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Forest Cover Change in the Western Carpathians in the Past 180 Years

A Case Study in the Orawa Region in Poland

Since the 19th century a slow expansion of forests into previous agricultural areas has been recorded in the Carpathians. The present article analyzes forest cover change in the Orawa region of Poland, using historical maps and contemporary satellite data. Forest cover change was analyzed with reference to elevation, under the assumption that it reflects a transformation of the vertical land use system developed in the 17th and 18th centuries. For the past 180 years, the proportion of forest in the study area has increased from 25% to 40%. Forest expansion largely affected pastures cleared within the forest belt and areas located immediately above and below this belt. Changes in forest area were largely related to a decline in agriculture and have occurred along with population growth. As a result, grazing has been replaced by forestry, nature conservation, and tourism.

Keywords: *Forest cover; deforestation; afforestation; satellite data; GIS; Carpathians; Poland.*

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Introduction

Most mountain areas of the world have a long history of human influences. Changes in natural vegetation, especially forests, and expansion of agricultural forms of land use have been occurring in mountains for centuries. Since the 19th century, several socioeconomic factors have initiated major changes in land use in a number of mountain ranges in Europe: abandonment of agricultural land and slow regeneration of natural vegetation, including forests, have been among the results. These processes have continued to the present day (MacDonald et al 2000; Piussi 2000); 1 reason is depopulation, recorded for example in the Alps (Bätzing et al 1996), the Pyrenees (Garcia-Ruiz and Lasanta-Martinez 1990), and the Carpathians (Soja 2001). In many cases, more complex socioeconomic reasons are involved, relating to industrial development or mass tourism, which create job opportunities outside the agricultural sector and result in a decline of the economic importance of agriculture (Grötzbach 1988; Lichtenberger 2000).

Human strategies of adaptation to environmental gradients and constraints have created a characteristic, well-documented vertical stratification of land use in mountain areas. Natural environmental limitations have forced mountain people to extend agricultural activities across elevation zones and adapt to seasonal weather changes (Allan 1986; Guillet 1986; Grötzbach 1988; Uhlig 1995; Grötzbach and Stadel 1997). Traditional vertical systems have been affected and transformed by macroeconomic changes (Lichtenberger 1988; Penz 1988; Grötzbach and Stadel 1997) and the increasing accessibility of mountain areas (Allan 1986).

In the Carpathians, expansion of forests after a long period of deforestation resembles what has happened in other mountain regions of Europe. Because of the post-World War II political situation, transformation of mountain economies has occurred under much less

FIGURE 1 View of Babia Góra, the highest mountain in the study area (1723 m). (Photo by Wojciech Gajdzik)

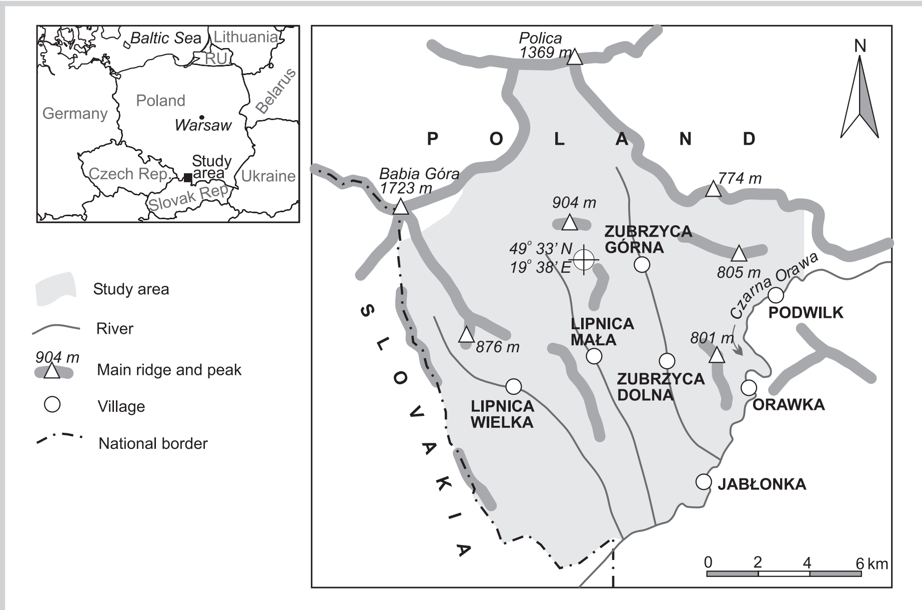


FIGURE 2 Location of the study area. (Map by author)

