Open Geosci. 2015; 7:888–896 DE GRUYTER OPEN

Research Article Open Access

Matej Masný* and Ľubica Zaušková

Multi-temporal analysis of an agricultural landscape transformation and abandonment (Ľubietová, Central Slovakia)

DOI 10.1515/geo-2015-0055

Received January 22, 2015; accepted April 22, 2015

Abstract: Socio-political changes in the countries of Eastern and Central Europe in the era of socialism had significant effects on agricultural landscape. Collectivisation (1950 - 1970) lost almost all of traditional agricultural landscapes. On the other hand, the phenomenon of agricultural abandonment started to be significant after 1989. In the model area (part of The Poľana Biosphere Reserve) these two processes that formed the agricultural landscape structure were analysed. The analyses were carried out using orthophotos that represented the landscape structure in 1949, 1986 and 2006. It was found that almost complete extinction of the traditional agricultural landscape represented by a mosaic of narrow fields and permanent grasslands occurred during the period. At the same time, increasing trend of abandonment processes was observed. In 2006, non-forest woody vegetation covered 48% of agricultural land. Natural reforestation as the final stage of agricultural abandonment extended to 46% on the former agricultural land in 2006. Abandonment processes were the most significant already in the period of socialist agriculture. To describe the changes, landscape metrics such as Number of patches (NP), Mean patch size (MPS), Patch size standard deviation (PSSD) and Mean shape index (MSI) were used.

Keywords: land-use change; traditional agricultural landscape; landscape metrics; agricultural abandonment; UNESCO Biosphere reserve

1 Introduction

In the process of transformation of traditional landscapes in most post-socialist countries, crucial role was played by collectivisation of agriculture [1–4]. Collectivisation was a politically driven process, based on the socialist idea of common property. In Slovakia this process occurred mainly in 1950 – 1970 [5] and brought eminent changes to agricultural landscape structure. However, agricultural land was not completely nationalised in Slovakia as it used to be in former Soviet Union countries. Most of the traditional farming forms were transformed into large-scale fields [5].

Traditional land-use includes obsolete practices and techniques that are not part of modern agriculture [6]. Most forms of traditional land-use are typically of low inputs and relatively low output per hectare. They offer many environmental services, such as high biodiversity support, preservation and revitalisation of the original soil functions. Their cultural value is also very significant [7, 8]. Traditional agricultural landscapes (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 collectivisation. They are significant as unique islands of species-rich plant and animal communities that have been part of continuous evolution over centuries [9, 10]. Small remnants of TAL are surrounded by intensive farmland or forest and these are becoming rare and highly valuable [11]. However, these areas are currently not subject to special protection and trends in declining management and abandonment are quite apparent [10].

The end of socialist agriculture after 1989 and transition from centralised to market-oriented economy brought other considerable changes to agricultural land-use. In this period agricultural cooperatives started to be transformed and the market started to be liberalised (transformation period). This led to a decrease in agricultural production and often also to rural migration. [12, 13]. In many post-socialist countries agricultural land abandonment began to dominate remarkably [12, 14, 15]. Abandonment is typical of marginal and mountain areas, in Common Agricultural Policy of the European Union defined as the less favoured areas [16]. In the territory of Slovakia, we can also find an abandoned farmland in lowlands (especially vineyards) [17]. Abandonment represents an opposite process of agriculture intensification [18]. Together with land-use intensification (suburbanisation,

***Corresponding Author: Matej Masný:** Matej Bel University, Banska Bystrica, Slovakia
Ľubica Zaušková: Matej Bel University, Banska Bystrica, Slovakia

industrial parks and traffic infrastructure construction), agriculture land abandonment belongs to main trends of Slovak landscape transformation in the last decade [19]. It has a strong, mostly negative environmental and socioeconomic influence. Reforestation of an abandoned land can connect the divided fragments of a forest and change its soil-hydric relations [20]. It causes loss of biodiversity in these areas and higher pressure on the remaining agricultural areas [21, 22]. The abandonment of agricultural land does not represent a completely new phenomenon. Expansion and subsequent contraction of agricultural land areas have been common since the origins of agriculture [23–25]. The change in post-socialist countries was very noticeable [13, 23, 26, 27]. However, these days the abandonment of agricultural land is increasing on a global scale [28, 29]. In predictions of European land development up to 2030, agricultural abandonment plays a crucial role (apart from local expansion and urbanisation) [30].

Disappearance of traditional forms and agricultural abandonment represent two eminent factors that have an influence especially on cultural and biological diversity of an agricultural landscape. This problem is important especially in the areas of biosphere reservations. Integrating cultural and biological diversity, especially the role of traditional knowledge in ecosystem management, is one of the main characteristics of biosphere reserves UNESCO[1].

The aim of our research was to analyse the state of areas with traditional management and to analyse abandonment of agricultural land. The analysis was focused on the situation before, during and after the period of socialist agriculture. By means of landscape metrics we evaluated development trends and the influence of these changes on a landscape structure.

