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RESEARCH ARTICLE

Factors affecting the persistence of traditional agricultural landscapes in Slovakia during the collectivization of agriculture

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Abstract Collectivization of agriculture (1950s–1970s) was one of the most important periods in landscape development in Slovakia. Traditionally managed agricultural landscapes, that covered more than half of the Slovak territory, were transformed into large-scale fields and only fragments of traditional agricultural landscapes survived. We mapped the remaining traditional agricultural landscapes using aerial photos and historical maps. We then statistically analyzed the various geographical factors and their influence on the transformation process of traditional and collectivized fields, i.e., slope steepness, soil fertility, distance from settlements and isolation from regional capital cities. The comparison was performed using classification tree analysis. We constructed a set of decision rules that explain why fields were managed traditionally or collectivized. Our findings show that traditional agricultural fields were more likely to persist on steep terrain, less fertile soils, and on locations that were closer to the settlements, but more isolated from the regional capital cities. Steepness played the most important role: small-scale fields located on steep areas were not accessible to heavy machinery and therefore, frequently survived the collectivization. We show that the selected geographical factors are good explanatory variables for the collectivization of arable fields and orchards. For vineyards and grasslands, however, the explanatory power of the selected geographical factors is lower, and we suspect that other factors, not depicted in the analysis play an important role.

Keywords Land-use change · Classification tree analysis · Driving forces · Post-socialist countries · Resilience · Cultural landscape

Introduction

Over the millennia, human intervention in natural ecosystems have created a wide variety of agricultural landscapes that have emerged and disappeared in

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Europe. Many landscapes have undergone multiple transformations: dynamic periods followed periods of relative stability. We can find legacies of historical landscapes such as open fields, e.g., *coltura promiscua* and *bocage* in Western Europe (Deckers et al. 2005), remnants of medieval field patterns called *pluzina* in the Czech Republic (Molnárová 2008; Sklenicka et al. 2009), traditional *common lands* in United Kingdom (Jones 2013; Newton 2013), terraced landscapes in Mediterranean regions (Agnoletti et al. 2011; Barbera and Cullotta 2012; Bevan et al. 2013) and agrarian mosaic landscapes in Central Europe (Štefunková and Dobrovodská 2009; Babicová and Gerhátová 2011; Baránková et al. 2011; Baran-Zgłobicka and Zgłobicki 2012) and in other continents as well (Palang 2010; Fischer et al. 2012).

The transformation of traditional landscapes started with the social and political revolutions since the eighteenth century, when the necessary technological power became available (Antrop 1997). However, most of the studies on traditional agricultural landscapes refer to landscapes that remained relatively unchanged during the industrialization period after the Second World War (Calvo-Iglesias et al. 2009; Agnoletti et al. 2011; Johann 2013). In Slovakia (Bezák and Mitchley in Press; Izakovičová and Oszlányi 2012; Kanianska et al. 2014) and other post-socialistic countries (Sklenicka et al. 2009; Bell et al. 2009; Palang 2010; Rohring and Gailing 2012; Fischer et al. 2012), a crucial role was played by the collectivization of agriculture.

Collectivization was a politically driven process, based on the socialist idea of common property that should be for the benefit of all working people equally. The aim of the collectivization was to minimize private property and to consolidated all agricultural land to large-scale fields suitable for industrial agriculture. Basically, Central and Eastern European countries followed the Soviet example. However, agricultural land was not completely nationalized in Slovakia as it was in former Soviet Union countries (Swinnen 1999; Palang 2010). Rather, ownership rights were gradually reduced.

Collectivization in Czechoslovakia started in 1949, when president Klement Gotwald declared that “There will be no socialism, if the countryside will not turn to socialism.” In the same year, new legislation to establish the Unified Agricultural Cooperatives were defined. The farmers entering the Cooperative transferred all agricultural and forest land to the cooperative farm. Formally, it was a voluntary decision. In reality, farmers were forced into it by political and economic pressure driven by the government and its bureaucracy. For example, the farmers that did not reach production quotas, were obligated to give land to the agricultural cooperative. Those that refused to give their land to the cooperatives were often marked as “kulaks” (Russian word for exploiters) and were summoned to court. Usually they had the choice to either give their land to a cooperative farm, or to spend several years in prison. Some of the individual stories of the victims of collectivization are documented in The Nation’s Memory Institute in Bratislava. Many farmers were forced out of their homeland and started to commute as employees to nearby urban centres that had expanding industry and urbanization. The number of people employed in agriculture decreased from 918,000 in 1948 (60 % of economically active population) to 290,000 in 1989 (12 %) (Bezák and Mitchley in Press).

