovice (the "Loucna Estate", "Janovice Estate", "Zlate Hory Estate" and "Velke Losiny Estate" collections) and in the State Regional Archive in Brno ("G 10 archive collection"). In the previous study (Kilianova et al. 2017) we have analysed historical maps from former military mapping (during the period of Austria-Hungary Empire) related to the study area Hruby Jesenik Mountains. Map sheets of the military mapping from 1836–1840 (called Franz's military mapping) are in fathom scale 1:28,800. The historical military mapping from 1876–1878 produced maps in scale 1:25,000. Visualization of forests and other land-use in these historical maps is very general and nor very precise. So, we did not use these maps in the frame of this study. But for these both time periods in the 19th century we did have available historical special forest maps including forest management plans in more detailed scale (1:10,000) and thus we used preferably these forest maps in appropriate scale.

Since 1947, all forests in the study area were owned by the state. Valuable historical data for this period were found in the forest management plans deposited in the archives of the Forest Management Institute in Brandys nad Labem, whereas newer data were found in the book of management records for NNR P deposited at the administration office of the Jeseniky Mountains PLA.

The identification of historical entries with the current forest stands in NNR P study area was easy due to the fact that the historical borders of the former private estates " established after 1621 " led along significant natural boundaries (e.g. mountains ridges) and they remained unchanged throughout the existence of the estates until 1947. The mountain forests in today NNR P were part of five estates (Figure 1). The Bruntal Estate was owned by the Teutonic Order, the Janovice Estate was owned by the Liechtenstein royal family, the Velke Losiny Estate was originally owned by a Bohemian noble family, the Lords of Zerotin but later also became part of the Liechtenstein dominion. The Loucna Estate was in the possession of several noble families and the Zlate Hory Estate was owned by the Archdiocese of Wroclaw. The landholding situation in these estates was remarkably stable for several centuries until the Second World War. Shortly after the war, the Czechoslovak government (ruled by the Communist Party since 1948) put the private estates under the state ownership. The original estate borders were kept and used for the newly formed state forest enterprises. This organizational division of the state forests is valid practically to date. Only in 1990, the former 'forest enterprises' changed their name to 'forest administration units' as the 'Forests of the Czech Republic' State Enterprise was established.

Results

Forests in the HJM are first mentioned in the "Chronicle of Bohemians" (original Latin name *Chronica*

Boëmorum), written by Cosmas of Prague in the years 1119–1125 (Blahova and Hrdina 2005). The Chronicle suggests that until the 12th century, the mountain forests in the HJM were part of the "borderline forests", an unpopulated and forested border mountains belt that formed a natural defense of lowland areas of the Bohemian Kingdom, intensely inhabited since the Neolithic era (Bouzek 2011). No major trade route led through the HJM in the Middle Ages as there was no suitable mountain pass that would allow crossing the mountain ridge and one main trade route already led along the western foothills, through the "Moravian Gate" (Kvet 2003). First significant colonization efforts of the HJM associated with anthropogenic impacts on the mountain forests in the form of selective logging date back to the 15th century, as the exploitation of iron ore and gold has started in the peripheral areas of the mountain range and first mining towns formed along the northern and southern mountain edges (Zlate Hory and Horni Mesto u Rymarova, respectively) (Hosek 1970).

