Analyzing the differences between permanent forests and postagricultural forests in the Bieszczady Mountains, Poland

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ABSTRACT: The study aimed to show if the permanent forests are different from the forests that growed on former agricultural land in the Bieszczady Mountains, southeastern Poland. It is important to investigate how different tree species react in former agriculture land and which are more adaptable to the given environmental conditions, in order to choose the most appropriate tree species and to develop strategies for optimal restoration of forest ecosystems. The results show differences in forest structure and parameters between the two categories. The post-agricultural forest had a much wide variety of tree species and a higher Shannon-Weaver diversity index value (3.06 vs. 2.53). The density of live stems were insignificant higher in the postagricultural forest, but the total live volume per hectare was higher in the permanent forest, with a difference between hardwood species, which had higher values in the post-agricultural forest, and softwood species which had a higher live volume in the permanent forest. However, the density and volume of snags were found to be much higher in the post-agricultural forest

KEYWORDS: post-agricultural forests, land-use legacy, Carpathian Mountains

1. Introduction

Deforestation as a consequence of agricultural expansion was one of the most important indicator of human pressure on the environment in the past centuries. Before the growth of farming practices in the 20th century, any increase in human population induces a growing demand for food production, followed by considerable clear-cutting and a expansion in arable land cover. In the late 19th and 20th centuries, socio-economic and political changes, as well as the development in farming practices, resulted in the agricultural abandonment and consequent afforestation (Matuszkiewicz et al., 2013).

Post-agricultural ecosystems are more and more frequent in present-day landscapes. Understanding the ecological impacts of agricultural legacies, which may last for decades to millennia following agricultural abandonment, is important for interpreting contemporary patterns of biodiversity and for developing strategies for the restoration of post-agricultural ecosystems (Brudvig et al., 2013).

2. Study Area

The Bieszczady Mountains, the westernmost range of the Outer Eastern Carpathians, located in southeast Poland, are a medium-height mountains, with an elevation varying between 500 m in the main valleys up to 1,346 m at the highest peak, Tarnica. The study area has 151,637 hectares and was delimited by a polygon as seen in Figure 1. The forests covered an area of 114,297 hectares (75.37%) in 1970, with the dominant forest association consisting of European Beech (Fagus sylvatica) and Silver Fir (Abies alba), with aproximatively 50-90% of these two species, supplemented with Norway Spruce (Picea abies), Grey Alder (Alnus incana), Sycamore Maple (Acer pseudoplatanus) and other species. The local vascular plant flora is composed of about 700 species, while the vertebrate fauna includes 284 species.

