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LAND COVER CHANGES IN THE POLISH CARPATHIANS BASED ON REPEAT PHOTOGRAPHY

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Abstract: Ground-based repeat photography was used to assess changes in land cover and land use in selected areas of the Polish Carpathians. A set of 100 photo pairs was used in the study. Archival photographs were taken from 1875-1975 and were repeated by the author between 2008 and 2012. Photo pairs were analysed both qualitatively and quantitatively. While the qualitative analysis showed the patterns of the changes, the quantitative approach provided estimates of the rates of land cover change. The results showed that abandonment of agricultural land is the main process associated with land use and land cover change in the study area. This process led to either an increase in the forested area or the spread of settlements. The highest annual forest rate of change was recorded in urban areas (median = 0.99%), while rural areas exhibited a slightly lower value (0.84%) and uninhabited areas displayed a substantially lower value (0.39%). The detailed scale of the investigation also showed that non-forest woody greening commonly occurred in the Polish Carpathians. Vegetative growth was observed in valley bottoms, along rivers and streams, and in towns and villages. This study suggests that ground-based repeat photography is a valuable research method for land use and land cover change analyses in mountainous areas.

Keywords: ground-based repeat photography, land use/land cover change, the Polish Carpathians, archival photography

1. INTRODUCTION

Land cover changes are among the main components of global change influencing climate (Heald & Spracklen 2015) biodiversity (Nagendra et al., 2013) and many other ecosystem services (Lawler et al., 2014). To better understand the linkages between ecosystems and human activities, it is important to distinguish between long-term and short-term changes in land cover and assess the scales of land use conversion and modification (Lambin et al., 2001). These distinctions can be made by analysing land change trends based on relatively homogenous data sets (Ramankutty et al. 2006). Although historical maps can be used for analyses of the last 250 years or even more (Munteanu et al., 2014; Bürgi et al., 2015) topographic maps from different periods are often thematically inconsistent (Leyk et al., 2005). The uncertainty associated with any comparison of topographic maps also depends on the original map production process and later transformations using geographic information systems (GIS) (Leyk et al. 2005; Kaim et al., 2014). Thus, the role of raw optical data is very important in long-term land cover change research. Although operational, high-resolution remote sensing products provide valuable data for assessing land change, they have only been available since the 1970s (Belward & Skøien 2014) or, at best, the mid-20th century (Song et al., 2015). Collections of historical aerial photography go further back in time and are even available for the 1930s (Browning et al., 2009; Nyssen & Petrie 2013). This time horizon is, however, still relatively short when compared to historical terrestrial photography, which goes back to the 19th century (Kull 2005; Meire et al., 2012). This photography can be used in land change research with a repeat photography method.

Repeat photography is the most popular, straightforward and easy-to-understand method of using archival photos for land change research. It requires the position from which an archival photograph was taken and a new photograph from that position, creating a photographic pair of the same scene (Rogers et al., 1984; Roush et al., 2007). The method was first used to analyse glacier movements in the Alps in the 19^{th} century and has since become popular, especially in North America (Webb et al., 2010). To date, repeat photography has been used for numerous applications. In Honduras, repeat photography showed that although deforestation occurred in the region, many areas also exhibited vegetation increases (Bass 2004). More trees were identified in populated areas as a result of cultural landscape transformation using photo pairs from Hindukush, Pakistan (Nüsser 2001), Cordillera Blanca, Peru (Byers 2000) and Montenegro in Europe (Nyssen et al., 2014). Vegetation stability or increases in landscapes managed by local communities were found in Yunnan, South China (Moseley 2006) and Nepal (Niraula et al., 2013). Terrestrial photographs revealed that tree invasion was more common in small openings than in large openings in the mountains of Colorado, United States over the last century (Manier & Laven 2002; Zier & Baker 2006). Increased tree cover in the treeline ecotone was documented using photo pairs in Montana (Roush et al., 2007) and Utah, United States (Munroe 2003). By contrast, greening trends in Senegal identified by remote sensing were questioned by repeat photography, revealing that, although greening was observed in the shrub layer, tree loss and decreased species richness were evident (Herrmann & Tappan 2013).