The main wave of land concentration ended in 1959. According to Demo (2001), an area of 1,789,178 ha (65 % of total agricultural land) was managed by 2,709 cooperatives in 1960. An additional 377,104 ha (13.7 %) of state agricultural land (nationalized after the Second World War or during the collectivization process), was managed by state farms. Under a new law (No. 49/1959), cooperatives could be further merged to achieve an “optimal” size. As a result, the number of cooperatives dropped from 2,683 to 1,902 in 1970, and the average cooperative size increased. Finally, regulation No. 123/1975 granted the right to agricultural organizations to use private land to ensure agricultural production. Before the end of communism in 1989, the mean size of collective and state farms was 2,667 and 5,186 ha respectively (Mathijs and Noev 2004). The goal of food self-sufficiency was achieved in the 1980s (Cambel 2005).

Collectivization fundamentally changed the overall character of rural areas (Lipsky 1995; Kristiánová and Adamková 2010; Hresko et al. 2010). The socialist ideal of equality and uniformity was applied to the “ideological” uniform landscape (Maandi 2009). There were, however, factors that inhibited a full transformation of the landscape which led to the remnants of the traditional agricultural landscapes discussed in this paper. TAL in Slovakia are defined as the remaining mosaic of small-scale arable fields or permanent agricultural cultivations such as grasslands, vineyards and high-trunk orchards or early abandoned plots of low succession degree, which have not been affected by agricultural collectivization (Špulerová et al. 2011). TAL are agricultural ecosystems that are characterized by the following features: (a) the small-scale structure of the plot division is preserved (b) the presence of original forms of anthropogenic relief (balks) (c) unchanged land use during the collectivization of agriculture and (d) the use of some traditional agricultural technologies.

According to data from the Statistical Office of the Slovak Republic, the area of the traditionally managed agricultural landscape before the collectivization was 2,287,000 ha—more than half of the entire Slovak territory. The current area of traditional agricultural landscapes is about 44,455 ha, which is <1 % of Slovakia (Špulerová et al. 2011). The purpose of this paper is to identify the main geographic factors and determine their potential role in the transformation or persistence of traditional agricultural landscapes in Slovakia during times of agriculture collectivization. Specifically, our aims were to (1) identify the geographic factors that played a key role in the process of land collectivization (2) compare the geographical factors of the collectivized and non-collectivized fields and (3) find the set of decision rules used for keeping the fields traditionally managed or for collectivizing them.

Methods

Mapping of traditional agricultural landscapes

The methodology of TAL mapping was published in Dobrovodská et al. (2010) and Špulerová et al. (2011). The preserved TAL in Slovakia were mapped using a combined method comprising visual interpretation of aerial photos and field surveys in 2009–2011. The visual interpretation was performed using Google Earth aerial pictures taken in 2007. TAL were identified based on the following characteristics: (1) polygons consisting of more than five mosaic fields (2) land use did not change since the time of collectivization of agriculture (pre-collectivization land use was identified from historical topographic maps) (3) polygons are not overgrown by trees—(i.e. <50 % woody vegetation) and (4) the area of the polygon is larger than 5,000 m^2. The combination of characteristics (1)–(4) creates a spatial pattern which clearly distinguishes TAL from surrounding areas (Fig. 1). In a second step, approximately 20 % of the sites were randomly selected from the Natural–settlement nodal regions of Slovakia (Miklós 2002). The selected sites were visited, attributes from the aerial mapping were verified, and additional data were recorded (e.g. the threat factors and vegetation information).

We analyzed four types of agricultural field: arable fields, grasslands, vineyards and orchards. The mapped TAL polygons were assigned to these four types according to the dominant land-cover type within the mosaic. To obtain land-cover information from the time of collectivization, we used historical military topographical maps from 1950 to 1956.

The boundaries of collectivized fields were taken from the current land parcel identification system (LPIS) which is the database of individual agricultural fields that are eligible for Common Agricultural Policy subsidies. The LPIS polygons were interpreted from aerial photos and verified in the field using a similar method as described above for TAL polygons. In this way, the resulting databases are comparable. To filter out those large-scale fields, that have just recently been created and are not a result of agriculture collectivization, we referred to the Corine Land Cover map from 1990 and restricted our analyses to those large-scale fields that were already present in the 1990s (i.e. the end of socialist era).