2 Study area

The study area is the municipality Ľubietová that is a part of the Poľana Biosphere Reserve. The core, the buffer as well as the transition zone of the reserve partly stretches to this model area (Figure 1). The Poľana Biosphere Reserve (Central Slovakia) is significant for its predominant presence of forests. However, there are also valuable meadows and pastures – permanent grasslands (especially in the transition zone). Mountain meadows and pastures are mown and used for grazing by cattle and sheep.

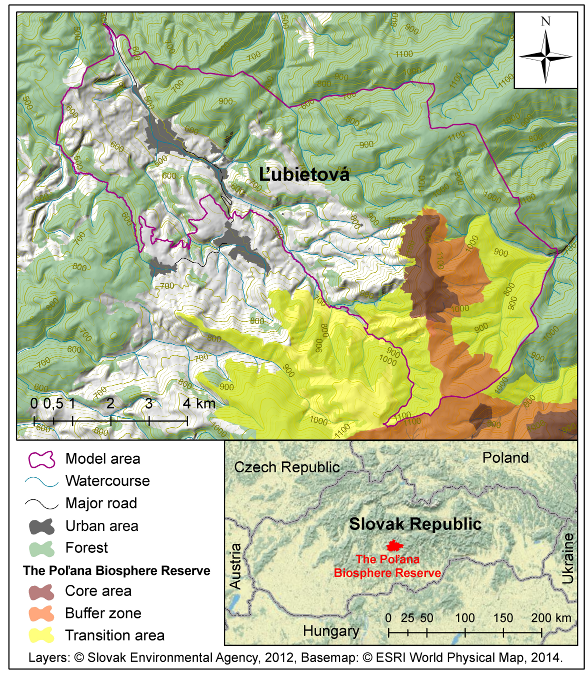

Figure 1: The Poľana Biosphere Reserve in the model area.

The modelled area covers 6104.36 ha. It is a former mining region, with 1138 inhabitants still living there[2]. From agricultural point of view, the modelled area and surrounding region are classified as a less favoured mountain area, the altitude is in range of 399 to 1272 m a.s.l, the slope conditions are relatively demanding and slopes reaches the level of 42.1°.

In the period of socialist agriculture, all collectivised land were cultivated by the Agricultural Cooperative of Strelníky. After 1989, this agricultural cooperative was transformed. A part of agricultural land (about 20%) started to be used by private farmers.

3 Data and methods

This study evaluates Ľubietová for three time periods viz. years 1949 (the state before collectivisation), 1986 (the socialist agriculture) and 2006 (the state of agricultural landscape after transformation).

For the spatial analysis, orthophotos (raster) in high resolution (1200 dpi) registered in the coordinate sys-

1 UNESCO: Main Characteristics of Biosphere reserves, 2014, http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/main-characteristics/

2 Statistical Office of the Slovak Republic: Urban and Municipal Statistics, 2014, http://app.statistics.sk/mosmis/sk/run.html

tem S-JTSK (Krovak's projection) were used. The data was provided by the Topographic Institute of Slovak Armed Forces. Using this data, categories of landscape elements were classified on a large scale (1: 3000). Considering the aim of this study and characteristics of the modelled area, we defined our own classification system of landscape elements. Three basic categories of landscape elements were selected that were sufficient to cover the landscape structure of the model area. The category concerning agricultural land was divided in more detail. The division created a basis for an analysis of traditional agricultural forms, which were defined by [9]. These traditional agricultural forms are represented by mosaic structures. At the same time, non-forest woody vegetation was classified within the agricultural land. Using remote sensing data, the main indicator of abandonment was the occurrence of woody vegetation in areas formerly used as agricultural land [28]. Following is the categorisation used for landscape elements:

1. Forests
2. Agricultural land
   (a) Mosaic of traditional agricultural land (TAL)
   (b) Large-scale arable fields
   (c) Permanent grasslands (PG)
   (d) Non-forest woody vegetation
      i. Continual spreading of registered forests
      ii. Dispersed groups of trees and shrubs
      iii. Strip ingrowths between individual areas of agricultural land (balks)
      iv. Ingrowths in watercourse lines
      v. Ingrowths in road lines
3. Urban areas and strengthened roads

For mapping, auxiliary data was used. It was a polygonal layer of registered forests from National Forest Centre. These data served especially for the differentiation of forests and continually spreading non-forest vegetation. The authors created vector layers of these landscape elements in ArcGIS 10.2 (ESRI) environment and we processed them in three stages.

At the first stage, the spatial representation of three basic landscape element categories was evaluated. The evaluation for each period was carried out.

