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Petr Sklenicka
Kristina Molnarova
Elizabeth Brabec, *University of Massachusetts Amherst*
Peter Kumble, *University of Massachusetts Amherst*
Blanka Pittnerova, et al.

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Remnants of medieval field patterns in the Czech Republic: Analysis of driving forces behind their disappearance with special attention to the role of hedgerows

Petr Sklenicka [a,*], Kristina Molnarova [a], Elizabeth Brabec [b], Peter Kumble [b], Blanka Pittnerova [a], Katerina Pixova [a], Miroslav Salek [c]

[a] Department of Land Use and Improvement, Faculty of Environmental Science, Czech University of Life Sciences, Prague, Czech Republic
[b] Department of Landscape Architecture and Regional Planning, College of Natural Resources and the Environment, University of Massachusetts, Amherst, MA, USA
[c] Department of Ecology and Environment, Faculty of Environmental Science, Czech University of Life Sciences, Prague 6 – Suchdol 165 21, Czech Republic

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ABSTRACT

Remnants of medieval field patterns, called "pluzina" in the Czech Republic, are valuable historical landscapes, similar in character to the bocage landscapes typical for some countries in Western Europe. The original historical pattern of fields and meadows has persisted due to the stabilizing network of hedgerows. As in other countries, the development of these medieval fields in recent decades for intensive agriculture or residential purposes has led to their dramatic decline.

This study evaluates the dynamics of the development of medieval pluzina hedgerows during the second half of the 20th century in the Plzen Region of the Czech Republic, using three datasets from 1840, 1950 and 2005. Between 1950 and 2005, 341 out of 483 hedgerows disappeared in the study areas, and the total length of the hedgerows decreased by 71%. At the same time, the average hedgerow width increased from 7.2 m in 1950 to 13.1 m in 2005. The study further tests the influence of three natural factors (natural soil fertility, slope gradient and aspect) and of historical (1950) and current (2005) land uses on the disappearance of hedgerows. The most significant factor that has contributed to the disappearance of hedgerows is the current land use in adjacent areas, grassland being by far the most conducive to the persistence of pluzinas. In addition, current land use has significantly influenced the hedgerow dynamics when assessed in interactions with slope gradient and with historical land use. The results of the study further show a significant influence of natural soil fertility. Our findings confirm two main trends which lead to the disappearance of medieval land use systems. Extensification of agricultural land leads to its abandonment and to afforestation of fields adjacent to the hedgerows as a result of spontaneous succession. On the other hand, intensification means that land adjacent to the hedgerow is used as arable land and gradual expansion leads to field enlargement, hedgerow removal and consequently to the disappearance of the entire medieval field patterns. The paper also discusses the principles of conservation and restoration of these valuable historical landscapes.

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1. Introduction

Well-preserved remnants of medieval field patterns represent an important artifact of cultural and historical heritage. These artifacts are important to archaeologists and historians, but the distinctive field patterns are also visually attractive landscape features. The medieval field pattern called "pluzina" in the Czech Republic can be defined as the economically useful part of the landscape belonging to the original medieval village. Pluzina includes all crop fields, meadows and pastures mutually interconnected by the system of field roads and belonging to one village (Gojda, 2000).

The character of a pluzina landscape is in many aspects comparable to the hedged field (bocage) landscapes that are well known as a symbol of some parts of Europe, e.g. Belgium (Flanders), England, Scotland, Wales, France (Brittany and Normandy) or the Irish highlands. The character of preserved pluzinas in the Czech Republic differs from that of typical bocage landscapes in some respects, especially in spatial composition. In pluzinas, long parallel plots connected to the individual farmsteads of the village prevail, with a minimum of shorter, transversal hedgerows. Another difference is the virtual absence of management of the pluzina hedgerows (Fig. 1).

The phenomenon of hedgerows or hedgerow networks has been the subject of a range of studies in other continents (e.g. Rao

* Corresponding author. Tel.: +420 224 384 352; fax: +420 234 381 848.
E-mail address: sklenicka@fzp.czu.cz (P. Sklenicka).

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Fig. 1. An aerial photograph (2006) of the typical striped pattern of unmanaged, relatively wide hedgerows of trees and shrubs, with a minimum of shorter, transversal hedgerows. Unlike the study areas, the depicted pluzina is situated in the North-East of the Czech Republic (near the town of Bruntal), as the pluzina remnants in our study areas are not sufficiently well-preserved and integrated to illustrate the original character of these field patterns.

et al., 1999; Schmucki et al., 2002; Tang et al., 2003; Wood and Stahmannn, 2004; Harvey et al., 2005). Hedgerows as linear features composed of trees and/or shrubs constitute a stabilizing network of the pluzina landscape. The historical purpose of hedgerows was to provide firewood for heating and other basic survival needs, cattle management, erosion control, and drainage. Hedgerows were also useful as permanent fences (Thoen and Lachaert, 2006), which, in Britain, were erected by landlords after the introduction of the Enclosure Acts in the 13th century (Russel, 1972; Williamson and Bellamy, 1987). Today, however, people value hedgerows especially for ecological, historical, visual, and educational purposes (Oreszczyn, 2000; Rich et al., 2000).