The use of repeat photography in long-term land change analyses is valuable not only in areas where the availability of historical maps is limited but also in regions covered by historical topographic maps. This is because maps generally only illustrate categorical objects (Leyk et al., 2005). Regardless of the differences in land use categories between compared maps, uncertainty arises due to the assumption that all objects in the same category on a particular map are exactly the same. This assumption limits the land change analyses to conversion only, without studying modifications (Ramankutty et al., 2006) or land use intensity change (Levers et al., 2015). In other words, repeat photography can be used to increase knowledge of land change processes, major contributor to global change in areas where examples of land use conversion are already known to the scientific community. It offers not only long-term perspective but also a detailed scale.

The objective of this paper was to analyse land use changes in the Polish Carpathians during the late 19^{th} and 20^{th} century using repeat photography. Although the major trends associated with land cover change have been relatively well studied and defined in the area (Kozak 2010; Munteanu et al. 2014), little is known about the land use modifications and small scale processes that cannot be detected using only topographic maps.

2. MATERIALS AND METHODS

2.1. Study area

The Polish Carpathians are located in the northern Carpathians in the core of Central and Eastern Europe (Fig. 1). The altitudes reach 2500 m in the Tatra Mountains but are substantially lower (1725 m in Babia Góra) in the Beskids. The northernmost part of the area forms the Carpathian Foothills, rarely exceeding 600 m (Balon et al., 1995). The landscape of the region typically consists of agricultural lands and forests, with settlements generally located in valleys. Major colonisation began in the 13^{th}-14^{th} century and ended in the 19^{th} century (Turnock 2002). Although the environmental conditions were unfavourable, agriculture was the main source of income for local residents for a long time, affecting the mountain forests. The impact on forests was twofold, including from the valleys upwards, as a result of widening agricultural lands around the villages, and from the mountain ridges downwards, which was due to grazing activities (Kozak 2010). The highest intensity of agricultural activities typically occurred in the 19^{th} century as a result of the high rural population density, low level of industrialization and lack of other alternative income sources (Kozak 2010). This resulted in deforestation for agricultural purposes and high land use intensity related to high shares of cropland. In some areas, arable lands were found at 900-1000 m, which is high, based on the conditions in the Carpathians (Turnock 2002; Kaim 2009). A significant increase in forest cover occurred in the second half of the 20^{th} century. However, forest cover expansion in the western portion of the Polish Carpathians was clearly different than that in the eastern portion, where depopulation took place following World War II and due to resettlement schemes (Snyder 2010), what triggered substantial forest cover increase (Kozak 2010). Since the 1960s, the share of arable land has decreased in the western portion of the area, while grassland has become the dominant vegetation in agricultural lands (Woś 2005). Gradual development of settlements has also occurred, both in the traditional tourist locations and in typical rural areas (Woś 2005; Kaim 2009). Currently, agricultural land abandonment is widespread in the area, resulting in increased forest cover in less favourable locations. In some municipalities, the share of abandoned agricultural land is estimated to be more than 30% (Kolecka et al., 2015). However, settlement development is simultaneously occurring, resulting in new housing and tourism infrastructure (Mika 2013).

2.2. Initial data preparation

Each repeat photography analysis is preceded by an extensive study of existing archives of historical photographs. Sufficient landscape characteristics, image quality and location probability are the most commonly recommended criteria for selecting original photographs (Pickard 2002; Molnia 2010). In this study, archival photos were examined from the collections of national parks, local museums, private collections, the National Digital Archives of Poland and in historical publications and albums. In total, approximately 6000 photographs were inspected. Finally, 339 historical photos (both postcards and original photographs) were considered for further research. Out of these, the original positions of 192 photos were successfully located. However, due to land cover changes in the foreground, only 134 archival photos could be repeated. The position of the original photography was determined using not only the characteristic points visible in each image but also additional sources such as archival topographic maps (providing historical road networks and local names found in the metadata of photos) and 3D Google Earth images (locations of the mountain ridges in relation to one another). In some cases, the photo pairs illustrated the same part of the study area from different perspectives. Thus, 34 photos were removed from the selection, resulting in a final set of 100 photo pairs, which were mainly located around tourist former centres (Fig. 1).