At the second stage, the acquired data on agricultural land and non-forest woody vegetation was analysed in more detail on the basis of landscape metrics. Most of them are based on mathematical or statistical approaches. Principles of landscape metrics were defined in several relevant works [31–36] and applied in studies of different regions [37–39]. For this research six indeces have been chosen that are focused on spatial composition of agricultural land and non-forest woody vegetation:

- Total Area (TA) – equals the total area of the landscape in hectares. It serves especially as a basis for other computation.
- Class Area (CA) – is a measure of landscape composition; specifically how much of the landscape consists of one particular patch type (in hectares).
- Number of Patches (NP) – represents number of individual patches (polygons) of landscape elements. Increases or decreases in landscape heterogeneity.
- Mean Patch Size (MPS) – represents average patch size. Decrease of this value points on fragmentation of landscape mosaic.
- Patch Size Standard Deviation (PSSD) – equals the square root of the sum of the squared deviations of each patch area from the mean patch size. When PSSD = 0, all patches in the landscape are of the same size, or there is only one patch of this class (i.e. there is no variability in patch size).
- Mean Shape Index (MSI) – represents a shape complexity. MSI is equal to 1 when all patches are circular (for polygons) and it increases (without any limit) with an increasing patch shape irregularity.

For calculation of landscape metrics we used an extension of ArcGIS (ESRI) software - Patch Analyst 5 (Centre for Northern Forest Ecosystem Research).

At the last stage, the reforestation of the model area was analysed. According to the definitions of the forest by the Food and Agriculture Organization of the United Nations (FAO)[3], all the delimited polygons were divided into two basic categories. First category was represented by areas defined as the forest; the second category included other woody vegetation (groups of trees and shrubs).

4 Results and discussion

4.1 Landscape structure

Evaluation of the area of basic landscape elements pointed on relatively little changes (Table 1). According to [40] a similar scenario can be also seen in the model area of Eastern Germany. In all categories there were changes espe-

3 Food and Agriculture Organization of the United Nations, Forest Resources Assessment Programme, Working paper 144/E - Terms and Definitions. Rome, Forestry Department of FAO, 2010, 27.

Table 1: Presence of basic landscape element categories.

	Forest		Urban areas and strengthened roads		Agricultural land		Total	
	ha	%	ha	%	ha	%	ha	%
1949	4036.57	66.13	99.22	1.63	1968.57	32.25	6104.36	100
1986	4100.51	67.17	137.19	2.25	1866.66	30.58	6104.36	100
2006	4104.13	67.23	137.26	2.25	1862.97	30.52	6104.36	100
Difference '49 -'86	63.94	1.05	26.93	0.62	-101.91	-1.67	-	-
Difference '86 - '06	3.62	0.06	0.07	0	-3.69	-0.06	-	-
Difference '49 - '06	67.56	1.11	27	0.62	-105.6	-1.73	-	-

cially in the period of 1949 – 1986. In the landscape structure of all periods, forests are predominant. Their presence increased by 1.11% (67.56 ha) during the observation periods. On the contrary, agricultural land decreased by 1.73% (105.60 ha). The presence of urban areas and roads changed only slightly.

4.2 Forms of agricultural land-use

After application of a more detailed division a relatively considerable dynamics of changes within the agricultural land in accord with [40] was observed. Within the modelled area, elements of traditional agricultural land (TAL) are represented by narrow-striped mosaic of permanent grasslands and arable fields. It was found that the mosaic of TAL and permanent grassland formed the only form of agricultural land-use in 1949 (before collectivisation). Large-scale arable fields were not in existence at all (Figure 2). Transformation into large-scale arable fields or permanent grasslands started in the following years. It confirms the findings [5, 8, 40, 41] about an influence of collectivisation into traditional agricultural forms in Slovakia. The spatial structure of agricultural land-use is expressed by means of landscape metrics in Table 2. According to our findings, traditional mosaic forms formed 17.13% of agricultural land in 1949 (CA). It equals 337.30 ha. In the following period their representation decreased up to 0.87%. It is connected with a noticeable change of polygons number (NP) and their average size (MPS). According to indexes PSSD and MSI the polygons of traditional mosaic forms had more similar area and more regular shape in 1986. A trend of decreasing area was preserved for year 2006 but only to a minimal extent. All the indexes achieved a very moderate decrease. Representation of TAL decreased to the level of 0.82% that is connected with another decrease in the number of patches (NP). In accord with [40] it can be stated that the extinction of TAL means the decrease of spatial heterogeneity on cultivated land.

A similar type of TAL is also typical for another part of the Poľana Biosphere Reserve, e. g. Hriňová, where TAL creates up to 50.99% of the agricultural land. We can also find it in other parts of Slovakia, e.g. in Liptovská Teplička (Low Tatra Mts.). There it represents 20.97% of agricultural land [11]. However, such high levels of TAL are only isolated cases. In general, low representation of TAL is typical for present agricultural landscape in Slovakia. According to [9] these structures cover together 42085 ha, what represents 0.9 % of the entire Slovakia.

Large-scale arable fields appear only during and after the period of collectivisation i.e. 1949. In 1986 it amounted to 8.92% (166.43 ha) of the whole agricultural land area in Ľubietová. From 1986 to 2006, it showed a decreasing trend. However, the average size of a patch (MPS) has increased. This implies that smaller patches disappeared and at the same time, the differences in area of individual patches (PSSD) as well as the irregularity of their shapes (MSI) increased.

