Risk Management as a Stimulus for a Settlement and Landscape Transformation? Soil Erosion Threat Assessment in the Fields of Four Deserted Villages Based on LiDAR-Derived DEMs and 'USLE'

Lukáš Holata, Jiří Kapička, Radek Světlík and Daniel Žížala

Abstract This paper draws attention to the dynamics beyond the shaping of historical landscape and deals with the settlement abandonment and landscape transformation during the Later Middle Ages. Despite long-lasting debate about the reasons of this process, explicit explanation is still missing. Among others, ecological issues, including soil erosion, have been frequently mentioned, although not always supported by data. We examine four deserted villages in the Czech Republic—Bzík and Kamenice in Pilsner region (Bohemia) and Bouchenec and Novošice in the Drahany Uplands (Moravia). Their remains have been preserved in woodlands and, therefore, the extent of medieval ploughlands could be reconstructed. LiDAR-derived DEMs and Universal Soil Loss Equation (USLE) have been applied to assess the soil erosion threat of the village fields. The results of the modelling indicate a high erosion threat for the majority of fields. This factor, together with resulting soil degradation, can be considered as a reason for the abandonment and subsequent landscape transformation.

L. Holata (✉)
Department of Archaeology, University of Exeter, Laver Building,
North Park Road, Streatham Campus, Exeter EX4 4QE, United Kingdom
e-mail: l.holata@exeter.ac.uk

J. Kapička · D. Žížala
Research Institute for Soil and Water Conservation,
Žabovřeská 250, 156 27 Praha 5 - Zbraslav, Czech Republic
e-mail: kapicka.jiri@vumop.cz

D. Žížala
e-mail: zizala.daniel@vumop.cz

R. Světlík
Gulag.cz z.s., Na Dolinách 524/40, 147 00 Praha 4, Czech Republic
e-mail: radek.svetlik@gulag.cz

I. Ivan et al. (eds.), *Dynamics in GIscience*, Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-319-61297-3_10

Keywords Landscape archaeology · Settlement abandonment · Landscape transformation · Water erosion · Middle Ages

Introduction

The current landscape is a record of various transformations and human activities in the past. In several parts of Europe, it also contains prehistoric elements (cf. Rippon 2004, 6–14). The main character of the Central European landscape had been formed during the 13th century as a result of a stabilisation of a settlement pattern and a nucleation of villages (cf. Klápště 2005). Nevertheless, since then, the landscape has undergone further dynamic development (especially due to the intensification of agriculture and the industrialisation) and most of the medieval elements have therefore been overlaid. Well visible remains of the medieval landscape (e.g. hedgerows) are to a large extent spatially restricted (cf. Houfková et al. 2015). The first large-scale map sources (e.g. the 18th and 19th century military maps of the Czech lands) do not fully reflect the 'archaic form of the landscape' and it is not possible to use them (directly, without additional data) for the reconstruction of older, medieval situation (Štěpánek 1967, 727). Also, woodland areas may not be 'ancient'; many of them had not existed in the Middle Ages and appeared later, during the (early) modern period. Nevertheless, due to this afforestation, many remains of past human activities have been preserved (cf. Kuna and Tomášek 2004), among other deserted medieval villages (DMVs).

The current settlement pattern can be considered as the remnant of a high medieval lay-out. A rough estimate indicates more than 5000 settlements that had been abandoned in the area of the Czech Republic in the period between the 13th and the 17th century (cf. Nekuda 1961, 176; Smetánka 1988, 9). The phenomenon of settlement abandonment during the late medieval and/or postmedieval period is documented in most European countries (e.g. Pohlendt 1950; Beresford 1954; Beresford and Hurst 1971; Gissel et al. 1981; Chapelot and Fossier 1985; Smetánka 1988; Dyer and Jones 2010). Many reasons for it have been suggested, both environmental and cultural. However, this disappearance has not been explicitly answered. In addition to more general statements (as 'Retreat from Margins', agricultural crisis or '*Fehlsiedlung*': cf. Abel 1966; Postan 1973) or a number of crisis events (wars, epidemics and famines have been frequently stated), the disruption of the ecosystem and ecological issues (cf. Klápště 2005, 269), including soil erosion, has been mentioned (cf. below).