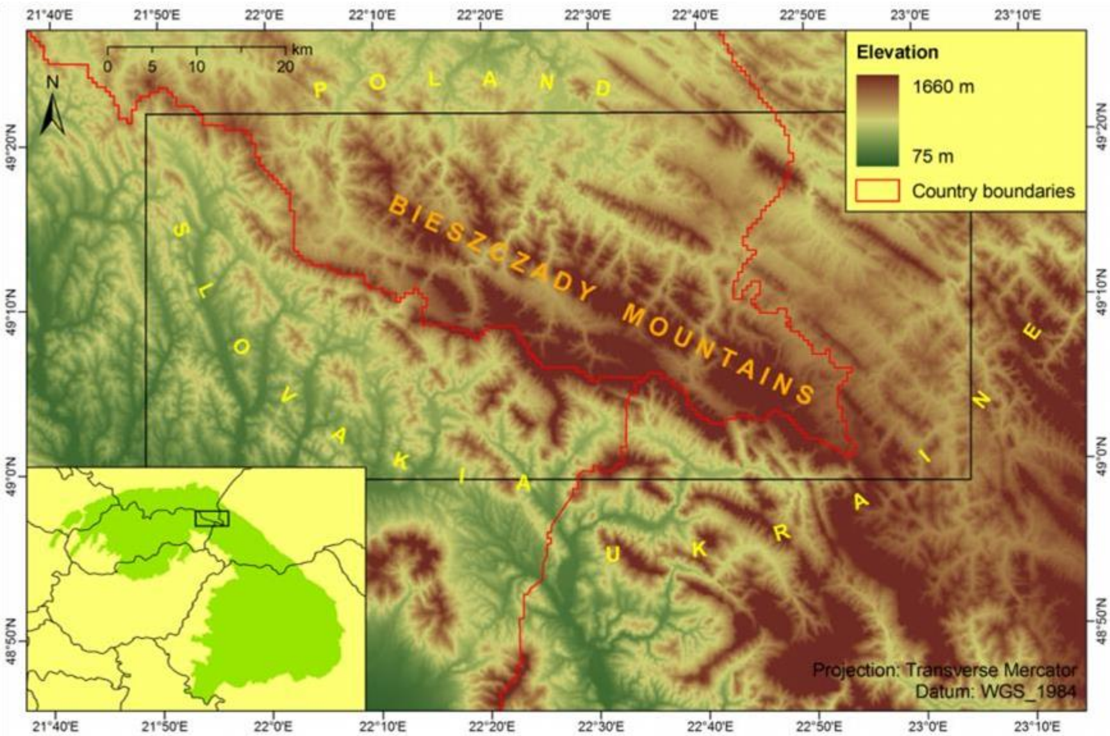

Figure 1 Study area – Bieszczady Mountains, Poland.

Bieszczady Mountains was subject to dramatic changes in population numbers, land use and land cover due to economic, administrative, political, social and ethnic changes during the last 150 years. Rapid economic and population growth during the 19th century and the first part of the 20th century required extension of agricultural areas, pastures and meadows at the expense of forests. Low agricultural profitability in the period between First World War and Second World War led some formely cultivated areas to become reforested. After the Second World War, land abandonment, spontaneous and forced emigration have occured due to political instability. After the stabilisation of the political situation, a considerable part of these former agricultural areas was handed over to the state forests and was subsequently reforested artificially. All this historical changes have affected natural processes and have resulted in the thorough transformation of the natural landscape of Bieszczady (Augustyn, 2004).

3. Methods & datasets used

3.1. Forest vector datasets

The forest cover datasets which have been used for our sampling design were based on three historical maps: first one from the 1860's, made during the second military survey of Austrian Empire (scale 1:28,800), the 1930's military maps made by Wojskowy Instytut Geograficzny (scale 1:100,000), and the Polish topographic maps from the 1970's (scale 1:25,000).

The forest was classified into three categories: permanent forest, with an area of 58,207 hectares which cover 50% of the total forest area; young forest, which represents areas that were forested in 1970 but not forested in 1860 or 1930, and covers 56,091 hectares (48.2%); and new forest that was not forested in 1970 but forested in 1860, 1930, and after 1970, wich covers only 2,142 hectares (1.8%). Since vector datasets are not available after 1970, we assume, based on agricultural land change map between 1985 and 2010 (Griffiths et al., 2013) that the areas which were forested in 1860 and 1930 but not forested in 1970, are currently reforested. The classification of the forest was made using the Union function of ArcGIS 9.3.

For the sampling design, the young forest and the new forest categories were merged into a category named post-agricultural forest.

3.2. Sample design

The initial sampling method that we have approached was a two-stage sampling. A number or five clusters (Figure 2) were selected, with an area ranging from 4.88 km2 to 8.42 km2, and within each area, a stratified random sampling approach was made. 110 plots were mapped, from which 10 were non-forest plots.

As seen in Figure 2, the forest is equally distributed between the two categories, permanent and post-agricultural forest, while the five cluster have an average of 31.5% permanent forest and 68.5% post-agricultural forest. The 100 forest plots were distributed disproportionately between permanent forest and post-agricultural forest, 23 plots for the first category, and 77 for the second. In order to obtain results that can be reprezentative for the whole area, only 46 plots were used for the analysis (Table 1).

Table 1 Distribution of sampling plots.