Permanent grasslands have the biggest proportion in agricultural land in each period. Management of traditional and collectivised permanent grasslands is similar [5]. At orthophoto it is practically not possible to distinguish between them. In this respect, collectivisation does not represent a major factor. Also in this category it is possible to observe a decreasing trend of the area representation (CA) from 61.84% (1217.39 ha) in 1949 up to 42.82% (797.79 ha) in 2006, the decrease being more obvious between 1949 and 1986. In this period the number of patches (NP) that had similar area (PSSD) and more regular shape (MSI) was increasing. Thus areas of permanent grasslands are relatively fragmented. On the contrary, in the following period their number decreased and average size (MPS) slightly increased. The patches had similar area (PSSD), however, their shape was more irregular (MSI). All these point towards the disappearance of smaller patches of permanent grasslands. Thus patches size criterion plays an important role in the process of abandonment. It is in

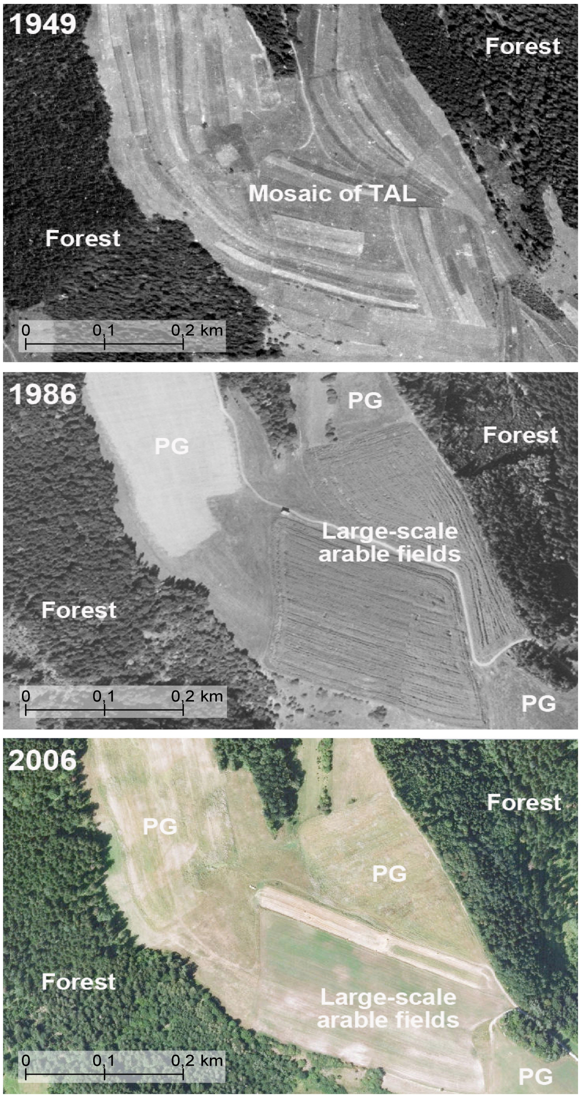

Figure 2: Illustration of an agricultural land-use transformation at orthophoto.

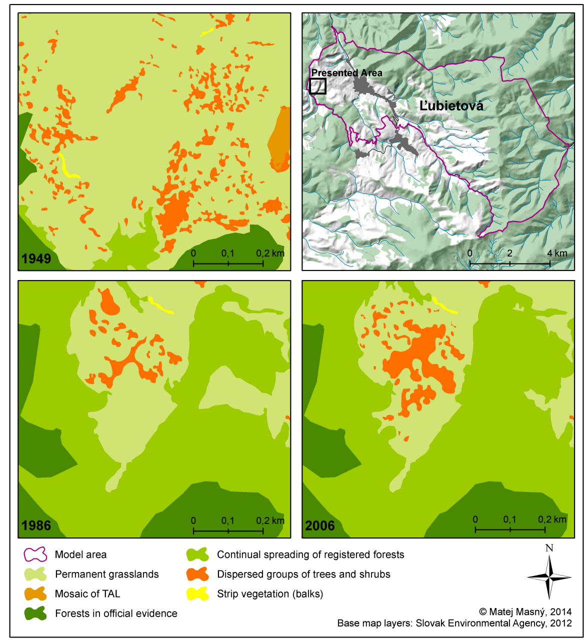

Figure 3: Illustration of spatial changes of landscape elements in the model area.

agreement with [42], who defined a small size of agricultural areas as one of the main risk factors of abandonment.