Remains of numerous deserted villages, including their hinterlands, have been documented during large-scale field surveys (cf. Černý 1979, 1992; Klápště 1978; Smetánka and Klápště 1981; Vařeka et al. 2006). On their basis, we are able to distinguish specific types of earthworks, among others also those associated with ploughlands. The economy of medieval villages that depended mostly on arable agriculture is expected in highly elevated/exposed/agriculturally marginal areas as well (cf. Žemlička 1980; Boháč 1983; Měřínský 1987; Klír 2008) and it is supported by artifactual evidence (cf. iron agricultural tools from DMV Spindlebach in Ore Mountains situated 800–880 m a.s.l. : Hylmová et al. 2013) and the palynology (Rybníčková and Rybníček 1975; Nekuda and Jankovská 2005; Jankovská 2006, 2011; Petr 2008).

Currently, the identification of the remains of past human activities, especially line features such as field boundaries, is facilitated by LiDAR data, despite the fact that these objects are hardly discernible by the surface survey (cf. Malina 2015, 516). Using DTM 5G (Digital Terrain Model of the Czech Republic of the 5th generation) and subsequent ground-truthing, more complete image of past settlement areas (abandoned villages and their hinterlands) have been obtained, even the total extent of original ploughlands (cf. Vařeka et al. 2011, 335; Čapek 2013; in print; Čapek et al. 2013; Holata and Světlík 2015; Malina 2015). This allows us, together with the analytical potential of LiDAR-derived DEMs, to assess the process of the settlement abandonment as well as the dynamics in the land use during the historical period from a different perspective.

The Evidence for the Erosion During the Medieval Period

The evidence of the large-scale soil erosion during the medieval period comes from many European areas and beyond. An exceptional erosion (and other land degradation) is documented in the area of North Atlantic (e.g. Jakobsen 1991; Dugmore and Buckland 1991; Amorosi et al. 1998; Dugmore et al. 2000, 2005; Hannon et al. 2001; Greipsson 2012; Silva-Sánchez et al. 2015) as the impact of the *landnám* (colonization and settlement of new areas, destruction of vegetation cover, inappropriate land management) and the Little Ice Age. In England, substantial alluviation and influxes of sediments into river valley floodplains occurred during the Late-Saxon to the high Middle Ages and the cessation of alluviation in the late Medieval period corresponds with the contraction/desertion of settlements, abandonment of the ridge-and-furrow cultivation, enclosure of the open fields and the shift to grassland in general (Robinson 1992, 206; Lambrick 1992, 217–223; Rippon 2012, 232–240). The evidence also comes from southern Europe (e.g. van Andel 1990; Boone and Worman 2007).

In the case of Central Europe, high hillslope erosion during the Middle Ages is demonstrated mainly in Germany based on many case studies (e.g. Rösner and Töpfer 1999; Dotterweich 2005, 2008; Enters et al. 2008; Dreibrodt et al. 2010; Larsen et al. 2016). It is associated with deforestation and farming activities at a high altitude, on steeper slopes, introducing the three-field crop rotation system, synchronous with the highest intensity of the land use. The end of medieval period is considered as a one of the peaks of increased soil erosion in the Czech Republic (Beneš 1995, 143).

Concurrently, soil erosion has been mentioned in connection with deserted settlements as a reason for their abandonment (e.g. Iceland: Sveinbjarnardóttir 1991; Dugmore et al. 2006; the Lower Alentejo of southern Portugal: Boone and

Worman 2007; Germany—the Harz mountains: Linke 1983; abandoned Oberwürzbach in the Black Forest: Schreg 2009, 327–328; or Horb in western Schwanberg: Hildebrandt 2004). In the context of the Czech medieval settlement, it has been supposed as one of the ecological effects of the extensive deforestation and extensive agricultural land use (Boháč 1982, 46; Černý 1982, 104–105; 1983, 430; Vermouzek 1985, 70). Thick sediments have been documented in the deserted village of Bystřec in the Drahany Uplands together with erosion control elements (Hrádek 2006). However, statements addressing the erosion threat are only a presumption for many cases, not approved by empirical research.

Aims of the Paper in a Broader Perspective

The main aim of this paper is to (1) assess erosion threat in the fields of four deserted villages using LiDAR-derived DEMs and the USLE equation. The subject of our interest is water erosion which has the greatest importance in the region of Central Europe. More specifically, we intend to (2) determine whether the soil erosion threat and its consequences could be included among the reasons for abandonment of these villages and their management as a stimulus for subsequent landscape transformations.