An important part of the preliminary study was approximately determining the year a historical photo was taken. For part of the collection, the dates were clearly defined in the metadata. However, a set of rules was established to indicate the period of photo acquisition for the remaining photos. For postcards or photos published in books and albums with no original photography dates, it was decided that they were taken at least one year before being published or sent. In some cases, the dates were defined based on an analysis of the photograph content. Acquisition dates of the historical photos ranged from 1875 to 1975. Photos were repeated by the author between 2008 and 2012.

All the collected photo pairs differed substantially based on their contents (types of land cover classes visible in the photos), locations and periods. Thus, the first step divided all the photo pairs into homogeneous groups before analysing land cover changes. This procedure was based on 79 binary variables that defined the general land cover trends (increase, decrease, no change and no class) of three main land cover classes (forest, agricultural lands and settlements) with additional information about the topographic position (valley floor, slopes or ridges) and additional contextual information (e.g., if the area visible in the photo pair is part of a nature conservation site, date the historical photograph was taken, etc.). Those variables were analysed using a correspondence analysis, which is a typical exploratory technique used to define the most homogeneous groups of photo pairs (Greenacre 2007). The results of the correspondence analysis were examined to define the features that best differentiated the data set: a) photo pair location (taken in different mountain regions), b) time period length, and c) type of landscape visible in each photo (1 - villages and their surroundings, 2 - towns and their surroundings (urban areas), and 3 - uninhabited areas).

2.3. Qualitative land use change analysis

All the photo pairs were subject to detailed analyses of land use conversion and modification. The land use conversion processes were identified based on six classes: settlements, agricultural lands, forest, water, rocks, and sport and recreational sites. Land use modifications were recorded based on four land use classes: settlements, agricultural lands, forest, and rocks (see Table 1 and 2 for details).

2.4. Quantitative land cover change analysis

A quantitative analysis was conducted using 37 selected photo pairs. In four cases, the image was additionally divided into middle ground and background due to substantial differences in scale among those parts of the photos, as originally proposed by Rhemtulla et al., (2002). This process resulted in 41 case studies, which were used to assess the land cover dynamics and landscape patterns over the study area (Fig. 1). The quantitative analysis first georeferenced image pairs to each other based on at least five adequately distributed control points. Then, the images were covered by a regular grid. One of three classes was then assigned to each grid cell: fully covered by forest, partly covered by forest or not covered by forest (Roush et al., 2007). The sizes of the grid cells differed among photo pairs due to geometry and scale differences, ranging between 20 and 30 pixels (5-70 metres in the field). If image georeferencing was not possible, e.g., due to a lack of control points, or the rectification resulted in an RMS error higher than half of the grid cell size (10-15 pixels), the quantitative comparison between images in the pair was based on the shares of each land cover class, which were based on the total number of grid cells in the image.