Hedgerows provide a habitat or food resources for a wide range of plants and animals (e.g. Green and Sears, 1994; Petit and Burel, 1998; Dover and Sparks, 2000; Hinsley and Bellamy, 2000; Maudsley, 2000; McCollin et al., 2000; Michel et al., 2006; Reif et al., 2008), including fauna that control agricultural pests (Marshall, 1988). Moreover, they are of high relevance to landscape connectivity (Forman and Baudry, 1984; Baudry et al., 2003; Molnarova, 2008) and also increase landscape heterogeneity (Hoobs, 1992; Quin and Burel, 2002), which not only provides ecological benefits but also has a positive influence on the visual quality of the landscape (Hunziker, 1995; de la Fuente de Val et al., 2006). While some authors connect the definition of hedgerows with their management, which prevents them expanding into adjacent fields (Pollard et al., 1974; Barr and Gillespie, 2000; Baudry et al., 2000), other authors admit more or less spontaneous growth (Forman and Godron, 1986; IDF, 1995).

The woody boundaries themselves are elements with high visual preferences, which enhance the aesthetic quality of rural landscapes, mainly by increasing their degree of "naturalness" and the percentage of plant cover, and by providing colour contrast (Angileri and Toccolini, 1993; Arriaza et al., 2004). An overview of the arguments for and against protecting hedges is presented by McCollin (2000).

Like pluzina landscapes, bocage landscapes and other traditional land use systems have disappeared or diminished in past decades. The reasons for this decline generally fall into two categories: land use polarization either toward extensification and land abandonment, or toward land use intensification (Plieninger et al., 2006). In addition to a general reduction in their quality, nearly 65% of hedgerows were destroyed in France due to the land consolidation process in the 20th century. 25% of linear woody elements were lost in England and Scotland from 1946 to 1974, and 14% in Ireland between 1937 and 1982 (Pointereau and Bazile, 1995; Countryside Council for Wales, 1997). Between 1984 and 1990, hedgerow length was reduced by 21% in England, by 27% in Scotland and by 25% in Wales (Barr and Gillespie, 2000). After hedgerow removal, many ecological problems arose: soil erosion; wind damage to crops and buildings; an increase in flooding; an increase in crop disease, microclimatic changes, etc. (Burel and Baudry, 1995; Merot, 1999; Kristensen and Caspersen, 2002).

Since hedgerows are landscape elements closely linked with farmed land, the authors investigating the driving forces behind hedgerows and their spatial distribution take into account not only the nature and intensity of their management (Watt and Buckley, 1994). The historical, environmental and socio-economic drivers are also investigated for their impact on the current character and the recent development of hedgerow networks. In post-socialist Central European countries, politics, employment and social pressures are seen as important factors determining changes and trends in the agricultural sector (Gross, 1996). On the other hand, in the Western European countries, the age of the farmers and the duration of farm ownership appear to influence landscape changes significantly (Kristensen et al., 2004). Thenail (2002) found that economic attributes such as production, economic levels, productivity and technical means decrease in direct proportion to the density of the bocage area. The importance of the spatial arrangement of land management units is identified by Mottet et al. (2006), when the distances of the parcels from the farmstead and their accessibility play a crucial role and co-determine the influence of other environmental and socio-economic driving forces in the local context. Sklenicka (2006) considers soil fertility and historical factors (especially the principles of inheritance) in a region to be the key factors that form the land use patterns in the Czech Republic, including those of the hedged landscapes.

In the Czech Republic, no general estimation has been made of the extent of pluzina landscape loss. In this study, the level of pluzina landscape preservation is defined as the state of its physical attributes in the presently existing spatial arrangement, including well-preserved original field patterns and the stabilizing network of woody hedgerows and systems of field roads. In this sense, the pluzina landscapes have been well-preserved only in small enclaves in a very small area of the Czech Republic. To ensure effective conservation of those landscapes still existing, it is essential to know the driving forces which affect the general development and especially the disappearance of this distinctive and valuable landscape pattern.

Therefore, the primary objective of this paper is to analyze the spatial changes in the hedgerows which form the stabilizing networks of medieval field patterns after 1950, and to investigate a set of possible driving forces behind this change. For the period from 1950 to 2005, this study determines the influence of natural conditions, such as natural soil fertility, slope gradient and aspect, on the level of preservation of the hedgerows which are crucial to the conservation of medieval pluzinas. Further, the paper assesses the influence of land use changes between 1950 and 2005 on the level of pluzina preservation. The hypothesis is that the impacts of spontaneous afforestation caused by the abandonment (extensi-

fication) or, on the other hand, of an increase in the amount of arable land leading to field enlargement and hedgerow removal (intensification), are significant drivers causing the disappearance of pluzinas. Based on our findings, some principles of pluzina conservation and restoration are defined.

2. Methods

2.1. Study areas

The study was carried out in the Plzen (Pilsen) Region (7561 km^2; 0.55 mil. inhabitants), which is one of the 14 administrative regions of the Czech Republic (Fig. 2). The region lies along the border with Bavaria (Germany). Historically, from the Middle Ages until 1945, the region was populated by ethnically mixed but linguistically distinct Czech and German people. After 1945, most ethnically German farmers were resettled to Germany, causing significant depopulation in the region.