Since at least the 17th century, top parts of the central HJM above the ATLE (formed by natural forest-free areas, alpine grasslands) were used for agricultural purposes (mowing and harvesting of hay, cattle and sheep grazing in summer months). The first literary reference to the agricultural utilization of alpine grasslands in the Loucna Estate dates back to 1639, when, according to the accounting books, fourteen persons paid to harvest hay in the mountains for two days (Anonymous 1639). Livestock grazing on the alpine grasslands is first mentioned in the urbarium of Janovice and Velke Losiny Estates (Anonymous 1689), who were both buying young bullocks in Poland and Hungary for this purpose. Other estates soon followed their example and by the beginning of the 18th century, alpine grasslands of the HJM were all used for summer (mostly sheep) grazing, which has become a common activity pursued in the area during the following 200 years. Grazing sheep stayed on the alpine grasslands from spring until fall when they were brought to the sheepfolds in the submontane villages. The numbers of grazing sheep on alpine grasslands were likely quite high (200–300 sheep on the alpine grasslands of just the Bruntal Estate). The historical importance of sheep grazing is evidenced by the local name of today recreational site Ovcarna (i.e. „Sheep stable") (Figure 1). A cattle grazing was causing damages on the naturally sparse forest of the tree line ecotone; therefore, it has been slowly reduced, and then completely terminated by 1800. Sheep grazing did not end until the mid-19th century, when sheep farming became gradually unreasonable due to an import of cheap wool from Australia to Europe. Scything and haymaking persisted on the top parts of the HJM for the longest period of all agricultural activities. In 1871, however, these activities were forbidden for damages caused to the forest (mowing along ATLE areas has occasionally caused unintentional damage to tree seedlings, which are especially rare in the local conditions). Processing of iron ore in ironworks and forges, which have been built since the 17th century in the mountain valleys in close vicinity of the iron ore mines, required large amounts of wood. Transportation of wood harvested in the mountains to the ironworks in the valleys was technically and economically feasible especially by means of river drives on rivers with a steep slope and sufficient amount of water but only in a short period of time in the spring after snowmelt. Some forest areas in the HJM were unsuitable for this type of wood transport (due to an impassable terrain combined with an excessive distance to the rivers suitable for river drives) and wood production in such locations was therefore not viable. This applied particularly to the western part of the HJM, where the climax spruce forests (below the ATLE) of the former Loucna Estate remained until the mid-18th century. In 1750, these forests were described as full of decaying wood and many fallen trees, making the passage for both man and livestock dangerous and, in some places, completely impossible. Moreover, these forests allegedly provided a safe shelter for large wild animals such as bears, wolves, and lynxes (Anonymous 1750). In contrast, wood harvesting in places suitable for river drives had a great impact on the state of the mountain forest. This fact can be indirectly deduced from the "Josefsky Cadastre" from 1786 (Skalos et al. 2010), which declares that the forests did not have large wood volumes (only about 180 m^3 of wood in harvest age per hectare). The high demand for wood in the central alpine areas of the HJM by the iron industry led to a gradual transition from selective logging to clear-cut logging. When all available forest stands in the vicinity of ironworks were harvested, clear cuts gradually shifted into higher mountain areas. According to the analyzed archival records, the most intensive wood harvesting by means of clear cuts took place in the eastern part of the HJM on the Bruntal Estate. In this area, the harvested logs were floated down the "Falcon Creek" and the "White Opava River" to the valleys. Between 1778 and 1808, a repeated harvest took place throughout the forests of the Bruntal Estate with almost no subsequent artificial restoration, leaving the stands to be spontaneously renewed by natural regeneration. Nevertheless, the natural regeneration in the alpine conditions was very slow. Based on the economic interests of the Teutonic Order (the owner of the Bruntal Estate since 1621) in further wood production, a first forest management plan was formulated in 1803 by the forest chief manager Jan Vavrinec Knappe. He divided forest districts into smaller units in order to reduce the annual harvest volumes (Knappe 1803). According to the management plan,

clear cuts were pursued right below the ATLE. For this reason, all old-growth mountain forests around the "Falcon Creek" east of Praded were completely harvested between 1803 and 1827. The combination of large clear cuts, livestock grazing and mowing led to a downward shift of the tree line (Anonymous 1827).

The exact extent of the ATLE shift in the HJM in the past, however, cannot be detected. The original ATLE before the anthropogenic exploitation of habitats was likely located at an altitude of 1,340–1,400 m a. s. l. According to the intensity of reported harvests on individual estates, it is estimated that the most significant ATLE shift occurred on the land of the Bruntal Estate. This fact is supported by a report of the Bruntal chief forester Riedel in the forest management plan from 1866. For the alpine grasslands in the Hubertov forest unit (east of Praded) Riedel reports (Anonymous 1866) old Norway spruce stumps several hundred feet above the ATLE, which was then located approximately at the same altitude as today in this particular area (Figure 2). Unfortunately, it is no longer possible to refine Riedel's historical entry. The Bruntal Estate bordered the forests of the Zlate Hory Estate (owned by the Wroclaw archiepiscopate), where the intensity of wood harvesting (also due to bad accessibility of rivers for river drives) was markedly lower. When comparing today extent of the alpine spruce forests on the territories of both former estates, we estimate the downward shift of the ATLE on the Bruntal Estate by approximately 100 meters of altitude (Figure 2).