pressure from rapid modernization than in the Alps. Although decline in the impacts of agriculture, land abandonment, and expansion of forests have been recorded in the Polish Carpathians since the 19th century, decrease in the population dependent on agriculture has been relatively slow. In southern Poland, the rural proportion of the population still exceeds 60%, more than half of which is engaged in agriculture (Kurek and Górz 2000).

This article presents the results of a study carried out in the watershed of the Czarna Orawa (Black Arva), located in the Polish Carpathians (Figure 1). The aim was to assess changes in forest cover since the first half of the 19th century and discuss related transformation of the traditional vertical system of land use.

Study area

The watershed of the Czarna Orawa, located in the northeastern part of the Orawa region, belongs to a former province of the Austro-Hungarian Empire, that became a part of Poland after World War I. The study area covers 186 km^2, stretching from the Czarna Orawa valley floor (approximately 600 m) to the main ridge of the Beskidy Mountains in the north (Babia Góra, 1723 m). The southern part of the study area, up to 900 m, has relatively gentle slopes. Higher up, the steep slopes of Babia Góra and Polica frame the lower-lying valleys and foothills (Figure 2).

The northeastern part of the Orawa region was colonized at the end of the 16th century. Forests were cleared to a great extent, mostly below 900 m, and a large part of the watershed was converted to agricultural land use. Cultivation was dominant close to permanent settlements, up to approximately 800 m. The belt above 800 m was used mainly for grazing. Several pastures were cleared within forests up to the timberline (1350–1400 m), forming the intermediate pasture zone; some came under cultivation at the beginning of the 19th century, because of the increase of population and so-called “land hunger” (Jostowa 1972). Natural alpine meadows located above the timberline, partially extended by clearing subalpine spruce forests and dwarf pine scrubs, formed the upper belt of pastures (Celiński and Wojterski 1963; Jostowa 1972).

The tide of deforestation turned, and forest expansion began in the middle of the 19th century, after new policies regulating the status of peasants and restricting customary rights to forest use had been introduced in the Austrian Empire, a phenomenon common in the history of mountain forests (Hamilton et al 1997). Several pastures were afforested, and grazing in forests was almost wholly forbidden (Kubijowicz 1927; Jostowa 1972). In the 1930s, the proportion of forested land in the study area was as low as 30%. By 1986, this had increased to 41% (Leszczycki 1938; Górz 1994). The upper part of the Babia Góra ridge (above 1200–1300 m) was included in the nature reserve in 1928, after which grazing on alpine meadows above the timberline gradually ceased, giving rise to regeneration of the alpine area (Celiński and Wojterski 1963).

The population in the study area reached a relatively high level at the beginning of the 19th century. In the second half of the 19th century, a major decline began, associated with outmigration. In 1921, the population was approaching 78% of the level recorded at the beginning of the 19th century. After World War II, the population grew steadily, reaching a level 30% higher than at the beginning of the 19th century by the 1980s, with a density of 70 individuals/km^2 (Leszczycki 1938; Gotkiewicz 1939; Górz 1994). In the 20th century, the percentage of the population directly employed in agriculture steadily declined. Farming was the main source of income for 95% of the population in 1950 but this percentage dropped to 43% by 1988 (Górz 1994).