		Total sampling plots			Selected sampling plots		
Clusters	Ha	Permanent	Post-agri	Total	Permanent	Post-agri	Total
1	813	12	8	20	12	3	15
2	477	2	19	21	2	4	6
3	488	1	17	18	1	6	7
4	682	2	24	26	2	6	8
5	842	6	9	15	6	4	10
Total	3,302	23	77	100	23	23	46

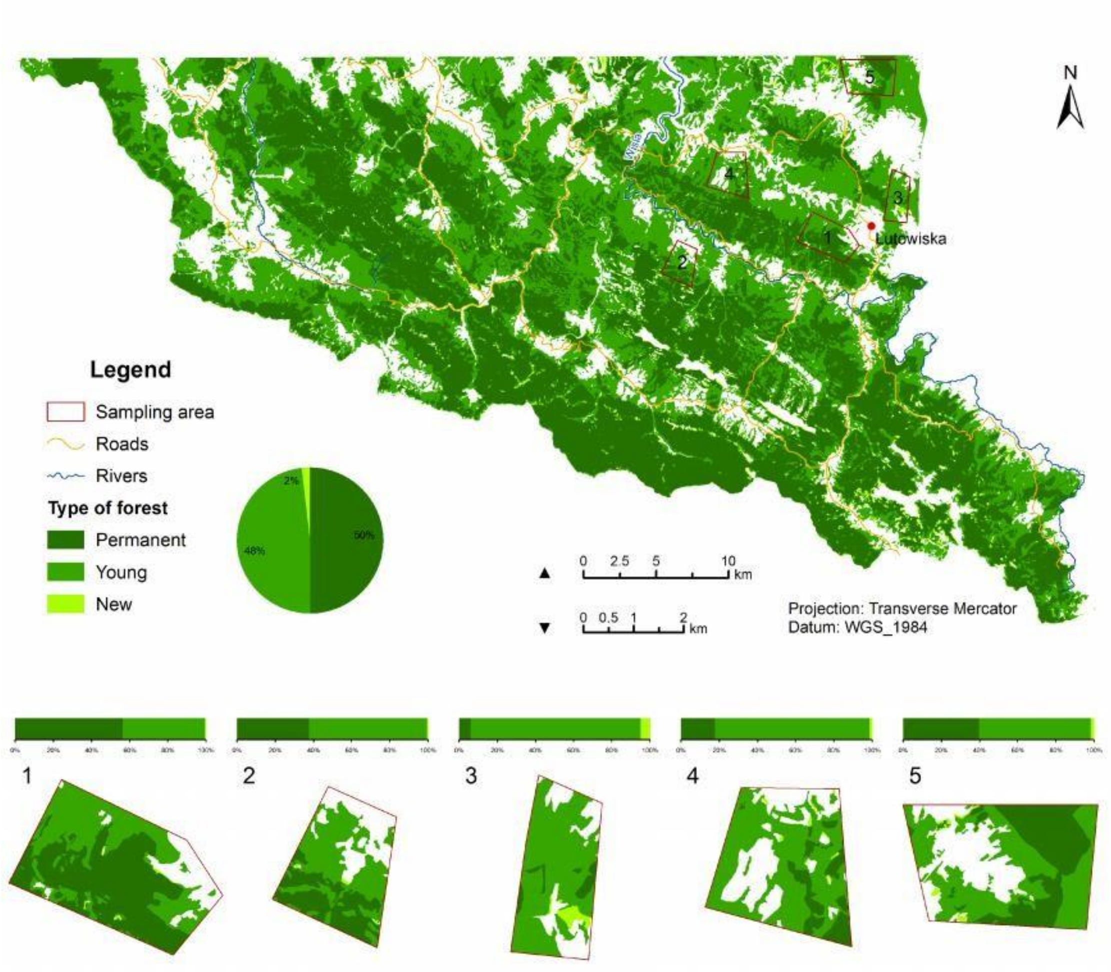

Figure 2 Bieszczady Mountains, Poland – forest types, distribution and sampling areas.

3.3. Data collection and analysis

The forest measurement used for our inventory was the diameter and the height (total and merchantable) of the tree. Tree diameter was measured at breast height (DBH, 1.3 m above the ground) using a diameter tape. Total height and merchantable height was measured using a Merritt hypsometer, which was calibrated to be used at a distance of 20 meters from tree, and 63 cm distance between the eye and the Merritt hypsometer. The merchantable tree height was estimated in 2.5 m logs. The number of logs was measured from 30 cm above ground to the point of the tree where the trunk had a minimum of 25 cm diameter inside bark.