Analysis of geographical factors

Slope steepness

We derived slope steepness from a digital elevation model (DEM) based on contour maps with a scale of 1: 10,000. To improve the DEM elevation points and elevation, breaklines (ridges, streams) have been used. For the interpolation, the ANUDEM TopoToRaster tool software was used. The resolution of the DEM and the slope raster was 30 m.

Soil fertility

To analyze soil fertility, we used the national soil database of Bonited Pedo-Ecological Units provided by the Soil Science and Conservation Research

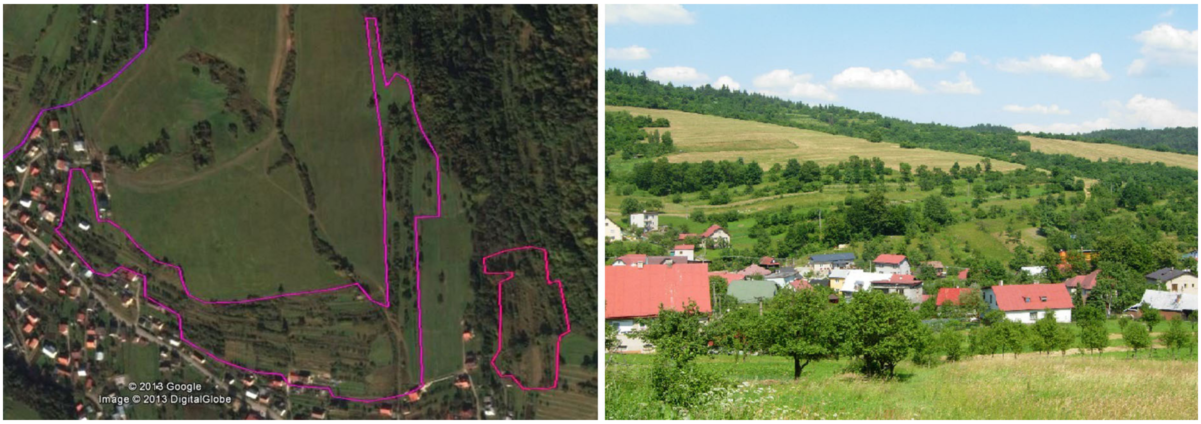

Fig. 1 Traditional agricultural landscape in Ochodnica (North–East Slovakia). *Left*—TAL polygons based on Google Earth picture interpretation, *Right*—picture taken at field research site

Institute in Bratislava. Soil fertility is expressed as a soil production potential (SPP) on a scale ranging from 0 to 100 (0 for non-productive soils, and 100 for the most fertile soils). According to (Džatko 2002) the SPP is a function of soil type (ST), slope steepness and aspect (SA), skeletal content and depth (SD), grain size distribution (G) and climate factor (K):

$$\mathrm{SPP} = \mathrm{K}(\mathrm{ST} + \mathrm{SA} + \mathrm{SD} + \mathrm{G})$$

Accessibility

We evaluated the accessibility as the time (in minutes) a person needs to walk from settlement to closest TAL mosaic. For the analysis, we used the VARCOST module from the IDRISI software. This approach was found to be the most suitable for distance analyses in comparative studies (Danielisová 2008; Horňák 2012). First, we analyzed the effect of topography to walking speed by calculating the friction of the surface, as function of the slope steepness. We then incorporated the effect of different land cover types that could have a barrier effect (buildings, rivers), could retard the walking speed (meadows, fields, forests), or could facilitate the walking (paved roads, paths, bridges, etc.). For the land-cover map, we used the Corine Land Cover layer from 1990 (Feranec et al. 1995). The friction coefficients, expressed by the proportion of the average walking speed without friction and retarded speed by different land-cover types (Table 1), were derived from empirical experience and from published sources (Soule and Goldman 1972; Mezníková 2011).