Historic data sources

I used old topographic maps and contemporary satellite imagery to establish a time series of land cover data. For the first half of the 19th century, 2 sheets of the topographic map of the Kingdom of Hungary were used. They were received as 6 × 9-cm slides from the War Archive in Vienna, and scanned with a resolution of 4000 dpi. The maps are part of the second military survey of the Austrian Empire (Konias 2000) and were compiled in 1823. The map scale was 1:28,800. Forests are represented by gray polygons. Unfortunately, dark hatching was used to present relief, making it frequently difficult to interpret land cover.

Land cover data for the first half of the 20th century were derived from the topographic map of Poland at a scale of 1:100,000. No cartographic materials presenting land cover in the study area could be found at a larger scale for this period. Digital images of the maps, scanned with a resolution of 600 dpi, were received from the Library of the Institute of Geography and Spatial Management of Jagiellonian University. The map was a result of a military survey conducted in the 1920s and 1930s (Krassowski and Tomaszewska 1979). Two sheets used in the study represent the situation in 1931. Forested areas are colored green, and their distribution can easily be distinguished.

A Landsat 7 Enhanced Thematic Mapper Plus panchromatic image taken in May 2001 and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite images taken in April 2002 were used as sources of information about current forest distribution. The Landsat image was a subset of a standard scene (path 188, row 26). The ASTER images were 2 standard scenes taken one after another along the orbital path.

Methods

The Landsat image was rectified to the local Polish “1992” coordinate system on the basis of ground control points taken from contemporary topographic maps at scales of 1:10,000 and 1:50,000. The root mean square (RMS) error of the rectification was 29 m. Next, all other map and image data were rectified using the Landsat image as a target. The old topographic maps are usually distorted in an uncontrolled way; therefore, rectification was performed twice in most cases, to minimize adjustment error within boundaries of the study area. The RMS errors ranged from 17 to 86 m for sheets of the topographic map of Hungary, from 34 to 40 m for sheets of the topographic map of Poland, and were 22 m for the ASTER image data. As might be expected, the greatest errors were noted for the map of Hungary, the oldest and least accurate data set. However, they were smaller than errors reported by Konias (2000) for the same topographic survey in other parts of the Carpathians.

Two classes of land cover were delimited: forests and nonforested areas. Forests included all growth types, as well as areas temporarily deforested but under forest use. Non-forested areas consisted of all other land cover classes, almost exclusively agricultural land and settlements. On the maps, the boundaries of all identifiable patches of both land cover classes were manually digitized on screen. For the most recent time period, the Landsat image was chosen as the primary source of information. Semi-automatic, on-screen digitizing based on the Region Growth tool developed by Erdas Imagine software (Erdas Imagine 1996) was used to identify forests and nonforest patches. Additionally, several island nonforest patches were manually digitized on screen on the ASTER satellite image. On-screen digitizing was found to be more effective than automatic classification, mostly because of the relatively small area studied and efficient use of field knowledge. Moreover, Petit and Lambin (2002) point out that visual interpretation is superior to automatic classification when the output needs to be compared with map data in a study concerned with detecting change. The accuracy of the final land cover map, assessed on a basis of field verification of a sample of 50 points, was 96%.

A digital elevation model (DEM) of the study area was created from contours at intervals of 10 m, digitized from 1:50,000 topographic maps. The DEM was interpolated to a raster with a resolution of 30 m, using TOPOGRID interpolation available in the ARC/INFO system (ArcDoc 1997).

The area and proportion of forests in the 50-m classes of elevation were assessed for each period studied (1823, 1931, 2001). The elevation range of 50 m was sufficient to depict vertical changes in the extent of forests; lower values could lead to errors related to the vertical accuracy of the DEM and the small area of elevation classes. Next, matrix overlays were used to identify areas of change for the periods 1823–1931 and 1931–2001. The distribution of change areas was analyzed in relation to elevation.