The sampling plots area was determined using the Bitterlich method, in a way that we do not measure more than 4-8 trees per plot. In 86.95% of the plots was used a Basal area factor (BAF) of 4.0 and the average number of the trees measured was 6.6 per plot.

Further, from the data collected was calculated the merchantable volume (m3 / ha), the number of trees per hectare and the basal area (m2 / ha). The data was summarised for live stems and for snags, and also for each hardwood and softwood species, using the Pivot Table tool of Microsoft

Office Excel. The boxplots which compare the forest attributes between permanent forest and post-agricultural forest were made using the R statistical software.

Also we determined the species richness, and Shannon-Weaver diversity index (H'), which is used to characterize species diversity in a community:

$$H' = -\sum p_i \ln(p_i)$$

where p_i is the relative abundance of each tree species.

4. Results

Total species richness in the studied area was 12 tree species, with a major difference between permanent and post-agricultural forest, 12 species were found in the post-agricultural forest and only 6 species in the permanent forest. The Shannon-Weaver diversity index (H') was 2.94 for the whole area, 2.53 for the permanent forest and 3.06 for the post-agricultural forest.

Aproximatively two-thirds of the study region was covered by deciduous forest (hardwood species). In the permanent forest the predominant species were European Beech (Fagus sylvatica) with 59.06% and Silver Fir (Abies alba) with 30.81%, followed by Sycamore Maple (Acer pseudoplatanus) with 7.05%, while in the post-agricultural forest was found a more balanced distribution of species: European Beech with 40.03%, Norway Spruce (Picea abies) with 21.33%, Grey Alder (Alnus incana) with 14.87% and Silver Fir covering 12.47% of the area.

Table 2 Live stems and snags per species of permanent and post-agricultural forest

	Live stems / ha			Snags / ha		
Tree species	Permanent	Post-agri	Total	Permanent	Post-agri	Total
Abies alba	92	56	148	5	1	6
Acer pseudoplatanus	22	17	39	0	0	0
Alnus incana	4	28	32	0	39	39
Betula pendula	0	6	6	0	0	0
Carpinus betulus	0	3	3	0	0	0
Fagus sylvatica	185	181	366	1	0	1
Fraxinus excelsior	1	2	3	0	4	4
Larix decidua	0	3	3	0	0	0
Picea abies	3	90	93	0	7	7
Pinus pinea	0	1	1	0	0	0
Pinus sylvestris	0	8	8	0	6	6
Prunus avium	0	1	1	0	0	0
Quercus robur	0	0	0	1	0	1
Total	307	397	703	7	57	64

Table 3 Relative density, Relative basal area and relative importance (average of relative density and relative basal area) of the main species of permanent and post-agricultural forest

	Relative density (trees/ha)		Relative basal area (m^2/ha)		Relative importance value	
	Permanent	Post-agri	Permanent	Post-agri	Permanent	Post-agri
Abies alba	97	57	17.22	7.65	57.06	32.08
Acer pseudoplatanus	22	17	0.35	1.39	11.26	8.99
Alnus incana	4	67	0.13	1.52	1.97	34.45
Fagus sylvatica	186	181	8.00	4.43	96.89	92.93
Picea abies	3	97	0.52	4.52	1.99	50.60
Other	2	35	0.35	3.48	1.36	19.05
Total	314	454	26.57	22.99	170.53	238.10