Table 1 Friction coefficients for analyzed land cover types

Land cover	Friction coefficient	Remark
Buildings, fences, water courses	99	Barrier effect
Railways	10	Crossable barrier
Motorways, pathways, bridges	1	No friction
Meadows	1.28	Mezníková (2011)
Bare soils	1.31	Soule and Goldman (1972)
Forest	1.59	Soule and Goldman (1972)
Landscape (background)	1.2	Empirical average

Isolation

Isolation was evaluated as the distance in hours by car from the TAL mosaic to the closest regional capital city (Bratislava, Banská Bystrica, Košice). For the analyses, we used the "Cost grow" algorithm, incorporated in the COST module (Eastman 2003) for the IDRISI software. The surface friction was adjusted for the use of motor vehicles (the effect of a road network is higher than the effect of relief topography). We used the map of the current road network, from which we excluded those highways that did not exist at the time of the collectivization. The maximum car speed was limited at 120 km/h on existing highways and 60 km/

h on roads. We also incorporated the walking distance from roads to the TAL mosaic for the areas that were not directly accessible by a car.

Statistical analysis of data

For each polygon, we calculated the average value of geographical factors and compared collectivized (48,849 polygons) versus non-collectivized polygons (2,871 in total) as response variables. To do so, we used a classification tree analysis: a non-parametric, probabilistic machine-learning method that classifies a response variable based on binary splits applied to predictors (Breiman et al. 1984). The splitting rules are defined in order to get the greatest increase in class purity for each node until the nodes reach the defined criteria. In order to terminate the tree's growth and avoid tree over-fitting, we limited the minimum number of polygons in any terminal node to 50 and allowed the next split only if the cross-validation error, expressed by cost-complexity parameter (cp), decreased by the cp factor of 0.01. For cross-validation, we used a v-fold method. Observations were split into 10 subsamples, and trees were calculated, without the excluded subsample that was used as a test sample for validation. The average cross validation error was then computed for each split. We used the Gini splitting method for the tree-fitting algorithm (Breiman et al. 1984). Since we were comparing polygons with different sizes, we weighted them with respect to polygon area. Therefore, the classification procedure aimed at minimizing the misclassification *area* (ratio between the misclassified area and the total classified area) instead of the number of misclassified polygons.

We used the Pearson correlation coefficient to test the co-linearity of the predictors. It was necessary to take the high correlation between the slope and soil fertility (R = −0.80) into consideration for the interpretation of results and discussion. The analysis was executed with R statistical software using the rpart package.

Results

Arable fields

Our analysis suggest that slope obviously was a crucial factor affecting the preservation of traditional arable fields (Fig. 2). The split rule shows that flat fields (slopes <8.9°) were collectivized; fields on steep slopes (slopes steeper than 11°) remained in small parcels and were not collectivized. It is obvious that for intermediate slopes (split rule: slope between 8.9° and 11°), collectivization or persistence was influenced by accessibility: less accessible fields were more likely to be collectivized, and the fields close to settlements tended to remain for private farming. Because of the high correlation between slope and fertility (R = −0.72 for the arable fields), we are unable to draw definite conclusions regarding the relationship between the slope and collectivization. However, given the fact that steepness limits the use of heavy machinery, we suppose that slope was more important than fertility for determining collectivization in this case.

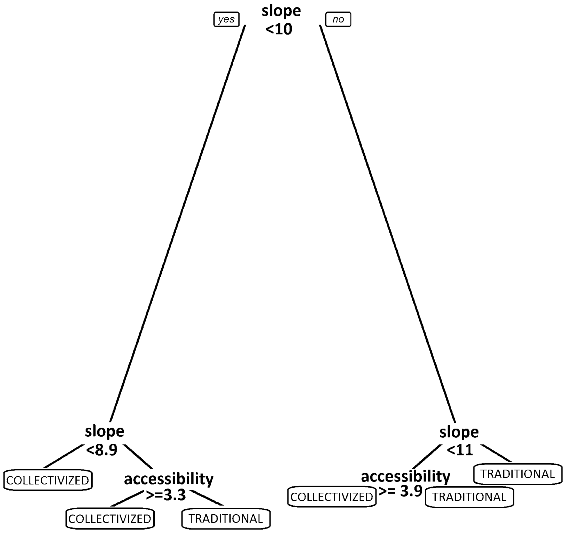

Fig. 2 Classification tree representing the role of selected geographical factors in the process of collectivization of arable land. (The vertical distance between the splits corresponds to the proportion of deviance explained by the splits). Misclassification rates: total 0.003, collectivized fields 0.0007, traditional fields 0.173. Number of samples: collectivized fields 31,467, traditional fields 1,549