4.3 Non-forest woody vegetation

The changes mentioned above are especially influenced by the presence of non-forest woody vegetation that is significantly increasing. In the study area, there are two categories of non-forest woody vegetation that are mostly present. These are continual spreading of registered forests and dispersed groups of trees and shrubs. The values are shown in Table 3. In 1949, groups of trees and shrubs dominated in non-forest vegetation and they covered 11% of agricultural land (CA). There was a high number of patches (NP) with an average size (MPS) of only 0.12 ha that had an eminent influence on the higher level of agricultural land heterogeneity (Figure 3). In the following period this category decreased, however, the index MPS slightly increased. It points out the elimination of smaller patches for reason of liquidation of agricultural land mosaic structures and the connection of patches (collectivisation). This process is confirmed also by the decrease in balks (linear elements) by nearly a half during this period. In accord with [40], it can be explained by the agricultural intensification that was accompanied by the formation of large-scale arable fields. In 2006, a moderate increase in dispersed groups of trees and shrub areas was observed, with higher increase in number of patches (NP) and lower average size (MPS). It points to the new spreading process of patches of non-forest woody vegetation and to an increase in heterogeneity (Figure 3).

Later the increase in land heterogeneity leads to its final homogenisation. As a result of non-forest woody vegetation spreading, biotopes are disappearing [14]. Land vegetation is increasing; however, species richness is decreasing [40].

Continual spreading of registered forests formed the second most numerous category of non-forest woody vegetation in 1949. They covered 8.95% (176.23 ha). However, in the following period this representation increased dramatically to 35.56% together with an increase in number of patches (NP) and differences in their sizes (PSSD). The

Table 2: Quantification of agricultural land-use forms by landscape metrics.

Year	Landscape element	TA (ha)[4]	CA (ha)	CA (%)[5]	NP	MPS (ha)	PSSD	MSI
1949	Mosaic of TAL	1968.57	337.3	17.13	46	7.33	11.78	2.12
	Permanent grasslands	1968.57	1217.39	61.84	146	8.34	50.13	3.16
	Large-scale arable fields	1968.57	0	0	0	-	-	-
1986	Mosaic of TAL	1866.66	16.27	0.87	11	1.48	1.07	1.62
	Permanent grasslands	1866.66	891.79	47.77	222	4.02	18.66	2.39
	Large-scale arable fields	1866.66	166.43	8.92	23	7.24	8.04	1.4
2006	Mosaic of TAL	1862.97	15.36	0.82	8	1.92	0.97	1.58
	Permanent grasslands	1862.97	797.79	42.82	198	4.03	18.19	2.5
	Large-scale arable fields	1862.97	150.38	8.07	19	7.91	9.55	1.45

[4] total area of agricultural land including non-forest woody vegetation
[5] percentage of the whole agricultural land area

same trend continued also in 1986 up to 2006, however, at a moderate pace. The MPS value decreased. This points out the new patches that are of smaller size. It is similar to the category of dispersed groups of trees and shrubs. Complete landscape metrics values of other non-forest woody vegetation elements are presented in Table 3.

An eminent increase of non-forest woody vegetation appeared already in the period of socialist agriculture. A similar scenario was observed by [14] in regions of Latvia. There can be several reasons of these processes such as economic factors [43], demographic factors [44] and geomorphological factors [45]. The influence of collectivisation on the abandonment processes are confirmed also by the findings from Poland, where the abandonment level was two-times higher on the collectivised land than on the areas that remained as private property [46]. In the model area, demographic factors, especially decrease in the number of inhabitants, may also play an important role. From 1949 to 2006, the number of inhabitants decreased of 733 (42.2%). The relationship between the decreasing number of inhabitants and the process of agricultural land abandonment was also confirmed in the East Carpathian Biosphere Reserve [47].

4.4 Area reforestation

The last analysis shows the eminent increase in reforestation in the model area (Table 4). Woody vegetation of forest character on the agricultural land increased to 40.11% of agricultural land especially in the period 1949-1986. However, already in 1949 this category covered only 16.11% of agricultural land. After 1986 this trend continued with an increase of 5.82%. In comparison with the research realised in the East Carpathian Biosphere Reserve (it reaches three countries: Slovakia, Poland and Ukraine) [48], it is a relatively small increase. In the period of 1986 - 2000 [48] noticed a reforestation increase to the level of 20.2% in the Slovak part of the East Carpathian Biosphere Reserve.

The findings on reforestation increase are in accordance with [49]. According to them, the permanent reforestation increase in the area of the Poľana Biosphere Reserve was occurring already since 1900.

Woody vegetation of a forest character covered almost 46% (855.70 ha) of all agricultural land in 2006. Thus the forest area (Table 1) increased by 20.85 %. In the entire Slovakia, woody vegetation of a forest character covers 273 000 ha of the agricultural land; which means that the area of forest increased by 5.5 % [50].

Reforestation in the modelled area is much more intensive comparing to the trend in Slovakia. Decrease in the presence of other woody vegetation category is caused by the transformation of these patches to woody vegetation of a forest character.

5 Conclusions

Our results confirm the findings of [2, 3, 51]. These prove the disappearance of traditional agricultural forms and also the eminent changes of landscape structure in the period of collectivisation. At the same time, our findings presented underline the seriousness of the phenomenon of agricultural land abandonment [19, 41, 52–54] in the territory of Slovakia. However, the results of the research point out the problem in the area that should be an excellent locality of harmony between human interests and biodiversity conservation. The abandonment process there exceeds the time frame of a transition from social-

Table 3: Quantification of non-forest woody vegetation by landscape metrics.