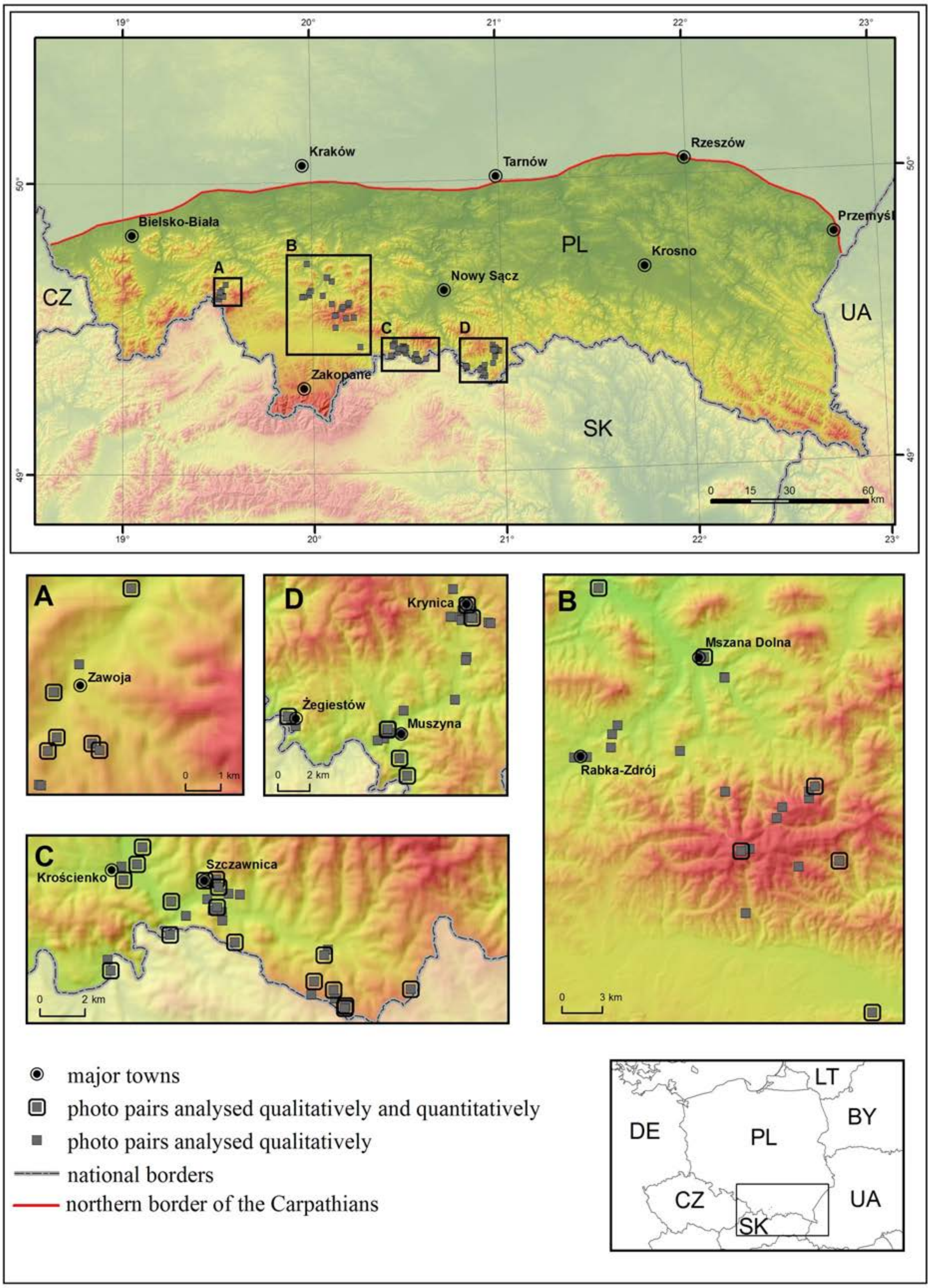

Figure 1. Study area and locations of the photo pairs

This procedure was previously tested on the same photo pairs with and without georeferencing, showing that the differences in shares between these pairs are considerably low (Kaim & Kolecka 2010). For each of the 41 case studies, the annual rate of change was calculated separately for each land cover class using a standardised formula (Puyravaud 2003):

$$q = \left(\frac{A_2}{A_1}\right)^{1/(t_2-t_1)} - 1$$

where A_1 and A_2 are the land cover shares (%) at time t_1 and t_2, respectively. This procedure enabled the comparison of land cover dynamics among photo pairs over different periods.

3. RESULTS

3.1. Defining homogeneous groups of photo pairs

The correspondence analysis used to define the most homogeneous groups of photo pairs revealed that the landscape visible in the photos (i.e., rural areas, urban areas or uninhabited areas) provided the best option for differentiating the data set. Two dimensions explained a combined 28.3% of the inertia (18.5% by the first dimension and 9.8% by the second dimension). Thus, the following results are presented for each group separately. The rural area subset consisted of 32 photo pairs, the towns and their surroundings subset included 35 pairs and uninhabited areas comprised 33 pairs.

3.2. Land use conversion and modifications

3.2.1. Rural areas

The main process was a conversion of agricultural lands to forest (20 photo pairs). Development of settlements on agricultural lands was also widespread (14 photo pairs). The construction of new recreational and sport facilities was found in three photo pairs (one example of destruction was also identified). Additionally, one photo pair showed the construction of a water reservoir in an area that was used previously for agricultural purposes (Table 1).

