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Using ALS data to estimate afforestation and secondary forest succession on agricultural areas: An approach to improve the understanding of land abandonment causes

Jaroslaw Janus*, Piotr Bozek

Department of Agricultural Land Surveying, Cadastre and Photogrammetry, Faculty of Environmental Engineering and Land Surveying, University of Agriculture in Krakow, Poland

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ABSTRACT

The aim of the article is to identify the relationships between the phenomenon of land cultivation abandonment and spatial features of parcels that influence the economic effects of land cultivation. The study covered submontane areas with unfavorable soil and climate conditions which, nevertheless, were a place of intensive agricultural activities until the beginning of the 21st century. The study area is also characterized by unfavorable parameters of land fragmentation. The study covered part of the Małopolska Region in southern Poland with an area of 1745 km^2. The area is divided into nearly 370,000 parcels. The study was based on ALS data with a density of 8 points/m^2. On its basis, a number of categories of high vegetation were determined and then processed into a 1 × 1 m grid structure. This allowed to define the height structure of vegetation in every parcel. Other features, including land use status at the end of the 20th century, were derived from cadastral databases and digital soil quality maps. To explain the causes of observed forest expansion, the following diagnostic features were used in the models of logistic regression: size of a parcel, its width, slope, soil quality, and accessibility to the road network. The results allow to formulate an unexpected conclusion: unfavorable spatial features of parcels, negatively affecting the profitability of agricultural production, have no statistically significant influence on the decision of land cultivation abandonment.

1. Introduction

The abandonment of traditional agricultural lands is a current phenomenon observed in many regions of the world. Its dynamics and location are subject to constant transformations linked to climate change processes, population migrations, and changes in agriculture functioning. Land abandonment affects primarily marginal lands (Tomaz, Alegria, Monteiro, & Teixeira, 2013), characterized by the least favorable conditions for cultivation and the lowest soil quality (Hatna & Bakker, 2011). This phenomenon may lead to the degradation of land used for agriculture (Kumar & Das, 2014), therefore it should be perceived as an important ecological problem occurring at the regional and global levels (Bajocco, De Angelis, Perini, Ferrara, & Salvati, 2012). However, in many environmental aspects, including biodiversity, the balance of positive and negative effects of land abandonment is still discussed (Queiroz, Beilin, Folke, & Lindborg, 2014).

A factor particularly favorable for abandoning land cultivation is the location of land in mountainous areas (Lasanta et al., 2017; Liu et al., 2017; MacDonald et al., 2000; Melendez-Pastor, Hernández, Navarro-Pedreño, & Gómez, 2014; Shi, Li, Xin, & Xu, 2018; Yan et al., 2016). As shown with the example of the Carpathians and the Alps (Price at al., 2017), biophysical factors in such areas influence the types of land use and their changes more than others, however, the impact of socio-economic factors is also noticeable (Loran et al., 2017; Serra, Vera, Tulla, & Salvati, 2014; Stoebner & Lant, 2014).

In Europe, the problem of land abandonment was recorded in both recent and distant past (Loran et al., 2017) and is now a major challenge for implementing effective policies limiting its negative consequences (Renwick et al., 2013; Sang, Dramstad, & Bryn, 2014; Terres et al., 2015; van der Zanden, Verburg, Schulp, & Verkerk, 2017). At present, it affects Central and Eastern Europe the most (Baumann et al., 2011; Gutman & Radeloff, 2016), as they experienced dynamic socio-economic changes after the fall of socialism at the turn of the 1989 and 1990 (Sokol, 2001). This had fundamental consequences for farming conditions and resulted in processes such as abandonment of cultivation and growth of forest cover that were similar in many countries of the region (Lieskovsky et al., 2015; Taff, Müller, Kuemmerle, Ozdeneral, & Walsh, 2010; Prishchepov, Müller, Dubinin, Baumann, & Radeloff,

* Corresponding author.
E-mail addresses: j.janus@ur.krakow.pl (J. Janus), piotr.bozek@ur.krakow.pl (P. Bozek).

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2013; Kuemmerle, Müller, Griffiths, & Rusu, 2009; Pazúr, Lieskovský, Feranec, & Oťaheľ, 2014). At the level of individual countries, it is possible to indicate a number of differences in the characteristics of these changes. They result from different models of agricultural functioning (Sarris, 1999), parameters of land fragmentation (Hartvigsen, 2014), and natural conditions, including soil quality, determining the profitability of agriculture.

The process of abandoning cultivation, particularly intense after the fall of socialism, affects agricultural areas of the Carpathian Region (Griffiths, Müller, Kuemmerle, & Hostert, 2013; Kuemmerle, Hostert, Radeloff, Perzanowski, & Kruhlov, 2008; Munteanu et al., 2014) and its main drivers were of economic and institutional character. Land abandonment phenomena in mountainous areas observed today in Europe are not limited to places that undergo dynamic system changes. Switzerland is an example where land abandonment is the dominant driver for the establishment of new forest areas (Gehrig-Fasel, Guisan, & Zimmermann, 2007). Research completed for this area showed a relationship between the observed processes of land abandonment and forest regrowth mainly with relative decline in the agricultural income from marginal land (Gellrich, Baur, Koch, & Zimmermann, 2007) and decreasing significance of agriculture associated with increasing urbanization (Price at al., 2015).