The southwestern (frontier) parts of the region are formed by forested highlands and mountains that transition into extensively used farmlands, especially pastures. These ecologically and aesthetically valuable areas are protected by the Sumava National Park and Biospheric Reserve, and by the Sumava and Cesky Les Protected Landscape Areas. Sixty percent of the remaining (inland) area is farmland, predominantly arable. Less than a third of the land area is composed of woodland, which is fragmented and dispersed throughout the territory.

Selection of the study areas can be divided into three distinct parts. First, using aerial photographs, the entire Plzen Region was visually assessed for the presence of areas with the typical features of a hedgerow-defined pluzina landscape. Second, using historic maps of the Stable Cadastre (1840–1852) and aerial photographs from 1950, these areas were compared and contrasted with the historical field patterns. The goal was to eliminate structures whose field pattern was not of historical origin. Third, a GIS database of the final set of five study areas with remnants of pluzina landscapes was established and their attributes were categorized.

The second half of the 20th century was chosen for the study period for two reasons. First, major changes in the landscape structure occurred in Central Europe during this period (Fry and Sarlöw-Herlin, 1997; Fjellstad and Dramstad, 1999). The second reason is purely methodological, as the first set of aerial photographs available in the Czech Republic covering the whole study area was taken in the 1950s. Therefore, the 1950s is the earliest historical period in which hedgerows can be accurately assessed. Any assessment of earlier periods would have to be based on historical survey maps, which would not provide reliable measurements of hedgerow attributes, especially their widths.

It is only possible to speculate about the origin and purpose of the hedgerows which form the stabilizing network of the pluzina structure. Based on archival historic texts and images, we can conclude that these hedges were used as a source of firewood for households throughout the 19th and 20th centuries. A dendrological survey which sampled the oldest trees confirmed that all observed hedgerows were established before 1880. Based on the graphical and written records of the Stable Cadastre (1840–1852), the establishment of the hedgerows in our study areas belongs to a period before 1840. Unfortunately, there is no specific historic documentation of the existence of hedgerows before 1840. The oldest military maps of the entire area (1st Military Mapping, 1764–1768) date further back, but their scale (1:28,800) was too small to depict the relevant attributes of the landscape pattern. Therefore, it is only possible to analyze the landscape pattern development since the mid-19th century. Before this date, we can only extrapolate or make assumptions based on maps of individual estates, pictures, sketches or town portraits.

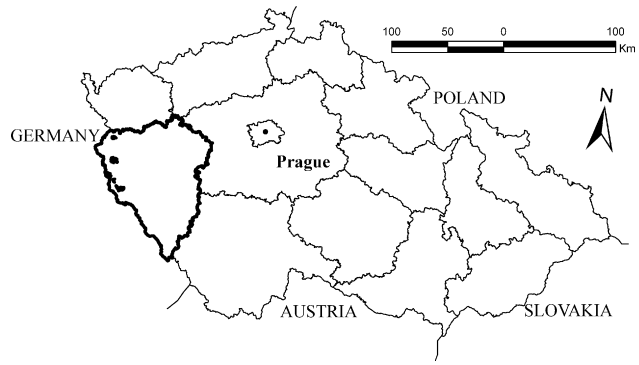

Fig. 2. Location of the study areas.

2.2. Data collection and analysis

Hedgerow width [m] proved to be the explained variable most suitable for assessing hedgerow development within this study. Firstly, it is significantly correlated with other assessed hedgerow attributes–hedgerow length and area. Secondly, its use provided easy location of control profiles for gaining data on explanatory variables in the same places where hedgerow width was measured.

Control profiles were generated for all hedgerows which were identified in the historical (1950) land use and the existence of which was confirmed in the maps of the Stable Cadastre (1840–1852). One control profile was established for each hedgerow, with the distance of the profile from the ends of the hedgerows calculated using random numbers. In these control profiles, the hedgerow width values in 1950 and 2005 were measured from 1950 aerial photographs and 2005 orthophotos. If the hedgerow had disappeared in the location of the profile, the hedgerow width in 2005 equaled zero. Values of the predictors were identified in the same profiles. The old maps of the Stable Cadastre (1840–1852; scale 1:2880) were used to verify the historical origin of the hedgerows and to estimate hedgerow length in this period. However, due to the character and the accuracy of these maps, data on hedgerow width was not calculated from them.

Explanatory variables were also identified representing natural soil fertility, slope gradient, aspect and historical and recent agricultural land uses (Table 1). Three variables, slope gradient, aspect, and natural soil fertility characterize natural characteristics. Two variables, historic land use and recent land use, represent one socio-economic characteristic in two study periods. The variables of slope gradient and slope aspect both describe morphological features of the study areas. The slope gradient values varied between 0% and 22% in the individual hedgerows, and orientations towards all directions were identified.

Natural soil fertility, comprising a complex of properties of the soil but not considering the effects of soil improvement measures, is expressed for individual soil quality units as a percentage of the most fertile unit in the Czech Republic. This relative expression of natural soil fertility was calculated for all agricultural land based on long-term testing of all 2199 soil quality units according to the yields of the main field crops (Becvarova et al., 1988). This value fluctuates between 4.86% and 100% within the Czech Republic; within our study areas, the values varied from 4.86% to 40.11%. A digitized soil map was obtained from the Soil Research Institute in Prague.