Land use modifications in rural areas were related to increased building density (19 photo pairs) and the appearance of new, individual trees in previously developed areas (23 photo pairs; Table 2). Agricultural areas were subject to land abandonment. Conversion of arable land into grassland was also identified. The analysis of the photo pairs identified more examples of forest regeneration than forest decline (Table 2).

3.2.2. Urban areas

Similar to the trend in rural areas, decreased areas of agricultural land were also observed around towns. However, more often than in villages, the former agricultural lands were converted into developed areas rather than into forest (Table 1). Establishment of recreational and sport sites was also observed close to towns (Table 1).

Table 1. Land use conversion matrix on rural areas (n=32), urban areas (n=35) and on uninhabited areas (n=33), S – settlements, AL – agricultural lands, F – forest, W – water, SR – sport and recreational sites, n/a– not applicable; the table shows only recorded conversions

	New photography					
	Rural areas					
Old photogrpahy		**S**	**AL**	**F**	**W**	**SR**
	AL	14	n/a	20	1	1
	F	-	-	n/a	-	2
	SR	-	-	1	-	n/a
	Urban areas					
Old photogr.		**S**	**AL**	**F**		**SR**
	S	n/a	-	-		1
	AL	25	n/a	23		8
	SR	1	-	-		n/a
	Uninhabited areas					
Old photogrpahy		**S**	**AL**	**F**		**SR**
	S	n/a	1	-		-
	AL	1	n/a	12		1
	F	-	-	n/a		1
	SR	2	-	2		n/a

Table 2. Land use modifications based on photo pairs in (R) rural (n=32), (U) urban (n=35) and (UN) uninhabited areas (n=33); S – settlements, AL – agricultural lands, F – forest, RC – rocks; the table shows only recorded modifications (the primary list included also not recorded combinations – AL: grassland > arable land, S & AL: single trees disappearance, F: clear cuts, windbreaks, RC: vegetation removal, quarry exploitation launching)

		R	**U**	**UN**
Land use class	**Modification process**	**Number of photo pairs**		
S	more dense	19	27	-
	less dense	-	-	3
AL	arable land > grassland	14	19	3
	fallows and secondary succession	12	12	11
S & AL	single trees appearing	23	24	13
F	dieback	2	-	3
	forest regeneration	5	1	11
RC	vegetation succession	1	1	6
	end of quarry exploitation	-	-	1

Figure 2. Forest cover increase in Zawoja, 1962-2009; historical photo: Babia Góra National Park

The observed processes of land use modification were similar to those identified in rural areas; however, the major processes were related to the increased density of developed areas and the appearance of new, individual trees. Secondary succession of agricultural lands and conversion of arable land into grassland were also widespread in this group of photo pairs (Table 2).

3.2.3. Uninhabited areas

The main land use conversion observed in uninhabited areas was a conversion of agricultural land into forest (Figure 2 background, Figure 3). The sport and recreational areas were more often abandoned than established in uninhabited areas (Table 1). One photo pair illustrated the destruction of a building and conversion of a settled area into grassland. The analysis of the photo pairs showed that land abandonment and the appearance of individual trees (also observed in the field balks) were common in the area (Table 2).

Figure 3. Conversion of former pastures into forests on mountain ridges, Gorce Mountains, 1934-2011; historical photo: (Jarosz 1935)

Forest regeneration was more commonly observed than forest decline. New vegetation was identified not only in previously anthropogenic-dominated landscapes but also on the rocky slopes of the Pieniny Mountains (Table 2).

3.2.4. Land cover dynamics

Out of 41 cases that were quantitatively analysed, 14 were located in rural areas, 12 in towns and their surroundings and 15 in uninhabited areas. A comparison of the annual rates of change among the land cover classes indicated that the highest median value for fully forested grid cells was recorded in urban areas (0.99%), while it was slightly lower (0.84%) in rural areas. The annual rate of forest change in uninhabited areas was substantially lower than in other groups of photo pairs (median = 0.39%; Fig. 4). Among the grid cells partly covered by forest, both gain and the loss can be observed; however, the loss was more frequent in rural and uninhabited areas than in urban areas. Nevertheless, all the medians of annual rates of change in grid cells partly covered by forest exhibited negative values (Fig. 4). Grid cells classified as non-forest decreased, with the maximum value of the median associated with rural areas (median = -2.27%) and slightly lower values observed in uninhabited and urban areas (Fig. 4).