Year	Landscape element	TA (ha)[6]	CA (ha)	CA (%)[7]	NP	MPS (ha)	PSSD	MSI
1949	Continual spreading of registered forests	1968.57	176.23	8.95	90	1.96	7.51	1.94
	Dispersed groups of trees and shrubs	1968.57	215.68	10.96	1765	0.12	1.08	1.47
	Strip ingrowths between individual areas of agricultural land (balks)	1968.57	8.09	0.41	97	0.08	0.14	2.42
	Ingrowths in water-course lines	1968.57	13.62	0.69	58	0.23	0.37	2.23
	Ingrowths in road lines	1968.57	0.26	0.01	4	0.06	0.03	1.91
	Total	-	413.88	21.02	2014	-	-	-
1986	Continual spreading of registered forests	1866.66	663.73	35.56	209	3.18	14.5	2.52
	Dispersed groups of trees and shrubs	1866.66	110.82	5.94	717	0.15	0.81	1.45
	Strip ingrowths between individual areas of agricultural land (balks)	1866.66	4.29	0.23	44	0.1	0.07	2.21
	Ingrowths in water-course lines	1866.66	10.51	0.56	10	1.05	0.91	3.03
	Ingrowths in road lines	1866.66	2.83	0.15	31	0.09	0.09	2
	Total	-	792.18	42.44	1011	-	-	-
2006	Continual spreading of registered forests	1862.97	765.97	41.12	260	2.95	19.93	2.51
Dispersed groups of trees and shrubs	1862.97	115.26	6.19	958	0.12	1.22	1.37	
Strip ingrowths between individual areas of agricultural land (balks)	1862.97	4.19	0.23	40	0.1	0.07	2.21	
Ingrowths in water-course lines	1862.97	10.75	0.58	6	1.79	1.7	3.3	
Ingrowths in road lines	1862.97	3.26	0.18	46	0.07	0.09	1.94	
Total	-	899.44	48.28	1310	-	-	-	

[6] total area of agricultural land including non-forest woody vegetation

[7] percentage of the whole agricultural land area

Table 4: Overview of a reforestation on agricultural land.

Year	Woody vegetation of a forest character		Other woody vegetation	
	ha	%[8]	ha	%[8]
1949	317.2	16.11	96.68	4.91
1986	748.71	40.11	43.47	2.33
2006	855.7	45.93	43.73	2.35
Difference ’49 -’86	431.51	24	-53.21	-2.58
Difference ’86 - ’06	106.99	5.82	0.26	0.02
Difference ’49 - ’06	538.5	29.82	-52.95	-2.56

[8] percentage of the whole agricultural land area

ist agriculture to market economy. The actual terrain exploration proves continuous succession spreading on the abandoned agricultural areas. These were not revitalised. The abandonment process in other areas of Ľubietová is currently not in progress.

References

[1] Bell S., Nikodemus O., Penēze Z., Krūze I., Management of cultural landscapes: what does this mean in the former Soviet Union? A case study from Latvia. Landscape Research, 2009, 34, 425-455.

[2] Palang H., Time boundaries and landscape change: collective farms 1947-1994. European Countryside, 2010, 2, 169-181.

[3] Rohring A., Gailing L., Linking path dependency and resilience for the analysis of landscape development. In: Plieninger T, Bieling C (Eds.), Resilience and the cultural landscape: understanding and managing change in humanshaped environments. Cambridge University Press, New York, 2012, 146-163.

[4] Fischer J., Hartel T., Kuemmerle T., Conservation policy in traditional farming landscapes. Conserv. Lett., 2012, 5, 167-175.

[5] Lieskovský J., Kenderessy P., Špuleroá J., Lieskovský T., Koleda P., Kienast F., Gimmi U., Factors affecting the persistence of traditional agricultural landscapes in Slovakia during the collectivization of agriculture. Landscape Ecol., 2014, 29, 867-877.

[6] Green B.H., Vos W., Managing old landscapes and making new ones. In: Green B. H., Vos W. (Eds.), Threatened Landscapes: Conserving Cultural Landscapes. Spon Press, London, New York, 2001, 139-149.

[7] Plieninger T., Höchtl F., Spek, T., Traditional land-use and nature conservation in European rural landscapes. Environ. Sci. Policy, 2006, 9, 317-321.

[8] Krnáčová Z., Hreško J., Kanka R., Boltižiar M., The Evaluation of Ecological Factors Affecting Environmental Functions of the Soils in Area of Traditional Agrarioan Structures. Ekologia, 2013, 32, 248-261.

[9] Špulerová J., Dobrovodská M., Lieskovský J., Bača A., Halabuk A., Kohút F. *et al.*, Inventory and classification of historical structures of the agricultural landscape in Slovakia. Ekologia, 2011, 30, 157-170.