Our intention corresponds with the current settlement transformations study approach which are now perceived in the context of wider transformations of land-use; the role of the natural environment in shaping cultural landscapes has been recently pointed out (especially Williamson 2004) and this issue is currently assessed, among others, in terms of human-environmental interactions as well. The hazards, sustainability, cultural responses to risk and environmental stress, and the resilience of human communities and societies in the past have been reflected in recent studies (e.g. Gerrard and Petley 2013; Curtis 2014), also in the context of medieval rural settlement and its economy (Schreg 2011, 2014).

Materials and Methods

Sites Selection, Their Characteristics and History

Due to previous surface surveys (cf. Černý 1992; Vařeka et al. 2008), all sites have been very well charted. Their selection also reflects different natural environments, topographies and diverse field system types. It allows us to assess the soil erosion threat under different conditions, type of field system, and thus different effect of field boundaries on the soil protection (cf. Janeček 2002, 118; Šarapatka 2012, 226).

The remains of the deserted village of *Kamenice* (residential area 440–470 m a.s.l., Pilsner region) are situated on the slopes under the hilltop. It had a radial field pattern around the residential area in the centre, most of field boundaries run along fall lines or in the angle of ca. 45° to the slope gradient, especially in the steepest parts (slope = 8°–12°, mean of the all ploughland = 4.67°). *Bzík* (Pilsner region, 535–560 m a.s.l.) is also situated under a hilltop, in the area of very steep slopes which in several parts reach to over 15° (mean = 8.18°). Field boundaries run along contours; furthermore, a large part of the field system is arranged in terraces. *Bouchenec* used to be the highest settlement in the Drahany Uplands (679–693 m a.s.l.), situated in a slight hillock near the highest point of the whole area. Its fields were placed on mild continual slopes (up to ca. 7°, mean = 4.63°). The field plots are arranged diagonally to the slope gradient, this is however documented in older plans only, not in LiDAR data. The hinterland of the deserted village of *Novošice* (Drahany Uplands, 553–574 m a.s.l.) was situated in the undulated terrain with very variable gradient of slopes (from flat areas to very steep slopes around ca. 20°, mean = 5.57°). In general, slight field boundaries preserved in the relief indicate a variable arrangement of field plots both along and perpendicular to contours (Fig. 1).

Based on the written evidence and a collected pottery, the existence of sites in the Pilsner region is dated from the 12th/13th to the 15th century (cf. Vařeka et al. 2008). The villages in the Drahany Uplands had been occupied from the 13th century. Bouchenec was deserted in the first half of the 15th century, Novošice in the first half of the 16th century (cf. Černý 1992).

Fig. 1 Location of deserted medieval villages

Identification of the Past Land-Use (Based on LiDAR Data and Surface Surveys)

For this analysis, georeferenced plans of sites in the Drahany Uplands were used (Černý 1992; Holata 2013). Additional relief formations, especially in the villages' hinterlands, have been identified in the LiDAR data (DTM 5G; applied visualisation cf. Zakšek et al. 2012; Doneus 2013). Their interpretation has been verified by recent surface surveys. The categorisation and vectorisation of all the identified remains have enabled the reconstruction of land-use for all deserted villages in the GIS. Field plots as well as residential, communication and mining areas have been delimitated. Potential meadows, pastures and forests have been located based on negative evidence and in accordance with the statements of historiography (especially Míka 1960; Lom 1973; Beranová 1975; Petráň and Petráňová 2000; Fig. 2). Having used these sources, intensely used parts of fields around residential areas have been delimitated as well, albeit only arbitrarily because of the missing field evidence.

Preprocessing of LiDAR-Derived DEMs for the Purpose of Soil Erosion Modeling

Still visible remains of field boundaries signify that original medieval relief has been preserved under woodland canopies up to the present. Nevertheless, it contains also later and recent objects (especially charcoal wooden platforms, tree windfalls or roads and forest ways) which had to be eliminated for the calculation of erosion threat models. More extensive objects documented by LiDAR data have been removed from the original point cloud and slight terrain anomalies have been smoothed with the resampling of DEMs to 3 m and by using the Low-pass filter.