4. DISCUSSION

4.1. Land use change

The objective of the paper was to analyse changes in land use and land cover based on repeat photography (100 photo pairs) in the Polish Carpathians from the late 19th and 20th centuries. Additionally, 41 cases were used to determine the land cover dynamics.

A correspondence analysis showed that type of landscape visible in a photo is an important factor that can be used to differentiate photographs in terms of land cover change processes, confirming the assumption that land cover change in the Carpathians depends on the distance to local centres (Pazúr et al., 2014). The changes are often twofold, including an increase in forest cover associated with abandoned agricultural lands and the development of settlements (Kozak 2009).

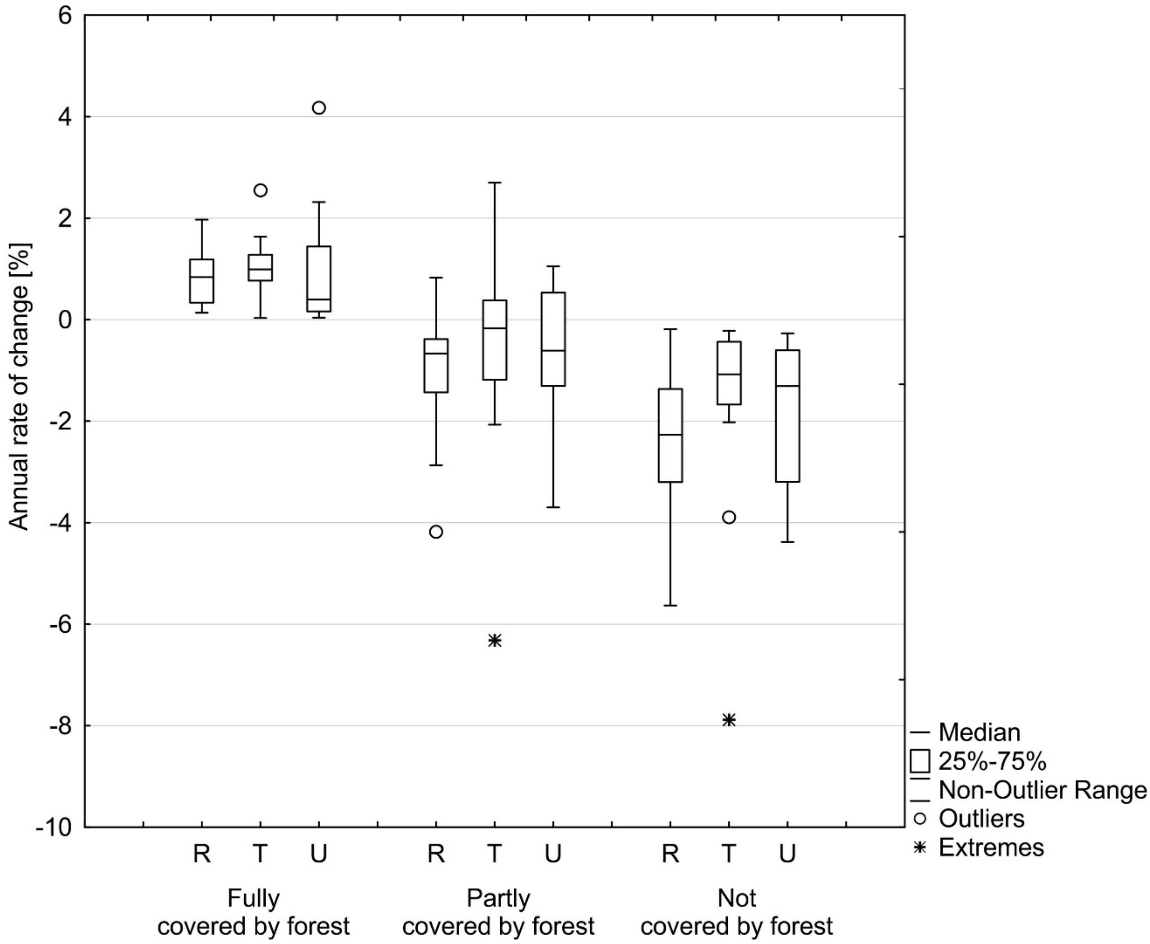

Figure 4. Annual rates of change among different land cover classes (R – rural areas, T – towns and their surroundings (urban areas), U – uninhabited areas)