Historic land use in 1950 was established from raster aerial photographs taken in 1950. Current land use was established from

Table 1
Description of the explanatory variables used in the study.

Name	Data type	Data source
Slope gradient	Slope classes [%]	Digital elevation models
Slope aspect	Aspect categories (N, NE, E, SE, ...)	Digital elevation models
(Natural) Soil fertility	Proportion of the most fertile unit [%]	Soil quality map (vector, 1:5000)
(Historic) Land use 1950	Land use classes	Digitized aerial photograph
(Recent) Land use 2005	Land use classes	Digital orthophoto

raster orthophotos taken in 2005 and verified by field research. The following four land use classes were distinguished: grassland, arable land, forest and hedgerow.

Aiming to reduce co-linearity, we first examined whether any of the pairs of selected predictors (listed in Table 1) are inter-correlated ($r > 0.60$) and could thus be considered as estimates of a single underlying factor. However, none of them displayed correlative features and all were therefore included in the analyses.

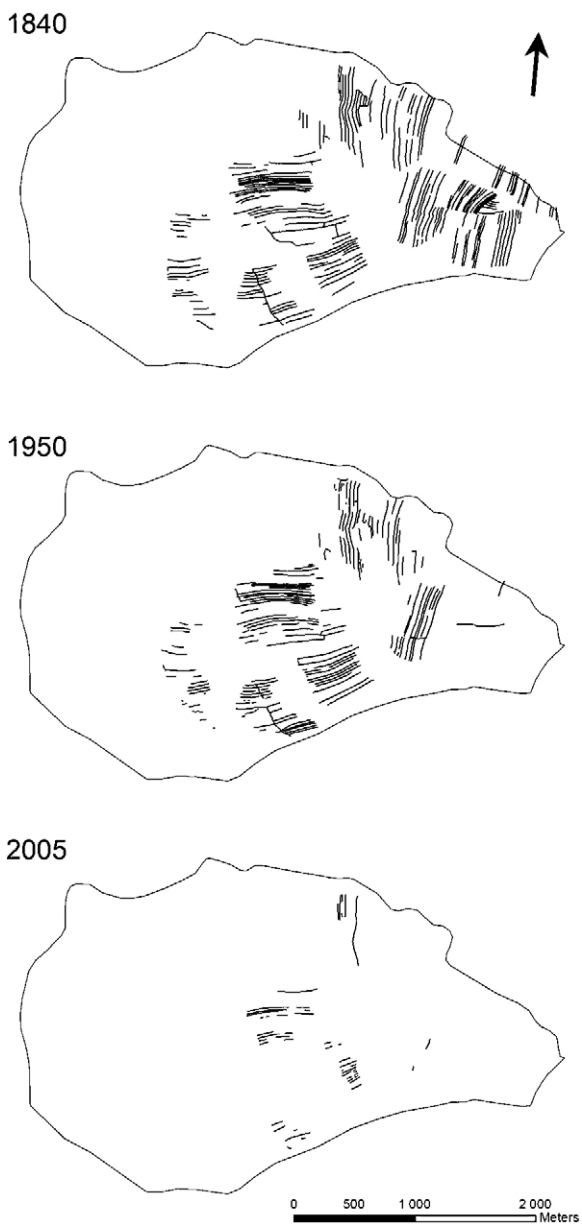

Fig. 3. Hedgerow dynamics, using one of the five study areas (Stokov) as an example.

Mixed-effect modelling was adopted to reduce the risk of spatial pseudo-replications arising from the distribution of the studied hedgerows among the five study areas potentially afflicted by undetected local drivers. Therefore, the respective study subareas (1–5) were treated as random effects in the models. We applied a generalized model with persistence/disappearance of hedgerows in 2005 as an explained variable coded as a binary response (with binomial error term and logit link). Fixed effects of the slope aspect, slope gradient, natural soil fertility, historic land use, recent land use, and their first-order interactions were examined as explanatory variables (predictors). Stepwise elimination of the terms was performed following Minimal Adequate Model (MAM) selection, starting with saturated models. A threshold of $P \leq 0.05$ was adopted as a criterion for retaining the term in the model (Crawley, 2002). The resulting levels of significance are based on Type III Sums of Squares. All procedures were performed using the MASS package of R (v. 2.20) software (R Development Core Team, 2005).

3. Results

In the five study areas, 483 hedgerows were identified in 1950 and checked against their existence in 1840 and 2005 (Fig. 3). Their total length amounted to 89.5 km, with a total area of 63.9 ha (Table 2). In 2005, 341 hedgerows had disappeared. The total length of the hedgerows had decreased by 63.5 km (71.0%), while their total area had decreased by 27.1 ha (42.4%). The average hedgerow width was 7.2 m in 1950 (considering all 483 hedgerows), or 7.7 m if only the 142 hedgerows which have persisted until today are taken into account. By 2005, the average width had increased to 13.1 m, which represents an increase of +81.9%.

Neither the predictors nor their interactions were found to significantly affect the increase in hedgerow width between 1950 and 2005 (mixed-effect model, normal distribution, all $P > 0.2$, results not presented). In contrast, narrowing of the hedgerows was shown to be a surprisingly rare event (unlike complete loss), observed only in 2.3% of the collected sample.