Grasslands

As highlighted in Fig. 3, high misclassification rates with this land-use type indicate that the selected predictors are probably not the key drivers for transformation or persistence of traditional grasslands. Nevertheless, it seems that accessibility is the most

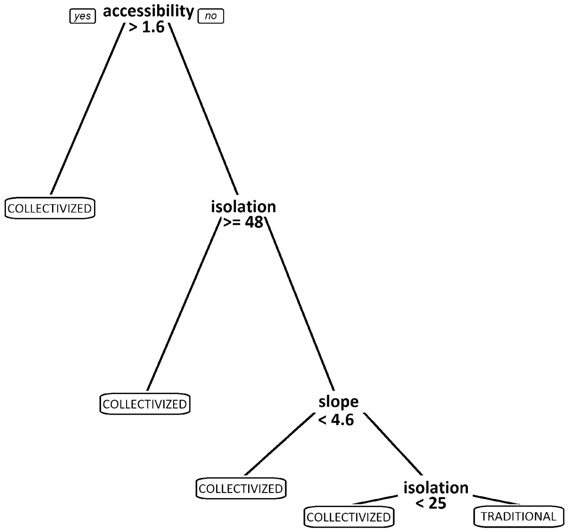

Fig. 3 Classification tree representing the role of selected geographical factors in the process of collectivization of grasslands. (The vertical distance between the splits corresponds to the proportion of deviance explained by the splits). Misclassification rates: total 0.040, collectivized fields 0.006, traditional fields 0.623. Number of samples: collectivized fields 16,307, traditional fields 493

important factor: less accessible fields were more likely to be collectivized. The role of isolation is unclear. More isolated fields tend to be collectivized, but with steeper slopes, the influence of isolation is the opposite. Flat grassland patches however, appear to be more frequently collectivized than steep ones.

Vineyards

Even though the first split is based on isolation of the patches, the proportion of deviance explained by slope on the second split is the most important. Traditional vineyards tend to remain in isolated areas with higher slopes and low fertility, or in very isolated, steep areas. However, high misclassification rates indicate that there are also other factors that affected the preservation of traditional vineyards (Fig. 4).

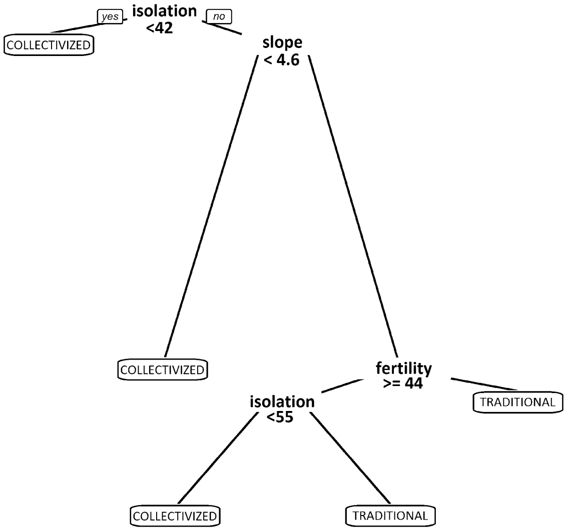

Fig. 4 Classification tree representing the role of selected geographical factors in the process of collectivization of vineyards. (The vertical distance between the splits corresponds to the proportion of deviance explained by the splits). Misclassification rates: total 0.253, collectivized fields 0.210, traditional fields 0.327. Number of samples: collectivized fields 818, traditional fields 243

Orchards

The most important factor is fertility, which depends partly on steepness. Therefore, we speculate that the role of slope is underestimated in that case. Traditional orchards tend to remain in less fertile areas (with higher slopes), or in areas with better accessibility. Low misclassification rates show, that these variables explain the preservation of traditional orchards sufficiently (Fig. 5).

Discussion and conclusions

This paper is a timely contribution to the understanding of the processes that determined transformation or persistence of TAL during the collectivization period in socialist Slovakia. Both collectivization and persistence of TAL were driven by political decisions. The majority of agricultural land was concentrated and collectivized. On the other hand, fragments of TAL survived due to regulation num. 69/1949, that allowed members of the cooperative farms to keep 0.5 ha of agricultural land (and an additional 0.5 ha of pastureland in submountain areas) for family farming.