The main process associated with land cover change was land abandonment, resulting in secondary forest succession and increased forest cover. This process was widespread in rural and uninhabited areas and was one of the two most visible processes in urban areas. Forest cover has increased in the Polish Carpathians since the 19th century, as documented in many previous studies (Affek 2011; Bucała 2014). However, the detailed scale of the repeat photography analysis showed that forest cover increases occurred not only on agricultural lands but also, e.g., in former sport and recreational areas. The agricultural land decrease observed in the study area was connected to the forest cover increase and to the development of new settlements. It was the second most widespread process of land use conversion observed in the area. The analysis showed that it took place close to the existing settlements, as well as in more remote areas. New buildings that are isolated from existing settlements are likely second homes and recreational centres (Mika 2013). In this case, these structures may have negative impacts on ecosystems (Radeloff et al., 2005) and landscape aesthetics (Kaltenborn et al., 2009).

Unlike most map sources, repeat photography can be used to analyse not only land cover conversion but also land cover modifications. The dominant and widespread processes in rural and urban areas included increased density of settlements combined with abandonment of agricultural lands. Agricultural lands that were not abandoned were commonly transformed into grasslands. These findings confirm that although the Polish Carpathians remain a popular destination for residential development and recreation, local economies are becoming less dependent on agriculture (Kurek 1996; Dej & Micek 2013). In the most remote, uninhabited areas, land abandonment is also widespread covering even up to 31.0% of the agricultural lands in some communes (Kolecka et al. 2015). This is particularly true in less fertile areas, where agriculture is least profitable, which is common in many European mountain areas (MacDonald et al., 2000; Pazúr et al., 2014).

The detailed perspective of repeat photography showed that in many parts of the Polish Carpathians, apart from secondary succession, new, individual trees or other non-forest woody elements appear in the landscape. They are visible in urban centres, on field balks and along rivers. Wyżga et al., (2012) found that vegetation growth along the Dunajec River was possibly due to land use changes in the whole catchment. As areas of arable land and intensive grazing decreased, the quantity of sediment transported by the river also decreased, increasing river channel incisions and enabling vegetation growth in the riverbeds. The development of vegetation in riverbeds, which was observed in many photo pairs, may also be a result of decreasing human activity in the riverbed itself, e.g., grazing. In the past, grazing was carried out in the least favourable areas, e.g., in wetlands, on steep slopes. The examples from France show that riverbanks were also used for grazing (Kondolf et al., 2007). The appearance of new vegetation in towns is likely connected to reduced land utilization for agricultural purposes. Grazing was common in many green areas in the towns. The role of agriculture is now limited, and vegetation appears relatively fast.

Many photo pairs showed that the conditions of forests have improved over time, although forest disturbances were also observed, especially in the western part of the study area. These disturbances can be potentially linked to emissions from heavy industry during socialist times and forest management practices of the Habsburg Empire (Main-Knorn et al. 2009; Munteanu et al., 2015). However, the historical photos show that forests in the late 19th and early 20th centuries were more intensively used by humans for activities such as clearcutting or grazing compared to later periods. This trend has also been observed in other parts of the Polish Carpathians (Augustyn & Kucharzyk 2008).