Soil Erosion Modeling

Water erosion is quantified using average annual soil loss (A) (t ha^{-1} year^{-1}) which is calculated on the basis of *USLE* (Universal Soil Loss Equation; Wischmeier and Smith 1965; 1978) in order to assess the soil erosion threat:

$$A = R * K * L * S * C * P$$

where R is the rainfall erosivity factor (20 MJ ha^{-1} cm h^{-1} was proposed as an average value for the Czech Republic until 2012—it is considered as an optimal solution, because past climate reconstructions testify for dry as well as rainy periods during village existence—cf. Kotyza et al. 1990; Kotyza 1992; Brázdil and Kotyza 1997). K is the soil erodibility factor, expressing soil susceptibility in terms of

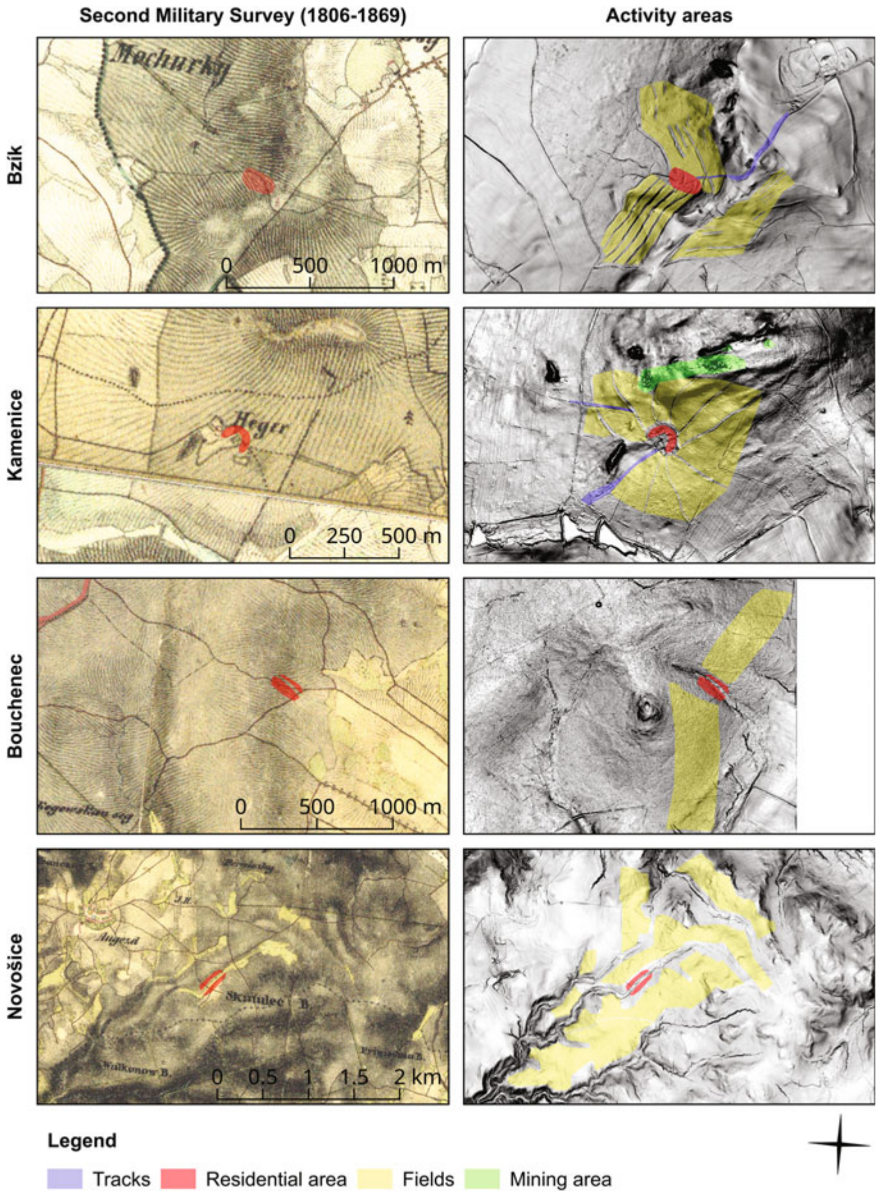

Fig. 2 Historical mapping with the range of woodlands and the reconstruction of medieval activity areas against the DTMs (visualised by anisotropic sky-view factor)

erosion depending on soil texture and structure. It was derived from forestry typology of soil types (SLT, ÚHUL 2013). *LS* is a 'topographic factor' combining the influence of the slope length and gradient (derived from modified LiDAR-based

DEMs). *C* is the cover-management factor, expressing the influence of sowing methods and agro-technology. Three-field crop rotation system has been considered together with the cultivation of flux, vegetable and legumes in the fields around residential areas (in accordance with Míka 1960; Lom 1973; Beranová 1975; Petráň and Petráňová 2000; for the settings of the factors in the Czech Republic cf. Novotný et al. 2016).