As a result of the huge disproportions between the sample sizes of the narrowed and completely lost hedgerows, we were unable to statistically test the factors leading to either partial or complete loss of hedgerow structures in this study. Therefore, only the factors that potentially contributed to the complete disappearance

Table 2
Dynamics of hedgerow attributes in the study areas.

Year	Total number of hedgerows	Total length of hedgerows [km]	Total area of hedgerows [ha]	Average width of hedgerows [m]
2005	142	26.0	36.8	13.1
1950	483	89.5	63.9	7.2[a] (7.7[b])
1840–1852	995	226.3	–[c]	–[c]

[a] Value for all 483 hedgerows which were identified in 1950.
[b] Value for 142 hedgerows which were identified in both 1950 and 2005.
[c] The width of hedgerows was not calculated in 1840, therefore total area was also not available for this period.

Table 3
Results of the mixed-effect model explaining loss of the hedgerows in the study area following the MAM procedure method based on Type III sum of squares.

Predictor	d.f.	χ^2	P
Land use 2005	3, 462	21.72	<.0001
Soil fertility	1, 462	4.45	0.036
Land use 2005 × Slope gradient	3, 462	2.96	0.032
Land use 2005 × Land use 1950	6, 462	2.26	0.036

The predictors are ordered according to decrease of χ^2 statistics, referring to the explained deviance with corresponding degrees of freedom (d.f.) of the predictor variable (first number) and residual deviance (second number). Only predictors significantly contributing to the model ($P < 0.05$) were included in this table. All missed terms (ASPECT and most interactions) were non-significant ($P > 0.05$), and were excluded from the resulting model.

of the hedgerows were analysed in detail. Recent land use was found to be the most determining factor in this analysis (Table 3). Most of the hedgerows persisting to date are adjacent to grasslands. In contrast, the hedgerows that have disappeared since the 1950s were situated in areas where forests and arable land are currently present (Fig. 4). Although historic land use itself was not significant, it produced a significant interaction with recent land use: proportional comparisons among the categories (Fig. 5) indicate that hedgerows were most likely to disappear

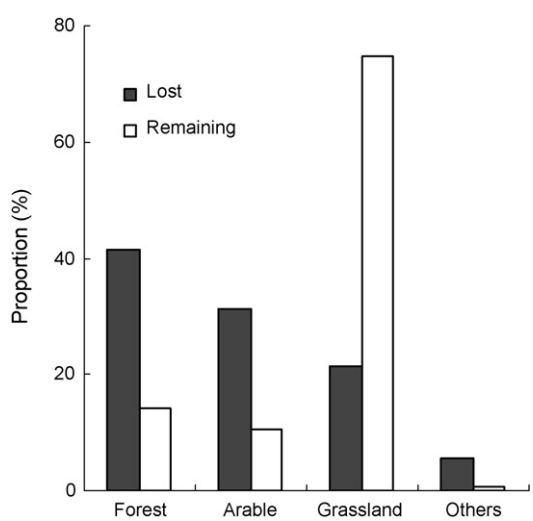

Fig. 4. Proportions of lost and remaining hedgerow structures between 1950 and 2005, in relation to current land use (2005) in the study areas.

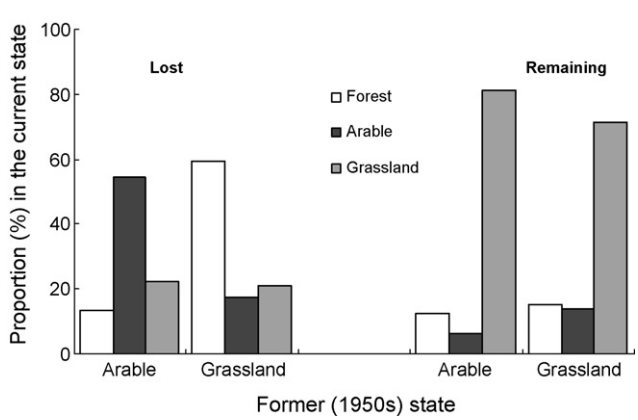

Fig. 5. Proportions of lost and remaining hedgerow structures between 1950 and 2005, in relation to the former land uses (1950) and the current land uses (2005) combined in the study areas.

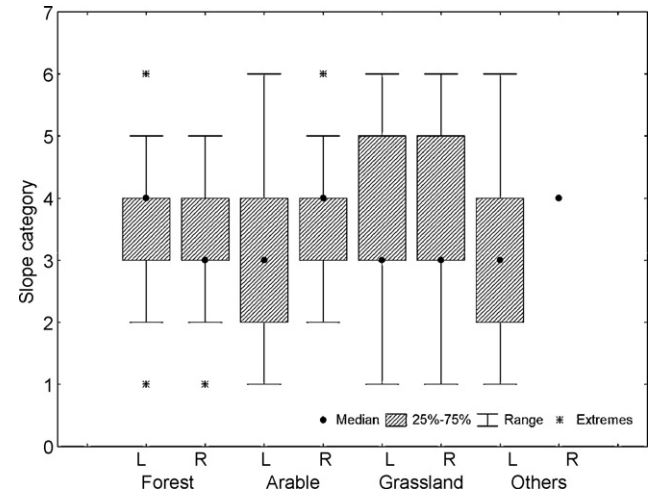

Fig. 6. Variation of slope categories (1–6) in lost (L) and remaining (R) hedgerow structures between 1950 and 2005, in relation to the current land use (2005) in the study areas. The last column [Others, category R] contained a single record, and is therefore displayed as the median value only without other box-plot attributes.

where arable land has persisted since the 1950s. Similarly, the transformation of former grasslands into forest stands lead to loss of the adjoining hedgerows. However, hedgerows adjacent to grasslands have persisted in most locations regardless of former land use.