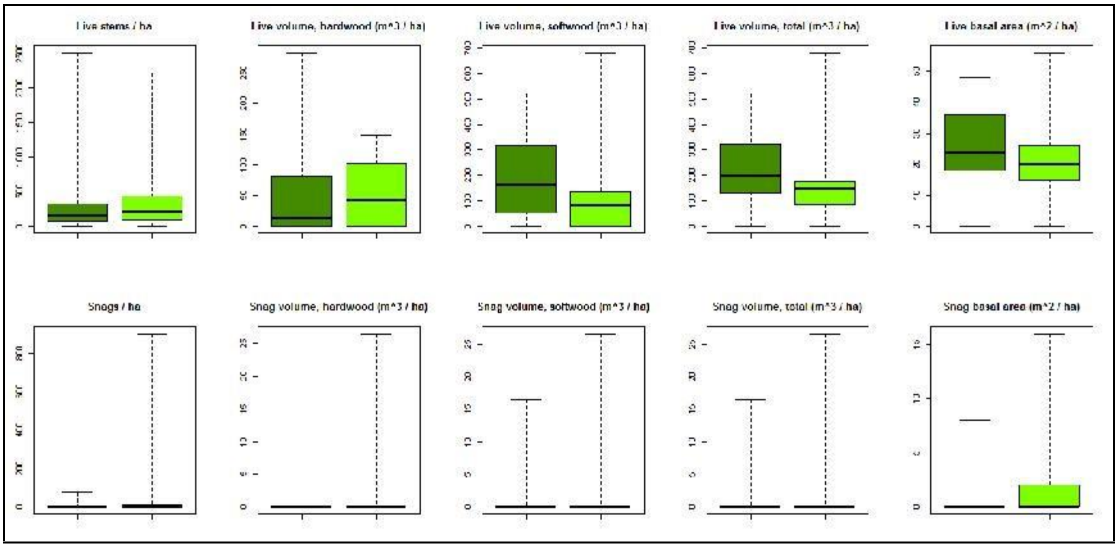

Figure 3 Boxplots comparing different forest attributes between permanent forest (dark green) and post-agricultural forest (light green).

The density of live stems were insignificant higher in the post-agricultural forest, but the total live volume per hectare was higher in the permanent forest, with a difference between hardwood species, which had higher values in the post-agricultural forest, and softwood species which had a higher live volume in the permanent forest. Live basal area (m2/ha) was also higher in the permanent forest (Figure 3).

The density of snags, the snag volume and snag basal area were found to be much higher in the post-agricultural forest. From the total number of snags, 68.42% were Alnus incana (Table 2).

Of all the tree species, Fagus sylvatica had the most high relative importance value for both categories of forest, followed by Abies alba for the permanent forest and Picea abies for the post-agricultural forest (Table 3).

5. Conclusions and discussion

The aim of the study was to quantify the differences in tree species composition, structure and forest parameters across permanent and recent, post-agricultural forests. The results obtained has shown differences in forest structure and parameters between the two categories. The postagricultural forest had a much wide variety of tree species and a higher Shannon-Weaver diversity index value.

The distribution of the coniferous and deciduous tree species between the two categories shows that hardwood species are more adaptable to the forest that growed on former agricultural land. This is caused due to soil pH, which remains consistently higher in post-arable forest than in permanent forest, which maintains differences in species composition. Different studies have reported a variable persistence of increased soil pH in post-agricultural forest (Koerner et al., 1997; Bossuyt et al., 1999; Matlack, 2009; Brunet et al., 2011; 2012).

The main problem that casts doubt on the credibility of results is the fact that we cannot assign all the gained forest to agricultural land. The possibility of recognizing a history of vegetation cover transformations depends on the accessibility of cartographic data. Klich et al., (2013) indicate the main directions in cover changes and land use in Bieszczady mountains between 1852 and 2004. According to this paper the forest increased in this period from 54.49% to 78.53%. The main land cover classes that were converted to forest are meadows with 62.70% and arable land with 37.21%.

Furthermore, because we could not make use of all the data gathered and we used only 46 plots out of 100, the values of species richness and Shannon-Weaver diversity index were underestimated. Another problem is that, as we can see in Table 1, more than half of the plots found in permanent forest were in the same sampling area, which make the results of this category of forest to be more biased.

In the context of biodiversity conservation nowadays, due to environmental issues that have become increasingly prominent in the past decades, an approach from the perspective of biomass and carbon storage instead of timber production potential would be more appropriate.

Special attention should be given to soil characteristics. Soil attributes can be strongly affected by agriculture, and agricultural effects may persist in second-growth forest for a considerable time after abandonment. Cultivation typically leads to a reduction in organic matter content relative to undisturbed soils, influences the concentrations of Phosphorus, Nitrogen, the water holding capacity, etc., all of which can limit or favor the development of different tree or plant species. Germination of plant species are influenced by tree species (Thomaes et al., 2011; 2014).

It is therefore important to study how different tree species react in former agriculture land and which are more adaptable to the given environmental conditions of the study area, in order to choose the most appropriate tree species and to develop strategies for optimal restoration of forest ecosystems.

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