Data Evaluation

Resulting models have been divided into 6 categories of erosion threat (after Novotný et al. 2016; Fig. 3). On this basis, two thresholds have been determined (below 1.0 t ha^{-1} $year^{-1}$ without threat or very slightly threatened, below 4.0 t ha^{-1} $year^{-1}$ as max. tolerable limit of soil loss, higher values means heavy erosion threat). Sites are compared with each other (using the boxplots with both thresholds; Fig. 4) and also with the long-term annual soil loss in current agricultural land in the Czech Republic (Table 1). In addition, flowlines have been also generated and displayed against field boundaries to assess their role in soil protection (Fig. 3).

Results

Kamenice: Almost the entire ploughland is threatened by erosion. Only restricted and fragmentary areas (3.5% of the total extent of fields) are threatened very slightly, but they occur in the most distant parts of the ploughland, in the hilltop position. The largest part of the whole extent of fields (51.3%) is threatened only slightly. Higher level of threat can be found around the residential area (mostly medium, but locally also heavily). Considerable is the extent the areas that are very heavily or even extremely threatened (28.4%). These areas are scattered especially in the north-east–north-west parts of the ploughland with the steepest slopes. In addition to this, field boundaries run here in the direction of water run-off and their impact on the erosion reduction is minimal. Overall, with the exception of three southern fieldplots, high erosion threat occurs across all the ploughland.

Bzík: Very high erosion threat is registered here, despite the fact that all field boundaries break the water run-off and a large part of the ploughland is arranged into terraces (heavily—extremely threatened areas cover 40.6% of which extreme is 25.6%). Affected were particularly upper parts of fieldplots and the terraced transect south from the residential area. Nevertheless, the extent of very slightly threatened areas is larger (17.8%) than in the case of Kamenice, but identically as in the previous case, these areas are situated in the fringe of ploughland in the southern and south-eastern–eastern part.

Bouchenec: Erosion threat is low in the ploughland (37.6% of the area is very slightly threatened, 33.8% then slightly). These areas cover both parts of the fields