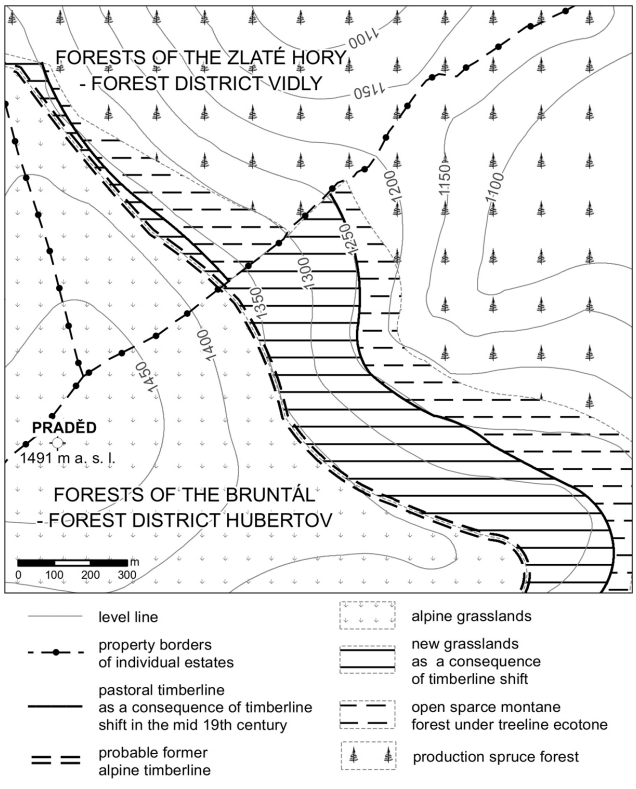

Figure 2. Reconstruction of the downward shift of the alpine tree line in the study area, NNR P, on the Bruntal Estate in 1866

In the middle of the 19th century, a turnover in the management of mountain forests occurred in the HJM. In 1852, the Imperial Patent No. 250 came into force in Austria-Hungary Empire (then Czechia was a part of the empire). According to §6, wood harvesting on steep slopes in high altitudes was allowed only in narrow strips or by means of gradual thinning, clear cuts were forbidden and harvested areas had to be immediately reforested. On June 24, 1853, the Austrian Imperial Forestry Association issued a call for artificial afforestation of mountain alpine areas. These initiatives reflected in the first artificial afforestation attempts in the HJM known as "award forest cultures", as the successful afforestation outcomes have been financially awarded by the monarch (Nozicka 1957). Historically, the first such award (in the amount of 400 ducats) in the HJM was given to the Loucna Estate for a successful afforestation of exploited alpine forest areas in the Rejhotice District at an altitude of 1,175–1,320 m a.s.l. An actual systematic and planned forest management in the highest altitudes of the HJM dates back to 1866, when the chief forester Riedel of the Bruntal Estate designated forests just below the ATLE as a special "protected forest". The forest management plan specifically prohibited clear cuts (formerly very common) in these protected forests and allowed only such actions that would help maintaining or raising the ATLE. Other large estates in the HJM followed this example over the next 13 years. In 1880, all alpine forests just below the ATLE were designated as special protected forests with a total area of 3,254 hectares (Table 1).

In the subsequent years, other forest stands were added to this group, and in 1887, for example, the area of the protected alpine forest increased to 332 hectares in the Zlate Hory Estate (Anonymous 1887).