Slope gradient was found not to be significant as a fixed effect. However, it was found to be significant in interaction with recent land use (Fig. 6). The persisting and lost hedgerows did not differ significantly in slope gradient in areas where forest stands and grasslands are now present, though the slopes tend to be generally steeper in present-day grasslands than in present-day forested areas. However, hedgerows adjacent to arable land have disappeared in all slope categories, but they have remained particularly on medium slopes (i.e., slopes that are neither flat nor extremely steep). Soil fertility was also found to be a significant

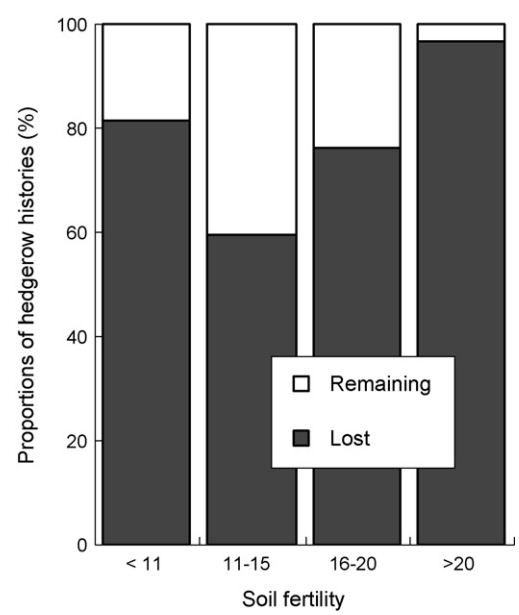

Fig. 7. Proportions of lost and remaining hedgerow structures in the study areas from 1950 until 2005 in relation to soil fertility, expressed in relative terms as a percentage of the most fertile unit in the Czech Republic (see Section 2.2 for further details).

predictor (Fig. 7): the risk of hedgerow disappearance rose with the increasing production potential of the land (mean ± S.D. for lost hedgerows: 13.8 ± 8.75, $N = 341$ and for remaining hedgerows: 10.6 ± 5.32, $N = 142$).

4. Discussion

4.1. Hedgerow dynamics

The hedgerows in medieval field patterns have worked as the stabilizing network of the pluzinas. Therefore, the disappearance of hedgerows leads to the disappearance of the entire pattern, and of a key part of Czech cultural history. Owing especially to the dramatic changes in land ownership and land use in the Czech Republic and in other Central and Eastern European countries in the second half of the 20th century (Lerman, 2001), medieval pluzinas without the stabilizing network of hedgerows were either lost entirely or have been significantly damaged. Consequently, by protecting the hedgerows, we also protect historically valuable field patterns. Our study therefore concentrates on the dynamics of the hedgerows and on selected driving forces which may cause the disappearance or a reduction of these hedgerows.

The results of our study confirm that there has been a dramatic decline in hedgerows: in the area studied here, hedgerow length decreased by 71% between 1950 and 2005. Tracking changes in hedgerow length was found to be the best method for describing the impact of hedgerow removal on pluzina landscapes, rather than simply tracking the development of the hedgerow area, which decreased by 42.4%. While the development of hedgerow area is in this case influenced by a significant increase in the width of the preserved hedgerows, the dynamics of their length incorporates their physical function of separating and defining the individual fields and thus preserving the original medieval pattern. Hedgerow decline, expressed as the loss in hedgerow length, also more clearly illustrates the changes in the visual character of the landscape and in its connectivity potential.

The above results show that there was a significant decline in hedgerow length in the second half of the 20th century. This loss amounted to 1.3% of hedgerows per year. In comparison, in the period of approximately 100 years between the mid-19th century and the mid-20th century, the loss in hedgerow length was 0.6% per year. Barr and Gillespie's results (2000) show that, compared to our findings, the rate of hedgerow disappearance in England, Wales and Scotland was much higher in the period from 1984 to1990 (3.5–4.5% of hedgerow length per year). However, these results cannot be simply compared. While the end of the 1980s was the culmination of the intensification of agriculture, the present study evaluates a longer period of 55 years, during which there were some periods when the pressure toward agricultural intensification was not as high. This is also confirmed by two other studies, which found a decrease in hedgerow length of 0.9% per year in England and Scotland between 1946 and 1974 and a decrease of 0.3% per year in Ireland between 1937 and 1982 (Pointereau and Bazile, 1995; Countryside Council for Wales, 1997).

It should also be noted that, unlike the 1950 and 2005 data, the 1840–1852 data was gained from the historical map of the Stable Cadastre (scale 1:2880), and is therefore affected by many inaccuracies in the data source. Nevertheless, since the scale of the map is very detailed and its authenticity is high, it is considered to be a reliable source of information for this general comparison of hedgerow length.