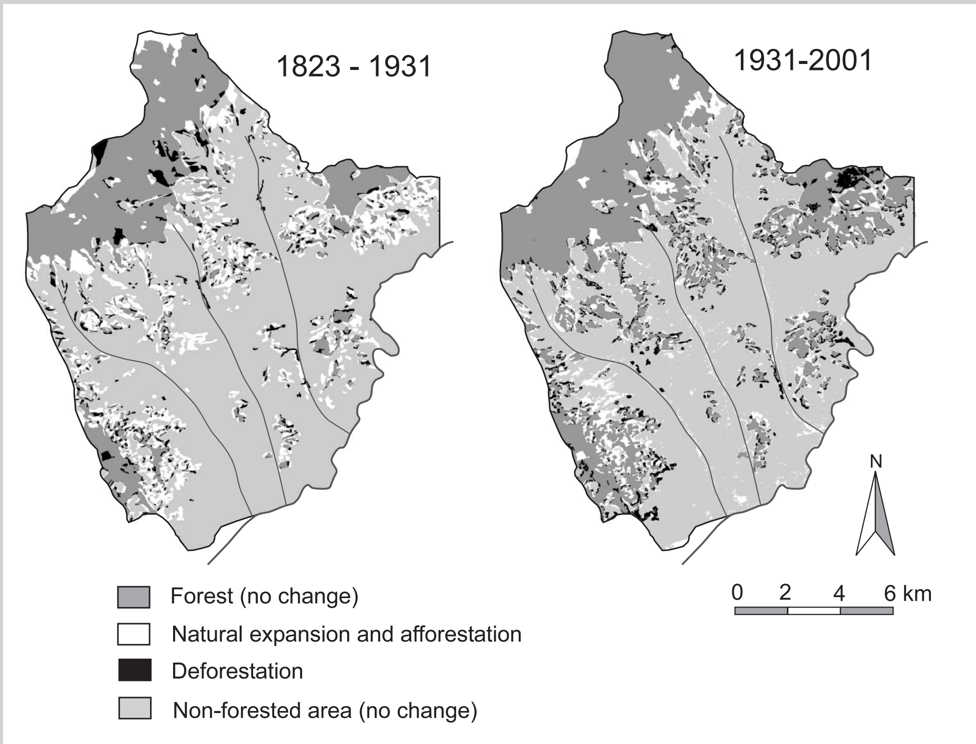


FIGURE 3 Changes in forest area, 1823–1931 and 1931–2001.

Above the timberline, there were differences between information provided by maps and satellite data. The maps present only the approximate course of the timberline, and vegetation above the timberline is depicted as nonforest, although for the entire period studied, there was a mixture of natural alpine meadows, dwarf pine scrubs, and cleared pastures (Kubijowicz 1927; Celiński and Wojterski 1963). Because the spatially explicit information for 1823 and 1931 is missing, the area above 1350 m was excluded from the analysis and referred to only on the basis of existing studies.

Results

Forest area increased steadily in the period studied. In 1823, this area was 47 km^2. The annual rate of net increase of forest area was 17.4 hectares in the period 1823–1931 and 12.1 hectares in the period 1931–2001. As a result, forests accounted for 74 km^2 in 2001, ie, 40% of the area studied, as opposed to only 25% in 1823 and 36% in 1931 (Figure 3). Between 1823 and 1931, forests gained 25 km^2, whereas deforestation affected only slightly more than 6 km^2. Between 1931 and 2001, 16 km^2 of agricultural land was converted to forests, and deforestation covered only 8 km^2.

Forest distribution varies with elevation. Generally, the proportion of forests is relatively low below 800 m, much higher in the mid-elevation belt, and lower again close to the timberline (Figure 4). Decrease of forest proportion close to the timberline was most pronounced in 1823 and was practically absent in 2001. The proportion of forested area has been increasing since 1823 in all elevation classes, and 2 belts with a high net increase of forest proportion can be distin-

FIGURE 4 Proportion of forest area in the different elevation belts in 1823, 1931, and 2001.