The actual forest management in the protected forests below the ATLE varied among individual estates, including the intensity of harvests. According to the

Table 1. Area of protected mountain forests in the study area, NNR P: situation in 1880

Estate	Year of establishment	Area of protected mountain forests, ha
Janovice	1870	793
Loucna	1876	928
Velke Losiny	1879	983
Zlate Hory	1865-67	192
Bruntal	1868	358
Total area		3254

Source: own calculation

forest management plan for the Janovice Estate in 1870 (Anonymous 1870), each forest stand should have gone through a selection cutting ten times during its rotation period in order to create a forest stand of ten age classes at the end of the rotation period. On the Bruntal and Loucna Estates, strip harvests (removal of trees in a row) combined with a preservation of individual seed trees and artificial reforestation were favoured over selection cutting. Around 1870, the lowest harvest intensity in spruce forests below the ATLE was reported for the Bruntal Estate (0.62 m^3/ha/year), the highest intensity for the Janovice Estate (2.5 m^3/ha/year). At the same time, harvest intensities in beech forests at the lower mountain areas started at 6 m^3/ha/year. Regardless of the management differences on individual estates, the key decision for the entire HJM was to abandon large-scale clear cuts (especially those perpendicular to the downhill slope) resulting in a stabilization of the timberline in the mid-19th century. In the second half of the 19th century, the intensity of forest management in the protected forests below the ATLE gradually reduced on all estates (e.g. prescribed harvest volumes on the Bruntal Estate (totaling 358 hectares of forests) declined from 300 m^3/year in 1866 to 220 m^3/year in 1875 and 200 m^3/year in 1884. The decline was caused by a developing coal mining industry in the Ostrava region (60 km far from HJM). From the mid-19th century, the firewood on the market has been slowly replaced by black coal (transported by rail) and, at the same time, there was an increased demand for long timber wood. River drives from the high areas of the HJM, however, only allowed transport of short fire wood logs, for which the market demand gradually subsided. For all the above reasons, harvesting fire wood (formerly highly demanded) in the extreme mountain conditions was no longer economically feasible for the forest owners. The gradual decline in harvesting led to changes in age structure of the forest stands below the ATLE, particularly to an increase of older age classes, as shown in Table 2.

Towards the end of the 19th century, there were no more prescribed harvests in the protected spruce forests below the ATLE on all estates and all of these forests were under a non-intervention regime. This forest management approach to alpine Norway spruce forests below the ATLE in the HJM has persisted throughout the entire 20th century until today.

Table 2. Age structure of the forest stands on the Bruntal Estate

Year	Area of forest stands (%)		
	Age 1-40 years	Age 41-80 years	Age more than 80 years
1866	45.5	15.1	39.4
1895	7.2	47.8	45.0
1933	16.0	13.2	70.8
2015	0	0	100

Source: own calculation

At the turn of the 20th century, an entirely new trend has arisen on the top parts of the HJM after the economically forced termination of sheep grazing (see above): attempts for intentional artificial afforestation of natural alpine grasslands above the ATLE. The first afforestation attempt was carried out on 165 hectares of alpine grasslands between Ovcarna and Praded in the years 1883–1907. It is noteworthy that the immediate surroundings of the Praded peak were not afforested in order to maintain the alpine herbal flora. The artificial afforestation of the natural alpine grasslands was conducted with a geographically non-native Swiss stone pine (*Pinus cembra* L.). The forest border areas were planted with also non-native Dwarf mountain pine. In some areas, these actions caused a short-term shift of ATLE all the way to the mountain ridge top. In 1918, further local afforestation of alpine grasslands was carried out on the Zlate Hory Estate and Janovice Estate by planting Dwarf mountain pine on a total area of 18 hectares. After 1920, however, the Swiss stone pine plantations (at the age of 30–40 years) began to wither and quickly disappeared completely. Thereby, the ATLE has returned to the level of the late 19th century, although the planted stripes of Dwarf mountain pine remained on the former natural alpine grasslands until today and their potential removal is frequently discussed by the local conservationists and foresters.

Discussion

Results of this paper suggest that the first hypothesis tested can be partly rejected – the current state of naturalness of forest ecosystem do not reflects only the intensity of timber logging in the past. The historical research revealed an important significance of distance of the forest stands to water streams, which enabled transport of harvested wood to the valleys, as the most important factor influenced primarily the intensity of timber logging.