From our findings, we have strong evidence that collectivization particularly affected those land patches that had the potential to increase production. Traditional agricultural landscapes remained on steep slopes, less fertile soils, and on sites close to the settlements, but that were more isolated from regional capital cities. Steepness is the major discriminant

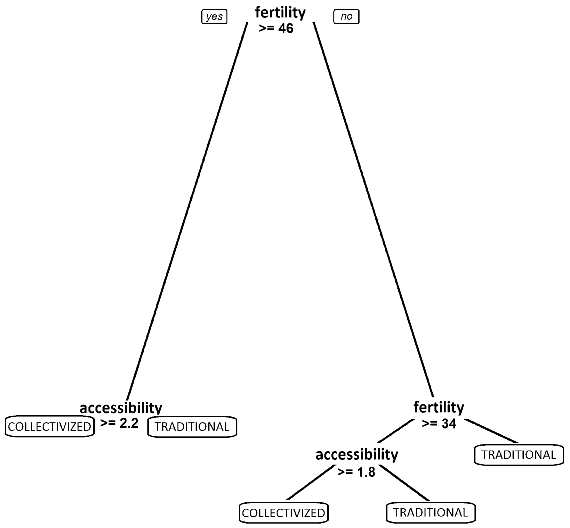

Fig. 5 Classification tree representing the role of selected geographical factors in the process of collectivization of orchards. (The distance between the split corresponding to the proportion of deviance explained by the splits). Misclassification rates: total 0.061, collectivized fields 0.087, traditional fields 0.048. Number of samples: collectivized fields 255, traditional fields 586

variable for collectivization of arable fields and vineyards. The small-scale fields that were located on steep areas were not accessible for heavy machinery, and therefore remained untouched by collectivization. This is in agreement with the overarching hypothesis that landscape changes in a given region are linked to their geomorphological characteristics (Bürgi et al. 2004) and with observations of the persistence of traditional agricultural landscapes in many European regions (Sklenicka et al. 2009; Agnoletti et al. 2011; Solymosi 2011).

Since soil fertility is statistically highly correlated with slope steepness ($R = -0.80$ for all polygons), it is difficult to determine pure relationship between those two factors and TAL persistence. Nevertheless, we analyzed soil fertility separately from steepness even if those two variables are highly correlated. This co-linearity could lead to underestimating the role of fertility in those cases where the splits were based on slope and vice versa. Our result identified soil fertility as an important driver. According to land consolidation rules, private parcels that were barriers for collective farming were taken away from owners and exchanged with parcels with the same or 20 % lower fertility. Practically speaking, those private farmers that did not join the cooperative farm, often got the least fertile soils in the cadastral area (Demo 2001). Our results are in agreement with other studies which also relate soil fertility to TAL persistence (Sklenicka et al. 2009) and to landscape change in general (Domon and Bouchard 2007; Baumann et al. 2011; Prishchepov et al. 2013).

Accessibility (distance from settlements) played an ambiguous role in TAL persistence. While the land that was left to cooperative members for family farming was usually located close to settlements, private farmers who did not join the cooperative farm, were re-located to remote areas during the land rearrangement process (Demo 2001). Since the number of private farmers was gradually reduced, most of the traditionally managed fields observed today are located closer to settlements. This ambiguous role of accessibility described above is responsible for the low explanatory power of this variable. Accessibility is the main discriminant in the case of grassland only, but the overall importance of geographical factors is low. This is in contrast to studies in Belgium where distance from settlements was found to be important for the development of TAL (Deckers et al. 2005). We, however, recognize the fact that accessibility is an important factor in the process of agricultural abandonment in post-socialist countries (Prishchepov et al. 2013; Müller et al. 2013).

According to Solymosi (2011), isolation is the main factor that determines persistence of traditional cultural landscape hotspots in Europe. It could be any form of isolation due to specific socio-economical, cultural, political conditions or land property conditions (Vos and Meekes 1999). Physical constraints in upland and remote areas prevent the modernization of agriculture (Plieninger et al. 2006). Modern development occurs faster near transportation nodes (Antrop 2005), along roads, railroad tracks and close to local centres (Solymosi 2011). In the Slovak case, even though more isolated fields were more likely to be preserved, isolation did not play such an important role as proposed by the authors above. In Western Europe, the transformation of traditional agricultural landscapes was driven by the ongoing adaptation of the agricultural sector to the global economy (Bignal and McCracken 2000; Strijker 2005; Widgren 2012), where isolation played a substantial role. Conversely, in the majority of Central and Eastern European countries, collectivization of agriculture was a political decision, made with no regards to economic profitability of large-scale farming in isolated areas (Rohring and Gailing 2012).