[10] Špulerová J., Dobrovodská M., Izakovičová Z., Kenderessy P., Petrovič F., Štefunková D. Developing strategy for the protection of traditional agricultural landscapes based on a complex landscape-ecological evaluation (the case study of mountain landscape in Slovakia). Morav. Geogr. Rep. , 2013, 21, 15-26.

[11] Štefunková D., Špulerová J., Dobrovodská M., Mojses M., Petrovič F., Traditional agricultural landscapes - a model of detailed land use mapping. J. Landscape Ecol., 2013, 11, 1-21.

[12] Müller D., Kuemmerle T., Rusu M., Griffiths P., Lost in transition: determinants of post-socialist cropland abandonment in Romania. J. Land Use Sci., 2009, 4, 109-129.

[13] Müller D., Munroe D.K., Changing Rural Landscapes in Albania: Cropland Abandonment and Forest Clearing in the Postsocialist Transition. Ann. Assoc. Am. Geogr., 2008, 98, 855-76.

[14] Nikodemus O., Bell S., Grine I., Liepins I., The impact of economic, social and political factors on the landscape structure of the Vidzeme Uplands in Latvia. Landscape Urban Plan., 2005, 70, 57-67.

[15] Müller D., Sikor T., Effects of postsocialist reforms on landcover and land use in South-eastern Albania. Appl. Geogr., 2006, 26, 175-91.

[16] Haddaway N.R., Styles D., Pullin A.S., Environmental impacts of farm land abandonment in high altitude/mountain regions: a systematic map of the evidence. Environmental Evidence, 2014, 3(17), doi:10.1186/2047-2382-3-17.

[17] Lieskovský J., Kanka R., Bezák P., Štefunková D., Petrovič F., Dobrovodská M., Driving forces behind vineyard abandonment in Slovakia following the move to a market-oriented economy. Land Use Policy, 2013, 32, 356-365.

[18] MacDonald D., Crabtree J.R., Wiesinger G., Dax T., Stamou N., Fleury P. *et al.* Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response. Journal of Environmental Management, 2000, 59, 47-69.

[19] Olah B., Boltižiar M., Gallay I., Transformation of the Slovak Cultural Landscape since the 18th Cent. and its Recent Trends. J. Landscape Ecol., 2009, 2, 41-55.

[20] Smith J., Smith P., Wattenbach M., Gottschalk P., Romanenkov V. A., Shevtsova L. K., et al., Projected changes in the organic carbon stocks of cropland mineral soils of European Russia and the Ukraine, 1990-1070. Glob. Chang. Biol., 2007, 13, 342-356

[21] Baur B., Cremene C., Groza G., Rakosy L., Schileyko A.A., Baur A. *et al.*, Effects of abandonment of subalpine hay meadows on plant and invertebrate diversity in Transylvania, Romania. Biol. Cons., 2006, 132, 261-273.