The second hypothesis tested can be also rejected – the former ATLE can be sufficiently exactly identified in local scale (as we have good available historical data, of course) and this can enable to management plan makers to responsible manage the forest stands with regard to biodiversity conservation targets (e.g. under Natura 2000 targets). Based on local knowledge of the former ATLE there is possible to remove non-native trees such as Dwarf mountain pine from the former alpine grasslands etc. Thus, in presented case study from Praded National Nature Reserve the knowledge of forest management history is important support decision tool for manage-

ment plan of this protected area. It can have broader implications for protected areas including montane Norway spruce dominated forests, because Norway spruce is a major economic forest tree species in the Central European mountain forests. The artificially established Norway spruce forests suffer from bark-beetle outbreaks, wind throws, ice breakage (Pretzsch 2005) and climate global change (Neuner et al. 2015, Yousefpour and Hanewinkel 2014).). The structure and dynamics of managed and unmanaged Norway spruce forests have long been a center of interest to the European foresters and a subject to many ecological studies (Kulhavy 2004). A high environmental value of the protected Central European mountains Norway spruce forests (confirmed by their inclusion in the national and European conservation networks such as Natura 2000 system) requires to evaluate the criteria of conservation value in protected forest reserves (Schultze et al. 2014) and evaluate management strategies (Torres-Rojo et al. 2014). Development of sustainable forest management alternatives needs a multidisciplinary approach (Reyer et al. 2015). Similarly, studies on ecological and management history of forests are based on interdisciplinary research methods, which examine biophysical, social, and political processes (Steen-Adams et al. 2007).

It is obvious, that we need more study interplay of culture and nature over time (Judd 1998). A lack of specific information regarding forest management history (Agnoletti and Anderson 2000) can be one of the barriers to successful applications of forest management into practice (Angelstam et al. 2004). Understanding the historical development of mountain Norway spruce forests is of great importance for their sustainable management, as shown by several studies of mountain Norway spruce forests in Central Europe (Jenik and Stursa 2003, Svoboda et al. 2012). Our study of the historical development of mountain spruce forests in the Hruby Jesenik Mountains supports these facts and, moreover, emphasizes the importance of transport accessibility of forest stands in the past for the current state of the mountain spruce forest. Up to the present, this factor has been overlooked by the traditional ecological studies of mountain forests ecosystems (Kral 2009) and also by the one of the most important studies on reconstructing European forest management in the past (McGrath et al. 2015). Currently, we can consider the mountain landscape in the study area as a landscape mountain archetype (Hresko et al. 2015).

In fact, the long-term anthropogenic influence makes it difficult to assess the effects of current climate changes on the former pastoral alpine tree line in the Hruby Jesenik Mountains, as documented in our study – the preserved autochtonous spruce forests extend to the current alpine tree line. Today, the historical influence of grazing and hay making on the alpine grasslands on the top parts of the NNR P is being partly replaced by downhill skiing (Hedl et al. 2012). In terms of biodiversity conservation on the alpine grasslands it is also important that the upward shift of the tree line, both as a consequence of finished grazing and global climate change, causes a gradual fragmentation and loss of alpine forest-free habitats (Tackenberg et al. 1997).

Conclusion

Understanding the past anthropogenic influence on the mountain forests in the Hruby Jesenik Mountains makes it possible to explain the current environmental processes taking place below the alpine tree line ecotone and can be interesting in wider international scale because of ecological importance of ecosystems near the alpine tree line ecotone in mountains. The historical investigation revealed major anthropogenic impacts on mountain forests in the study area. Until the early 18th century, the remnants of climax Norway spruce forests below the alpine tree line in the Hruby Jesenik Mountains were only affected by a locally conducted selection logging. By the end of the 18th century, the same forests were utilized in two different ways based on available wood transport: (i) forests that allowed transport of harvested wood to the valleys by river drives were intensively harvested by clearcutting with no subsequent artificial restoration, leaving the stands to be spontaneously renewed by natural regeneration, whereas (ii) forests that did not allow river drives maintained their primeval character. In the subsequent years, the clear cuts often reached the tree line, and, in combination with grazing and hay making, caused a downward shift of the tree line by up to 100 meters of altitude. Abandoning the no longer suitable clear-cut harvests below the alpine tree line in the mid of the 19th century has visually eliminated the historical influence of forest harvests as one of the factors causing the alpine tree line altitudinal downward shift.

Knowledge of the forest management history from local study area can have wider implication for Central European montane forested protected areas. Authors of this manuscript believe that knowledge of forest management history can be considered as a commonly used support decision tool for management plans of forested protected areas.

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