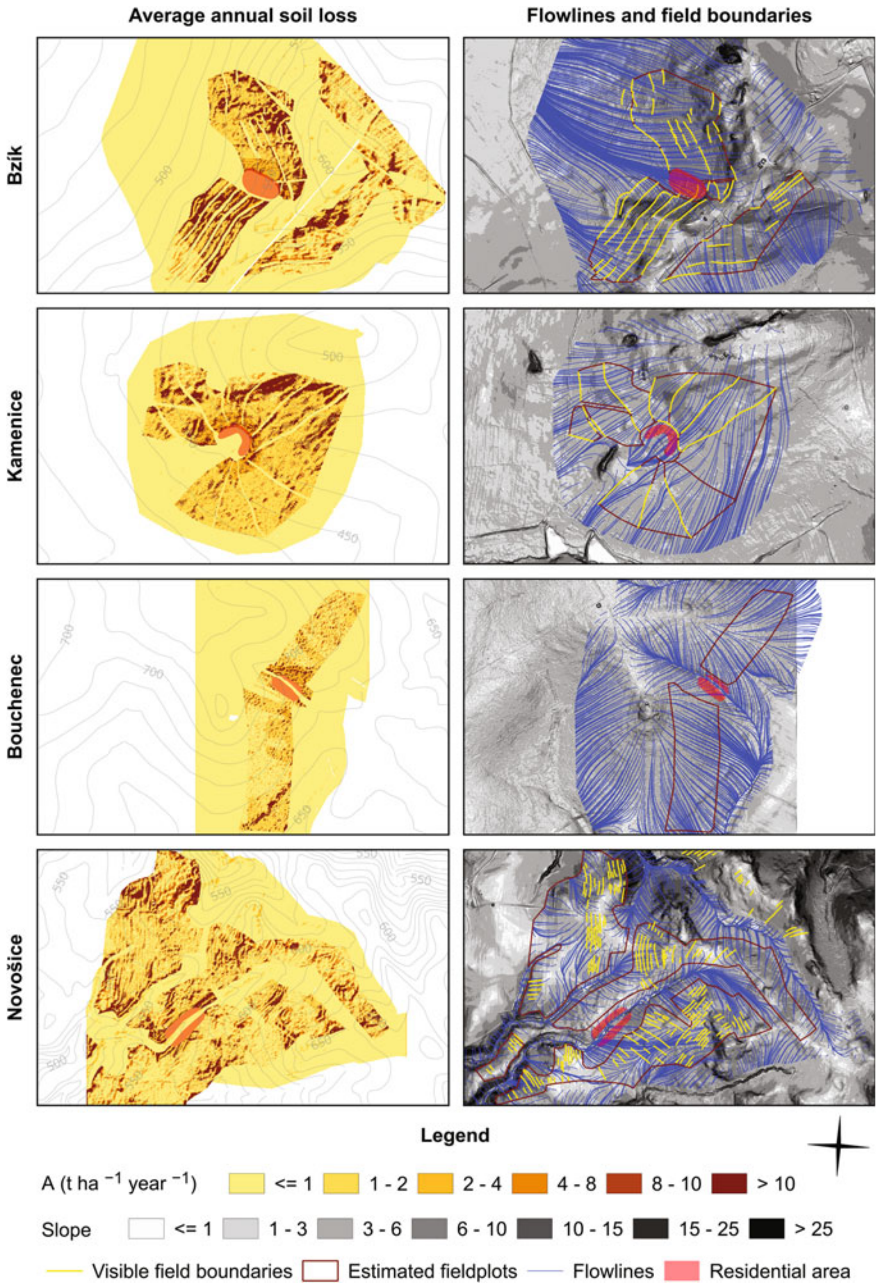

Fig. 3 Soil loss in the ploughlands (*left*) and flowlines against field boundaries and slope (*right*). The scale is the same as in the Fig. 2

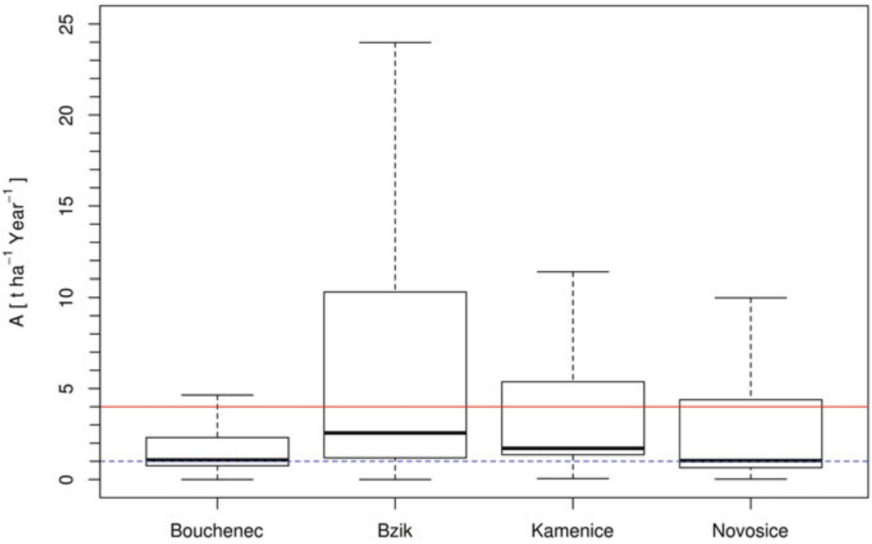

Fig. 4 Boxplots of erosion threat for all sites

Table 1 The erosion threat of the sites and compared with the current Czech agricultural land

Average annual soil loss (A)	A [t ha^{-1} Year^{-1}]	Distribution (%)				
		Bouchenec	Bzík	Kamenice	Novošice	Czech R.
Very slightly threatened	Below 1.0	37.6	17.8	3.5	45.2	49.6
Slightly threatened	1.1–2.0	33.8	26.5	51.3	18.0	18.3
Medium threatened	2.1–4.0	12.0	15.1	16.8	10.0	15.6
Heavily threatened	4.1–8.0	9.5	10.8	9.7	13.7	10.4
Very heavily threatened	8.1–10.0	2.4	4.2	3.2	3.7	2.0
Extremely threatened	Above 10.1	4.6	25.6	15.5	9.5	4.2
Total		100	100	100	100	100

(lowest values are recorded in the central area of the southern field). Heavily—extremely threatened areas are restricted to local anomalies and scattered around the whole ploughland. Only in the southern part they are concentrated into the continuous strip (also because of the absence of field boundaries). Another area with higher erosion threat adjoins the edge of the village in the northern field.