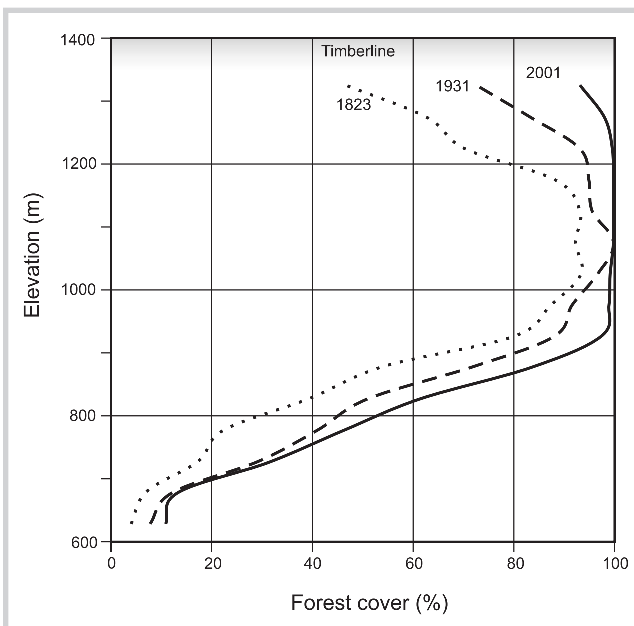
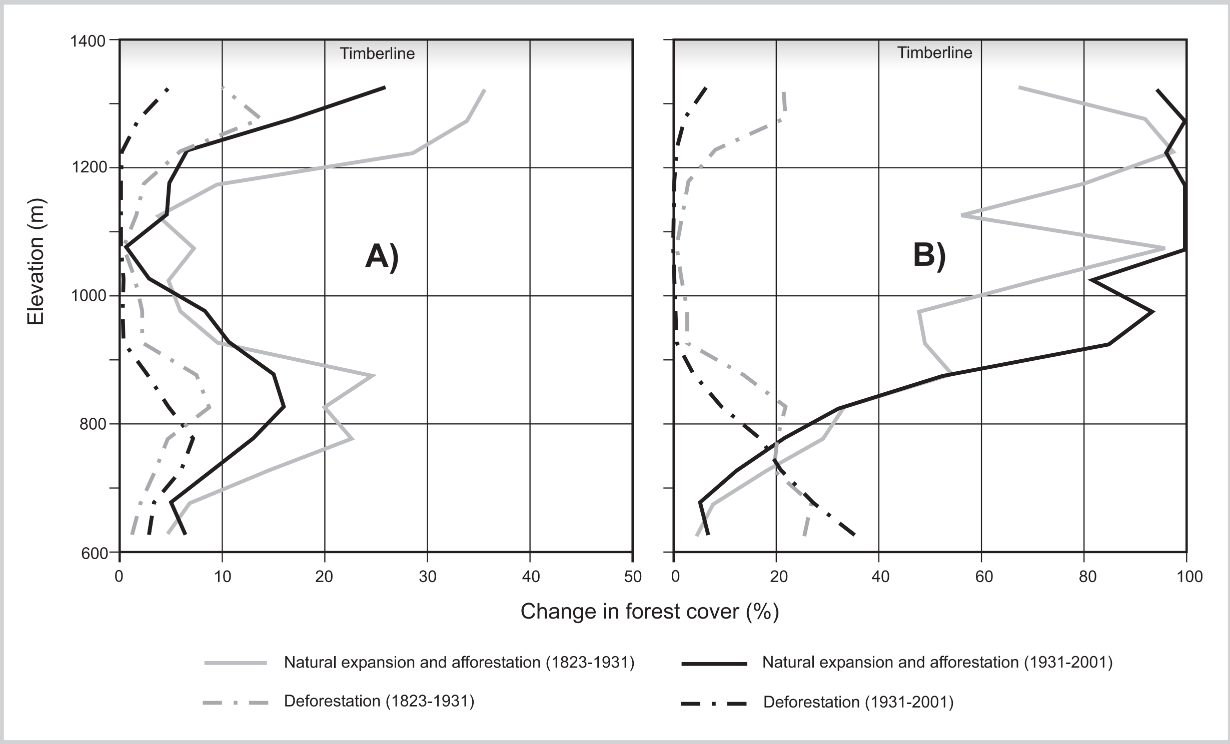