4.2. Land cover dynamics

The comparison of land cover dynamics among different landscape types showed that forest cover increased faster in urban areas compared to other areas. Simultaneously, the disappearance of grid cells not covered by forest was slower in urban areas than elsewhere. This trend suggests that agricultural lands were abandoned and converted into forest relatively rapidly in rural and more remote areas. In urban areas, some previous agricultural lands close to the towns were relatively quickly abandoned and forested, while others were converted into settlements. Such divergent land change patterns associated with former agricultural lands have transformed traditional land use zoning in the Carpathians. Currently, due to land abandonment, forests are developing further down slopes, while settlements are simultaneously spreading up slopes. This process is resulting in the disappearance of the agricultural belt and transforming the traditional landscape, potentially affecting forest ecosystems negatively (Radeloff et al., 2005; Conedera et al., 2015; Fig. 5). The mean value of the annual forest change rate was relatively high (0.94%) when compared to other areas in the Polish Carpathians (Kozak 2010) or the Carpathian Basin (Munteanu et al., 2014). At the same time, the values of the annual rates of change for non–forested grids (the mean value -1.95%) were also slightly higher than the rates of agricultural change observed in the region (Munteanu et al., 2014). Munteanu et al., (2014) showed that after World War II, i.e., a similar period as used studied in this paper, the rates of change in the area were higher than at any point over the last 250 years (-0.54%). Furthermore, in the eastern part of the Polish Carpathians, where post-war resettlement took place, the rates were even higher than those observed in this study (up to -5%). In general, the higher values based on repeat photography may be a result of the Modifiable Areal Unit Problem (Kozak & Szwagrzyk 2016), as the areas shown in the photography are smaller than those analysed with e.g. historical maps. However, the values observed in this work are similar to those reported in many Carpathian case studies (Kozak 2010; Munteanu et al., 2014).

4.3. Representativeness of the results

An analysis of high numbers of photo pairs illustrating a region can be considered a meta-analysis. As Rudel (2008) noted, the meta-analytic approach is possible when the cases are comparable, i.e., the data are similar, the methods used to collect the data are similar and the conditions in which the data were collected are similar. All of these conditions are satisfied using repeat photography, what makes it valuable in land change studies. However, there are also potential disadvantages of applying the method to land change research. One disadvantage is that repeat photography does not yield fully representative results for any type of landscape (Pickard 2002). It is difficult, to define the exact number of photos needed to fulfil the criteria of representativeness. Any study based on repeat photography starts by extensively collecting historical images and ends with only a small portion of images, especially for quantitative analyses (Molnia 2010).

Thus, research is only conducted in areas where the number of available photos is relatively high. This results in two problems associated with representativeness: underrepresentation and overrepresentation of some areas (Klett 2010). In the first situation, the solution might be adding more historical photos from different times and aims of taking. Photos that illustrate the background landscape, often by accident, are particularly valuable (e.g., documentary photography).

Figure 5. Settlement pressure transforming altitudinal land use zonation and the cultural landscape of the Carpathians, Krynica 1935-2011; historical photo: Ryszard Kruk and Bożena Mściwujewska-Kruk private collection.

Therefore, I decided to use not only postcards but also photos taken by national park staff, as well as those documenting construction projects. Overrepresentation in a region is common when postcards are used. This is because some views are perceived as more attractive and popular, triggering increased photographic activity in specific places. One possible solution may be to add case studies with additional historical photos of nearby locations characterised by similar conditions. Therefore, I used photos taken in four study regions rather than in one region with a large number of photo pairs.

5. CONCLUSIONS

This study showed that the landscape of the Polish Carpathians has changed substantially over the last century. Among the land use conversions, the transition of agricultural lands into forests was dominant in rural and uninhabited areas. In towns and their surroundings, the spread of new settlements on agricultural lands was a dominant process. However, the appearance of new forests was also widespread. The processes associated with land use modifications were mainly related to abandonment of agricultural lands, triggering secondary succession and changing arable lands into grassland. Both in towns and in rural areas, new building densities increased. Additionally, many photo pairs illustrated new, individual trees. These trees were visible along rivers, on field balks and in towns. This type of change cannot typically be documented by studies using archive maps and medium-resolution satellite imagery.

The comparison of historical and contemporary photos highlighted changes to the vertical structure of land use in the Polish Carpathians. Settlement growth generally occurred in the valley bottoms and spread upslope. Forest expansion occurred in the highest portions of the forest zones of mountains and on slopes, lowering the forest-agricultural boundary. Both types of change have resulted in a gradual decline of the traditional agricultural zone. The results showed that the dynamics of the changes are relatively fast, leading to landscape homogenisation with dominant role of forests.

The analysis shows that using repeat photography may substantially improve our knowledge of land change processes, including modifications or indications of change that are not visible on maps or in remote sensing images.

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