[22] Smelansky I., Biodiversity of agricultural lands in Russia: Current state and trends. IUCN - The World Conservation, Moscow, IUCN - The World Conservation Union, 2003, 52.
[23] Tullus T., Tullus A., Roosaluste E., Kaasik A., Lutter R., Tullus H., Understorey vegetation in young naturally regenerated and planted birch (Betula spp.) stands on abandoned agricultural land. New Forests, 2013, 44, 591-611.
[24] Ramankutty N., Foley J.A., Estimating historical changes in global land cover: Croplands from 1700 to 1992. Global Biochem. Cy., 1992, 13, 997-1027.
[25] Yeloff D., Geel B. van, Abandonment of farmland and vegetation succession following the Eurasian plague pandemic of AD 1347 - 52. J. Biogeogr., 2007, 34, 575-582.
[26] Henebry G.M., Carbon in idle croplands. Nature, 2009, 457, 1089-1090.
[27] Kuemmerle T., Oloffson P., Chaskovskyy O., Baumann M., Ostapowicz K., Woodcock C.E. *et al.*, Post-Soviet farmland abandonment, forest recovery, and carbon sequestration in western Ukraine. Glob. Chang. Biol., 2011, 17, 1335-1349.
[28] Alcantara C., Kuemmerle T., Prishchepov A.V., Radeloff, V.C., Mapping abandoned agriculture with multi-temporal MODIS satellite data. Remote Sens. Environ., 2012, 124, 334-347.
[29] Cramer V.A., Hobbs R.J., Standish R.J., What's new about old fields? Land abandonment and ecosystem assembly. Trends Ecol. Evol., 2008, 23, 104-112.
[30] Verburg P.H., Berkel D.B. van, Doorn A.M. van, Eupen M. van, Heiligenberg H.A.R.M. van den, Trajectories of land use change in Europe: a model-based exploration of rural futures. Landscape Ecol., 2010, 25, 217-232.
[31] Forman R.T.T., Godron M., Patches and structural components for a Landscape Ecology. Bioscience, 1981, 31, 733-740.
[32] Gustafson E.J., Parker G., Relationships between landcover proportion and indices of landscapespatial pattern. Landscape Ecol., 1992, 7, 101-110.
[33] McGarigal K., Marks B., FRAGSTATS, spatial pattern analysis program for quantifying landscape structure. General Technical Report. USDA, Forest Service, Pacific. Northwest Research Station, Portland, 1995.
[34] Cushman S.A., McGarigal K., Neel M.C., Parsimony in landscape metrics: strength, universality, and consistency. Ecol. Indic., 2008, 8, 691-703.
[35] McGarigal K., Cushman S.A., Neel M.C., Ene E., FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Massachusertts, 2002
[36] Peng J., Wang Y., Zhang Y., Wua J., Li W., Li Y., Evaluating the effectiveness of landscape metrics in quantifying spatial patterns. Ecol. Indic., 2010, 10, 217-223.
[37] Klaučo M., Gregorová B., Stankov M., Marković V., Lemenkova P., Determination of ecological significance based on geostatistical assessment: a case study from the Slovak Natura 2000 protected area. Centr. Eur. J. Geosci., 2013, 5, 28-42.
[38] Schindler S., Poirazidis K., Wrbka, T., Towards a core set of landscape metrics for biodiversity assessments: a case study from Dadia National Park, Greece. Ecol. Indic., 2007, 8, 502-514.
[39] Baran-Zgłobicka B., Zgłobicki W., Mosaic landscapes of SE Poland: should we preserve them? Agrofor. Syst., 2012, 85, 351-365.
[40] Baessler C., Klotz S., Effects of changes in agricultural land-use on landscape structure and arable weed vegetation over the last 50 years. Agric. Ecosyst. Environ., 2006, 115, 43-50.
[41] Fazekašová D., Boltižiar M., Bobuľská L., Kotorová D., Hecl J., Krnáčová Z., Development of Soil Parameters and Changing Landscape Structure in Conditions of Cold Mountain Climate (Case Study Liptovská Teplička). Ekologia, 2013, 32, 197-210.
[42] Pointereau P., Coulon F., Girard P., Lambotte M., Stuczynski T., Sánchez Ortega V. *et al.*, Analysis of farmland abandonment and the extent and location of agricultural areas that are actually abandoned or are in risk to be abandoned. JRC Scientific and Technical Reports (EUR 23411 EN), Publications Office of the European Union, Luxembourg, 2008.
[43] Widgren M., Resilience thinking versus political ecology: understanding the dynamics of small-scale, labour-intensive farming landscapes. In: Plieninger T., Bieling C. (Eds.), Resilience and the cultural landscape: understanding and managing change in humanshaped environments. Cambridge University Press, New York, 2012, 95-110.
[44] Elbakidze M., Angelstam P., Implementing sustainable forest management in Ukraine's Carpathian Mountains: the role of traditional village systems. For. Ecol. Manage., 2007, 249, 28-38.
[45] Burgi M., Hersperger A.M., Schneeberger N., Driving forces of landscape change-current and new directions. Landscape Ecol., 2004, 19, 857-868.
[46] Keenleyside C., Tucker G.M., Farmland Abandonment in the EU: an Assessment of Trends and Prospects. Report prepared for WWF, Institute for European Environmental Policy, London, 2010.
[47] Olah B., Boltižiar M., Petrovič F., Land use changes' relation to georelief and distance in the East Carphatians Biosphere Reserve. Ekologia, 2006, 25, 68-81.
[48] Kuemmerle T., Hostert P., Radeloff V. C., Van der Linden S., Perzanowski K., Kruhlov I., Cross-border Comparison of Postsocialist Farmland Abandonment in the Carpathians. Ecosystems, 2008, 11, 614-628
[49] Olah B., Boltižiar M., Land Use Changes within the Slovak Biosphere Reserves' Zones. Ekologia, 2009, 28, 127-142.
[50] Zaušková Ľ., Midriak R., Šebeň V., „Biele plochy“ z pohľadu pustnutia kultúrnej poľnohospodárskej krajiny [„White areas“ (forest on non-forest land) from the viewpoint of abandoning agricultural landscape], Forestry Journal, 2012, 58, 121-128. (in Slovak with English summary)
[51] Izakovičová Z., Oszlányi J., The landscape of Slovakia, its nature and transformations. In: Elmar C. (Ed.), In lost landscapes: reflections from Central European Border Regions. Regional Development Agency Mura, Murska Sobota, 2012, 115-131.
[52] Midriak R., Zaušková Ľ., Sabo P., Gallay I., Gallayová Z., Lepeška T. *et al.*, Spustnuté pôdy a pustnutie krajiny Slovenska [Waste lands and abandonning agricultural landscape of Slovakia], Matej Bel University, Banská Bystrica, Slovakia, 2011, 401.
[53] Munteanu C., Kuemmerle T., Boltiziar M. *et al.*, Forest and agricultural land change in the Carpathian region - a metaanalysis of longterm patterns and drivers of change. Land Use Policy, 2014, 38, 685-697.
[54] Gerard F., Petit S., Smith G. *et al.*, Land cover change in Europe between 1950 and 2000 determined employing aerial photography. Prog. Phys. Geog., 2010, 34, 183-205.