FIGURE 5, A AND B Proportion of forest cover change in the elevational belts: A) in relation to the total area, and B) in relation to either non-forest (natural expansion and afforestation) or forest area (deforestation) at the beginning of the period studied.



guished: a lower one (750–900 m) and a higher one (above 1200 m). Forests expanded over time, both to lower and higher elevations, with a vertical range of 400 m in 1823 (lower boundary at 900 m, upper boundary at 1300 m), 500 m in 1931 (850–1350 m), and 550 m in 2001 (800–1350 m).

Similar results were achieved with reference to the vertical distribution of areas of change. The most notable changes in forest area occurred below 900 m and above 1200 m (Figure 5A), and the greatest land cover change dynamics were observed in the areas adjacent to forests. Between 1823 and 2001, natural expansion of forests and afforestation comprised 33% of the 50-m vertical range below the forest belt of 1823 (850–900 m) and 50% of the range above (1300–1350 m). Deforestation processes were occurring largely in the same areas, although with much less intensity, comprising a small percentage of the area of elevation belts.

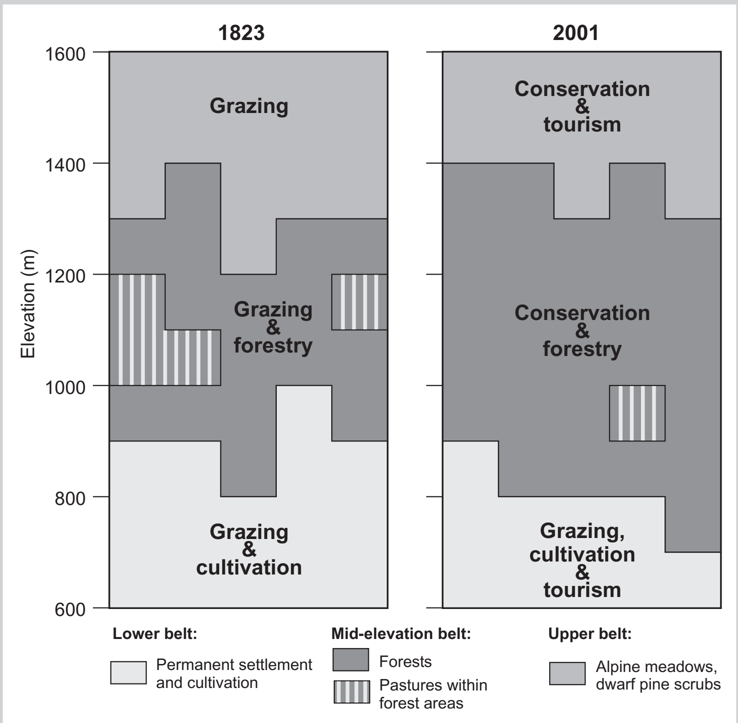
A different pattern was observed when changes in forest areas were related to either forest or nonforested areas at the beginning of the period studied (Figure 5B). In such cases, the intensity of natural expansion of forests and afforestation, expressed as the proportion of nonforested areas being converted to forests, generally increased with elevation, reaching values close to 100% above 900 m, whereas the intensity of deforestation, expressed as the proportion of forests being deforested, was decreasing, and the highest values were recorded at the lowest locations.

Discussion

The accuracy of source data is an important issue in any land cover change study. In the case of historical maps, the spatial errors, distortions, and different levels of generalization may significantly affect the delimitation of areas of change, and a high risk of detecting spurious changes is involved (Petit and Lambin 2002). In the study area, deforestation processes, natural expansion of forests and afforestation occurred within a relatively complex land cover mosaic, usually close to the edges of forests. Given the quality of historical data used in the study and various sources of error, the exact distinction between true and spurious changes was, in this case, practically impossible to detect. The figures for the proportion of forest found in the study area for 1823, 1931, and 2001, however, agreed closely with values available from other sources and general remarks on land cover change tendencies (Leszczycki 1938; Jostowa 1972; Górz 1994). Therefore, it was assumed that a significant proportion of the changes detected actually occurred.