Novošice: Undulating relief of the village hinterland also implies very variable threat of the soil erosion. Almost half of the ploughland is very slightly threatened (45.2%), especially in the central part of the southern and eastern fields. However, heavily—extremely threatened parts spread to over 26.9% of the ploughland (9.5% is extreme threat). These are documented across the whole extent of ploughland, mostly in the northern fringe, but also in the broader residential area surroundings. As most of the field boundaries are slight only, their influence on soil protection is low (in addition to this, most of them are not situated transversally, especially in the area adjacent to the village from the south-east).

Only in case of Novošice, the extent of a very slightly threatened area corresponds with the current agricultural land in the Czech Republic. Together with Bouchenec percentages show similar trend in the range of categories (but the extent of heavily—extremely threatened areas is higher). On the contrary, there is an opposite trend in the case of Kamenice and especially in Bzík with large areas of heavily—extremely threatened areas and limited range of very slightly threatened areas. A high erosion threat occurred despite the fact that field plots are divided into small sections (in contrast to the current fields). However, the placing of meadows around streams is considered to be a positive factor in terms of erosion threat, which protects the streams against soil accumulation.

Discussion

The results are mostly determined by the characteristics of LiDAR-derived DEMs, especially their resolution and vertical accuracy of the relief under woodland canopies (local depressions are most problematic). The quality of the DEM should be verified by a surface survey and selected testing areas compared with a detailed measurement using a total station. Other factors in USLE (especially *R* and *C*) could be only expertly estimated based on the current knowledge of historiography. In contrast with the modelling of erosion threat in current agricultural land, percentages of areas with erosion threat cannot be considered absolutely, but only as an expression of the main trend.

From today's perspective, all occupied areas are not suitable for agriculture in terms of soil erosion threat. Although threat in Bouchenec is low and restricted to small areas, it was the higher settlement in the whole region and a very low agricultural potential is assumed (only slight erosion threat could have a serious impact). High erosion threat is documented despite the fact that the ploughlands are divided into small fieldplots (compared to the current agricultural practice). Most of the fields occupied slopes, often with very steep gradient and for that reason heavy erosion threat occurred also in areas where field boundaries interrupt the surface run-off, or in terraced fields in Bzík—even this arrangement did not protect the high soil loss there. In this respect, the issue of accumulated material on field boundaries has emerged. Written sources for post-medieval period indicate the effort to carry soil from various places back to the fields (cf. Černý 1930; Cílek 2012, 95). This work activity is deemed as a necessary workload during the year as a coping and mitigation of erosion threat. Nevertheless, many field boundaries are parallel with flowlines as well and erosion threat is heightened by the lay-out of the field system. In the cases of Kamenice and Novošice, sedimentation of the soil deposits could have occurred in the residential areas as a consequence of their position below the fieldplots, missing soil protection elements and also supposed intensely used parts around them.

As a consequence of high erosion threat together with growing crops with high nutritional requirements (grain) and the three-field crop rotation system (inclusive of winter months without vegetation cover), overall soil depletion and degradation is taken into account: higher erosion > higher nutrient run-off > reduction of organic matter in soil > reduction the quality of the soil structure > higher predisposition to desiccation > lack of soil moisture for plants > poor germination. Economy of these villages, if it depended only upon arable agricultural, is considered vulnerable because of low yields. Currently, we are still far away from the understanding why or for what reasons these parts of the landscape were occupied and used for arable agriculture, whether their location was mistaken based on the perception of past communities and what were the particular causes for their final abandonment. Nevertheless, following our results, we argue that arable agriculture of such areas was a risk management, which can be considered as one of the reasons for their abandonment and a stimulus for landscape transformation. Contrasted to other documented cases, the vast majority of these ploughlands were not incorporated into the surrounding territories and used for arable agriculture by their communities (cf. Štěpánek 1969, 663–679; Smetánka 1988, 47). It resulted in the transformation of the landscape and afforestation of original settlement areas.