In the preserved hedgerows, the width increased significantly (by 81.9%) during the study period. This trend is closely linked to the management of the adjacent land, which was mostly used as extensive pastures or meadows. Another phenomenon which contributed to the increasing hedgerow width was the minimal or non-existent management of the hedgerows themselves, which were to a certain extent allowed to expand onto the adjacent land during the study period. From an ecological standpoint, wider hedgerows are more effective as plant and wildlife habitats, and perhaps also as conduits. From an aesthetic standpoint, the hedgerows, despite their increasing width, retained a linear character and their effect in this respect did not change. From a historical standpoint, wider hedgerows do not reflect the original state of these elements in the Middle Ages.

4.2. Drivers of hedgerow dynamics

The results of our study show the significant role of land use in areas adjacent to the hedgerows. While hedgerows disappeared regardless of historical land use in these areas, recent land use is the strongest predictor of loss. The hedgerows that have been preserved are typically adjacent to grasslands. In places where hedgerows have been lost, the current land use is mostly woodland or arable land. These results confirm the two main trends which have led to the disappearance of bocage landscapes and other traditional land use systems, described by Plieninger et al. (2006): extensification leads toward abandonment of the land, and natural succession leads to a gradual return to woodland of the areas adjacent to the hedgerows. Where intensification takes place, land adjacent to the hedgerows is arable. During the 2nd half of the 20th century, the parcels of arable land were enlarged and hedgerows were removed, mostly due to the development of mechanized farming and the growing pressure for agricultural productivity.

The significant interaction of recent land use and slope gradient indicates that in areas which are currently used as arable land, hedgerows disappeared from mild or moderate slopes but remained on steeper slopes during the study period. Compared to grasslands or woodlands, arable land requires more management and farm equipment has to be driven over the fields several times each year. Therefore, on moderate slopes, there was a tendency toward hedgerow removal, with the aim of enlarging the fields and increasing work productivity. Most of the hedgerows belonging to medieval pluzinas run along the slope gradient. On steeper slopes, the technical parameters of farming mechanization made contour plowing impossible, and therefore the pressure toward field enlargement and hedgerow removal was not as strong. In areas currently in woodlands or grasslands, the slope gradient in the lost and remaining hedgerows is similar. Interestingly, in the current state, grasslands occur on steeper slopes than woodlands, which is a fact that we cannot rationally interpret and explain. It may result from factors we have not tested in this study, such as the distance of a parcel from the farm, the disappearance of a farming community, employment and social pressures, etc. (Gross, 1996).

A significant interaction between recent land use and historic land use also has important implications. Historically, the land use classes adjacent to hedgerows were arable land and grassland. Some of these areas later became forested. The interaction can be interpreted in the following way: where there was arable land in 1950, hedgerows disappeared mostly in the places where arable land can still be found. Where arable land was directly forested (managed afforestation), hedgerows also disappeared. In these cases, it was a deliberate process, not a consequence of land abandonment. On the other hand, where arable land was substituted by grasslands, hedgerows were largely preserved. Where there were historically grasslands, hedgerows disappeared mainly in the areas which are currently woodlands or arable lands. In contrast, hedgerows were preserved where grasslands were sustained. These findings offer additional confirmation of the

trends in hedgerow dynamics mentioned above (Plieninger et al., 2006), specifically of hedgerow removal due to agricultural intensification, which took place mainly on arable land or due to spontaneous afforestation following field abandonment.

The results show that both spontaneous and managed afforestation of land adjacent to the hedgerows lead to loss of the typical character and integrity of medieval pluzinas. This loss mostly occurs where the land adjacent to the hedgerows is currently arable, although on some steeper slopes this form of management leads to pluzina preservation. Under grassland management, pluzinas do not tend to follow either of the above-mentioned trends leading toward the disappearance of these traditional agricultural patterns (intensification × extensification).

The results of the study further confirm our hypothesis that there is a statistically significant effect of natural soil fertility on the preservation or disappearance of hedgerows, and therefore of the entire medieval pluzina, which is consistent with the findings of Thenail (2002). Hedgerow removal was most intensive on the most fertile soils (fertility > 20%). The intensification pressure towards field enlargement and hedgerow removal was, logically, stronger on the more fertile land, and therefore the level of hedgerow preservation in these areas is very low. A high level of hedgerow disappearance was also observed on the least fertile soils (fertility < 11%). This finding is also consistent with our original hypothesis, as there is a natural tendency toward afforesting or abandoning the least fertile areas. On soils with natural soil fertility between 11% and 15%, there is the highest level of hedgerow preservation. It appears that in these areas, meadow or pasture management was still profitable, but the soils were not fertile enough to sustain crop fields. Last but not least, it should be noted that, in the studied region, we have found remnants of medieval pluzinas only on soils whose fertility was relatively low: the production potential of these soils was not higher than 40% of that of the most fertile land in the Czech Republic.

4.3. Principles of pluzina landscape preservation

While grain size, land use heterogeneity and hedgerow connectivity are the main issues in the preservation and restoration of bocage landscapes (Deckers et al., 2005), pluzina landscapes are somewhat different. As well-preserved examples of these landscapes are extremely rare, historical criteria should be paramount. Each hedgerow is important to the integrity of these landscapes, which are above all characterized by their scale and the elongated shape of their individual fields. Therefore, the original spatial features of the medieval pattern should be preserved and the development of the areas and the design of measures for soil conservation, flood control, traffic system, ecological network, afforestation, and land use changes should be subordinated to this concept. This principle should be reflected by the methodologies employed in all forms of landscape planning, but especially in the land consolidation program, the forestry plan and the master plan.