The growth of forest area has been a dominant process of land cover change in the study area since 1823, although several forested areas have been cleared. The proportion of forested land has increased in all vertical belts, much more rapidly close to the timberline than at lower altitudes. Forest expansion in 2 directions—toward the climatic timberline and downward, lowering the upper limit of contiguous

FIGURE 6 Transformation of the vertical land use system in the northern Orawa region, 1823–2001.



agricultural area—and land use changes in alpine areas above the timberline related to conservation policies have led to reconstruction of the traditional vertical land use system (Figure 6) that developed in the northern Orawa region in the 17th century and was in use until the first half of the 20th century (Jostowa 1972). The traditional system was typical of mountain areas worldwide, with grazing dominant in the highest mountain belts (Guillet 1986; Uhlig 1995). Its decomposition in northern Orawa involved breaking local ties with vertical belts above the permanent settlements due to changes in land use (nature conservation, tourism, recreation and forestry instead of agricultural land use), and macroeconomic transformation resulting in decreased agricultural pressure, land abandonment, and forest expansion. Local agricultural activities were confined to a much narrower area than at the beginning of the 19th century, mostly around permanent settlements within the lowest elevation belt. The mid-elevation and upper belts, formerly important grazing areas, were abandoned and presently have no significance for local agriculture, although they provided opportunities for additional income related to tourism, because of the development of nature conservation.

In the 19th century, the transformation of the vertical system of land use and expansion of forests in the Orawa region reflected changes in land rights and restrictions on forest use by the local community. At the same time, the liberation of the peasantry and economic development significantly intensified mobility, as in other mountain regions in Europe (Lichtenberger 1978). The population decreased from more than 10,000 at the beginning of the 19th century to 8000 in 1921, mostly because of outmigration (Leszczycki 1938; Gotkiewicz 1939), reducing agricultural pressure in the area studied. In the 20th century, transformation of the vertical system of land use and expansion of forests were caused by a decline in the economic importance of agriculture and occurred alongside population growth, contrary to the population dynamics recorded in the study area in the 19th century and observed in other mountain areas (eg, Garcia-Ruiz and Lasanta-Martinez 1990). Although the total population of the study area was steadily increasing and exceeded 13,000 in 1988, the population declaring farming as a main source of income dropped from more than 9000 in 1950 to less than 6000 in 1988 (Górz 1994), as a consequence of off-farm employment. The number of private nonagricultural enterprises rose from less than 100 in the 1980s to more than 700 in the 1990s, and tourist traffic has increased 2-fold since the 1970s (Wojewódzki Urząd Statystyczny 1977, 1984, 1997).

The expansion of forests and related changes in vertical land use systems have been documented at several other locations in the Polish Carpathians (Kozak et al 1999; Wężyk and Pyrkosz 1999). These changes were reported from the Alps as a consequence of modernization (Lichtenberger 1988; Grötzbach and Stadel 1997), where the traditional *Almwirtschaft* system was affected (Penz 1988). It is expected that similar changes in forest cover may occur in response to economic development in mountain areas in developing countries (Scherr and Templeton 2000).

Conclusions

A slow expansion of forests in the northern Orawa region has been recorded on the basis of a time series of historical maps and satellite data. The proportion of forests has increased from 25% to 40% since 1823. Forest expansion has affected mostly agricultural land above 800 m, especially pastures located in the subalpine belt of spruce forests. Land cover change reflects a major transformation in the traditional vertical economy of the mountain area—a decline in grazing and the development of nature conservation, tourism, and forestry. As a result, the economic links between the lower agricultural belt and the upper belt of pastures have been broken. The major causes were the mobility of the local population since the middle of the 19th century and development of off-farm employment, which decreased the significance of agriculture.

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