Among the countries of Central and Eastern Europe, the cropland abandonment phenomenon is strongly affecting part of Poland, and its causes should be considered in a wider perspective than only in the aspect of the Carpathian influence. The current structure of land use in Poland is the result of the impact of a number of historical, socio-economic, and natural factors. This also applies to changes in the area occupied by forests associated with periods of the intensification of agricultural production and the process of abandoning land cultivation. Analyzing this phenomenon over a longer period of time is a difficult task, due to multiple periods of loss and recovery of statehood by Poland and very significant changes in its area and borderlines over the past two hundred years. Just before the outbreak of World War II, arable lands occupied 65.8% of Poland's area, while forests – 22.2% of its area (Bański, 1997). The period of World War II was associated with the periodic cessation of cultivation of about 7.5 million hectares, but these areas were quickly restored to cultivation after the war ended. The quick population growth in Poland after the war led to large-scale deforestations, which also happened on areas with low soil quality and unfavorable conditions for agricultural production. The area occupied by agricultural land reached its maximum in the 1950s when it amounted to 67.2% of Poland's area (Poławski, 2009). From that moment, the first period of forest cover growth related mainly to limiting the cultivation of the lowest quality land has begun. In the 1960s, the area of arable land decreased by nearly 860 thousand ha (Bański, 1997). Since then, this trend has gradually weakened and further decrease in the area of agricultural land was largely associated with the expansion of urban and communication areas (Woch & Woch, 2014). During this period, virtually until the beginning of political transformation in 1989, the phenomenon of large-scale abandonment of land cultivation in Poland a was nearly not observed even in areas of marginally low productivity of agricultural production. In general, in 1950–1990, the total decrease in the area occupied by agricultural land was from 1.7 million ha (Bański, 1997) to 18.7 million ha registered in 1990. Changes in the area of agricultural land were accompanied by corresponding changes in forest cover indicators. The minimum value of this indicator at the level of 22% was recorded in 1950, then it gradually grew reaching 27.3% in 1970 and 28% in 1990 (Poławski, 2009).

At the beginning of the 1990s, in Poland as in most Eastern and Central European countries, the economy changed from a centrally controlled model to the one based on free market principles (Gomułka, 2016; Noszczyk & Hernik, 2017). As a result of this change, the transformation of land use after 1989 took place in a differentiated manner depending on the part of the country and the agricultural model. The first characteristic type of change was observed in the northern part of Poland with a low population density where large-scale state-owned farms dominated before the transformation. This area was quickly affected by the phenomenon of often massive abandonment of crops associated with the liquidation of the abovementioned farms, because in the initial period after the transformation there were no short-term actions to sell or rent them quickly. In 1996, permanent abandonment of land in the case of selected communes in such areas was registered for even 40% of the area of agricultural land (Bański, 1998). However, the abandonment was transient in this case and it did not lead to the occurrence of secondary forest succession, and at present these areas are practically entirely intensively used for agriculture by large-scale, modern farms, next to which medium family farms try to function.

The second type of land use change applies to densely populated and highly fragmented areas of Central and South-Eastern Poland, where large-scale farms were rare and agriculture was dominated by small and medium-sized family farms. In these areas the phenomenon of abandonment of crops appeared with a certain delay in relation to the date of the beginning of the system transformation but it is now permanent and still growing. The delay results from the family nature of agriculture and traditional affection to the cultivation of land. For this reason, the decision to abandon cultivation is often made only after the younger inheritors have taken over their farms. Therefore, this process is strongly associated with demographic changes in the Polish countryside (Stasiak, 1992), which lead to a significant decline in population of typically agricultural areas. Abandonment of land is particularly visible in areas with unfavorable conditions for conducting profitable agricultural production due to poor soil quality and unfavorable parameters of land fragmentation (Janus, Glowacka, & Bozek, 2016). In such places especially there are no willing people to continue agricultural activities in the inherited farms, but also to develop the existing farms or to create new ones, which is a common phenomenon observed in the rest of Poland. In the scale of the whole Poland, the area occupied by forests and vegetation of a forest character has been constantly increasing since the post-communist transformation. In 1995, it reached 28.4% of Poland's area, while in 2016 it was 30.6% (Polna, 2017). The latter value is already close to the long-term goal planned to be achieved in 2050, which is the level of 33%.

The cropland abandonment and the accompanying forest cover growth concerns the area of the Polish part of the Carpathians in particular, where high dynamics of abandonment processes have been observed (Kolecka et al., 2015). An attempt to show what are leading drivers of these processes was the subject of an extensive research project based on ALS data (Kolecka et al., 2017). The analysis covered a set of areas representing 230 communes located in the area of the Polish Carpathians and a large set of diagnostic features determined on the basis of statistical and topographic studies, databases, and ALS data regarding the slope and elevation range. It was shown that topography and employment outside of agriculture are the main factors affecting farmland abandonment, this phenomenon is particularly strongly present on steep slopes and at lower elevations in the fragmented forest-agricultural landscape (Kolecka et al., 2017). The methodology adopted in the above studies, based on large test areas, allowed to determine the leading drivers favoring the expansion of forest cover at the level of communes. Due to the adopted spatial scale, the answer to the question about factors that influenced the owners' decisions to cease cultivation or to resign from running the holding at the level of individual plots remains open. Applying the research element to the lowest possible level, such as the level of plots, requires an appropriate set of diagnostic features reflecting the difficulty of their cultivation (slope, lack of direct access to roads) or the lowering of the income that can be obtained (small area, unfavorable shape, soil quality) determined independently for each plot.

The necessity to search for appropriate dependencies at this level results from the ability to increase the precision of tools and programs preventing the negative effects of land abandonment process. It is