Methodologically, we experienced a few problems that are common in landscape-historical research, and are mainly related to incomplete data availability. Regarding the difficulty in capturing the full sample of TAL that survived the collectivization of agriculture, it must be acknowledged that the greater part of the land was collectivized until 1960, the collectivization effectively ended in the middle of seventies and communism regime ended in 1989. Since, we mapped the remaining TAL in 2010 and 2011. This implies, that the TAL that were abandoned or transferred to another land-use type after the end of communism were consequently omitted from our data. Indeed, agricultural land abandonment was a widespread phenomenon in Slovakia (Munteanu et al. 2014; Gerard et al. 2010) and other post-socialistic countries during the transition to market-oriented economy (Kuemmerle et al. 2008; Baumann et al. 2011; Alcantara et al. 2012; Prishchepov et al. 2013; Griffiths et al. 2013). For the analysis of collectivized fields, we used the layer of agricultural fields mapped in 2010. This layer contains some new fields that originated after the end of communism. To filter-out those fields, we used the Corine Land Cover layer from 1990. Since the Corine Land Cover was mapped with a coarser scale (minimum mapping unit was 25 ha), not all new large-scale fields were recognized and filtered out. In turn, some isolated large-scale fields that originated during the collectivization period were not recognized in the coarse Corine Land Cover layer and were filtered out. A similar problem occurred with the map featuring current settlements and the road network (except highways) which was used to calculate accessibility and isolation for the time of collectivization. Since the current road network (except highways) is literally based on the old road system, and the distribution of settlements has not changed substantially, we believe that the use of the new map would not significantly influence the isolation calculation.

We analyzed only four geographical factors, which we hypothesized to be the most significant for TAL persistence in a process of agriculture collectivization. It appears that the four predictor variables explain the persistence of traditional orchards and arable fields sufficiently, since the misclassification rates (ratio of misclassified area to the total classified area) were low. In the case of grasslands, the total misclassification rates were low as well, but this was mainly caused by an unequal number of collectivized and non-collectivized fields. Only 38 % of traditional grasslands were classified correctly. Since the management of collectivized and non-collectivized grasslands is relatively similar and is not as intensive as in the case of arable land, we may, therefore, conclude that geographic conditions did not play an important role in collectivization. In the case of vineyards, the role of analyzed geographical factors was influential, but there were other factors that may have played significant roles as well. These include economic factors (Strijker 2005; Solymosi 2011; Widgren 2012), changes in population density and age structure (Bruns et al. 2000; Petrovič 2006; Elbakidze and Angelstam 2007; Rescia et al. 2012), historical land use (Deckers et al. 2005; Sklenicka et al. 2009), cultural differences (Solymosi 2011), education level and willingness for innovation (Bignal and McCracken 2000; Pinto-Correia and Breman 2008), as well as other factors, or causes and conditions of landscape evolution (Zarina 2010), that played a role on a local scale.

Even though the study of landscape persistence is desirable (Bürgi et al. 2004), there are only few studies that have analyzed the persistence of traditional agricultural landscapes. According to a review by Solymosi (2011), there are three main preconditions determining the existence of traditional cultural landscape hotspots: (1) isolation (in geographic, economic, infrastructural, political and cultural terms) (2) a geographical setting which is difficult for agriculture and (3) ethnic or social differences from the national mainstream. In case of Slovakia, we found the geographical settings for agriculture (slope and fertility) to be more important than isolation. While we did not analyze ethnic or social differences, it is possible they played a role, especially in the case of vineyards, since wine making has a long tradition and is part of local culture and identity in particular localities.

In this study, we have analyzed the persistence of TAL at the time of collectivization. After the transition to an open-market economy, landscape dynamics have changed completely and additional factors now play important roles. As TAL are vanishing rapidly, there is a great need to find a sustainable approach to improve their ability to survive the pressure of globalization. More studies regarding TAL dynamics and resilience, such as Hresko et al. (2010), Lieskovský et al. (2013), Mojses and Petrovič (2013), will help to design the policy rules to keep these landscapes preserved and vital.

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