Pluzina patterns form scenic and ecologically valuable landscapes. Therefore, their use should be oriented toward extensive forms of agriculture, agricultural tourism, eco and heritage tourism, and other forms of individual and family recreation, not primarily toward agricultural production. This is particularly appropriate, given the findings of this study that pluzina landscapes have survived primarily on agriculturally less fertile soils. Therefore, there should be little conflict with the demand for intensification and mechanization of farming, while the existence of pluzina landscapes with their historic and scenic values have the potential to add economic value to otherwise marginal land.

Where conflict exists, there is a need to define a compromise solution between, on the one hand, the conservationist's demand to preserve hedgerows abundant and wide enough not to compromise their ecological and aesthetic functions, and, on the other hand, the production demands of the farmers. It is evident that in the case of such valuable features, the implementation of conventional agriculture would in most cases be very problematic. Nevertheless, land cultivation and management should be ensured to prevent excessive expansion of the hedgerows into adjacent fields. This study supports grazing and mowing of adjacent grasslands as the most suitable forms of management to mitigate the effects of abandonment (Pavlů et al., 2005, 2007; Hejcman et al., 2007).

In Western Europe, it is usual for decisions on hedgerow management to be made by farmers (Baudry et al., 2000). This approach does not work very well in the so-called "post-communist countries", where individual farming based on private land ownership was interrupted for almost half a century. Current farming practice in the Czech Republic is based mostly on land rental, which tends not to support conservation goals and tends not to reconnect the severed relationships between the farmers and the land (Sklenicka and Salek, 2008). Baudry et al. (2000) outlined another major reason behind hedgerow disappearance: diminishing farming communities, leading either to increasing intensification and field enlargement, or to abandonment. Since we can probably assume neither an increase in the number of farmers, nor the reconnection of severed farmer–land relationships to take place in the near future, the essential methods of pluzina preservation should focus on legal protection attended by management subsidies, as is the usual practice in the case of protected natural areas.

There is no need to establish an entirely new category for legal preservation of pluzina landscapes. There are currently two appropriate categories included in two relevant Czech Acts. The Cultural Heritage Act includes a "Landscape Zone" category, which is used for protecting culturally and historically valuable parts of the landscape, while the Nature and Landscape Preservation Act defines a "Natural Park" category, usually used for conserving the landscape character, which incorporates all aesthetic, natural, cultural and historical qualities of the landscape (Vorel et al., 2006). However, these acts, or rather the authorities who implement them, do not recognize pluzina landscapes. A major reason for this is the lack of a relevant basis for evaluating pluzina landscapes in the entire area of the Czech Republic, in order to establish an information system and to define the scope of medieval field pattern preservation. A continuation of our study through an analysis of pluzina development trends and their driving forces would form an integral part of this information system.

After an evaluation of the whole area of the Czech Republic, it would be possible to identify criteria for classifying pluzina landscapes according to their type, level of preservation, aesthetic influence, etc. Typical examples of various pluzina types associated with different regions, and some unique specimens, are particularly worthy of legal protection. The main characteristics of pluzinas identified for conservation should be a high level of integrity, represented by a high proportion of preserved hedgerows. In pluzinas with these characteristics, high visual quality can be assumed. The current state of the field pattern and hedgerows is important, but as a part of conservation management some progressive measures can be implemented in order to reconstruct the original historical patterns. Pluzinas unsuitable for conservation are those in which irreversible changes have occurred, disturbing the original pattern and features of the pluzina landscape.

Given the historical and ecological importance of pluzina landscapes in the Czech Republic, it is important to provide a level of protection for those that still exist. If protected, they have the

potential to provide valuable ecological benefits to the landscape and water resources of the country. Due to their historical importance, pluzina landscapes also have the potential to add to the already valuable cultural and eco-tourism resources of the countryside, and play a role in maintaining cultural identity and contributing to regional economic development.

5. Conclusions

Apart from their high historical value, the remnants of medieval field patterns are some of the most scenic landscapes in Central Europe. The study presented here is the first to assess the development of medieval pluzinas and the forces which contributed to their development, and more recently to their disappearance, in the Czech Republic. The original medieval field pattern has only been preserved where hedgerows have persisted on the borders of the original plots. Hedgerows, their dynamics and the driving forces behind their disappearance have therefore been the main subjects of this study. Hedgerows, a characteristic feature of these landscapes, play an important role in improving both the ecological and the aesthetic qualities of the region. In addition to positive microclimatic effects, some of these linear elements have a strong influence on flood mitigation and soil erosion processes.

The results of this study have shown, on the one hand, a major decrease in hedgerow length, and, on the other hand, a significant increase in the width of the persisting hedgerows between 1950 and 2005, and the consequent disappearance of whole field patterns. Two main trends in hedgerow disappearance have been confirmed—intensification and extensification of land management. The most significant factor that has contributed to the disappearance or persistence of hedgerows is the current land use in adjacent areas. Grassland is the most resilient to the two tends mentioned above, and is therefore the most conducive to persistence of pluzinas.

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