Considering risk management of past communities also implies remarkable dynamics beyond the settlement abandonment and landscape transformations: choice of the position for occupation and perception of the landscape > village economy, intense arable agriculture and the role of subsistence strategies > soil degradation caused by long-term using of unsuitable areas for agriculture > response of communities to the stress (coping with the high erosion threat and mitigation of implications) > the role of possible transformation of the village ecosystem as an adaptation to changing conditions > sustainability of village economy > decision to abandon the settlement > leaving the areas without agricultural use > change of land-use.

All sites indicate different problems than we have in current agriculture. On the one hand high erosion threat occurred also in small and discontinuous fieldplots. On the other hand, a high proportion of grassland (although it should be confirmed by additional evidence) protected the watercourses. It evokes a comprehensive approach of agricultural land use concerning ‘inputs’ and ‘outputs’: soil without any degradation = good yields = necessary adequate care.

Conclusion

We assessed, based on the LiDAR-derived DEMs and USLE, the soil erosion threat in the fields of four deserted villages. Our outputs indicate that the only a minor extent of ploughlands is without erosion threat or threatened very slightly. On the contrary, the range of heavy—extremely threatened areas is considerable. The lowest erosion threat is documented in Bouchenec (the highest settlement in the whole region), the high erosion threat occurs in the both sites in the Pilsner region, especially Bzík. From this point of view, none of the settlement areas are suitable for agricultural use, which is considered as risk management in these environments. Soil erosion threat and subsequent soil degradation can be included among the reasons for abandonment these villages and their management as a stimulus of subsequent landscape transformations. Our outcomes imply remarkable dynamics in the process of settlement abandonment and beyond the shaping of historical landscape in general. Although this is the first support of such statement for the Czech deserted villages based on data, other procedures (especially empirical research) are necessary for the validation.

Software

LiDAR data were interpolated in Surfer 12 using Natural Neighbor algorithm. Elimination of later and recent objects and filtering of LiDAR data were realised in QGIS. Relief Visualisation Toolbox (RVT) was used for LiDAR data visualisation. USLE2D and Esri ArcGIS 10.3 (with Spatial Analyst and 3D Analyst extensions) were used for calculations of erosion threat models. Graph was prepared using Rstudion (R version 3.3.2). An Internet application, the Erosion Control Calculator (http://kalkulacka.vumop.cz) was used for C factor.

Sources of Support

This work was supported by the Ministry of Agriculture of the Czech Republic [grant number NAZV QJ1230056 - The Impact of the expected Climate Changes on Soils of the Czech Republic and the Evaluation of Their Productive Functions] and by the H2020-MSCA-IF-2014 'ABANDONMENT—People under Pressure: Settlement Abandonment and Human Responses to Environmental and Socio-Economic Stress during the Medieval and Postmedieval Periods'.

References

Abel, W. (1966). *Agrarkrisen und Agrarkonjunktur in Mitteleuropa vom 13.–19. Jahrhundert*. Hamburk/Berlin: Parey.

Amorosi, T., Buckland, P. C., Edwards, K. J., Mainland, I., McGovern, T. H., Sadler, J. P., et al. (1998). They did not live by grass alone: The politics and palaeoecology of animal fodder in the North Atlantic region. *Environmental Archaeology, 1,* 41–54.

Beneš, J. (1995). Erosion and accumulation processes in the late holocéne of Bohemia, in relation to prehistoric and medieval landscape occupation. In M. Kuna & N. Venclová (Eds.), *Whither archaeology? Papers in honour of Evžen Neustupný*. Praha: ARÚ.

Beranová, M. (1975). *Zemědělská výroba v 11./14. století na území Československa*. Praha: Academia.

Beresford, M. W. (1954). *The lost villages of England*. London: Royal Geographical Society.

Beresford, M. W., & Hurst, J. G. (Eds.). (1971). *Deserted medieval village*. London: Lutterworth Press.

Boháč, Z. (1982). Katastry – málo využitý pramen k dějinám osídlení. *Historická geografie, 20,* 15–87.

Boháč, Z. (1983). Vesnice v sídelní struktuře předhusitských Čech. *Historická geografie, 21,* 37–116.

Boone, J. L., & Worman, F. S. (2007). Rural settlement and soil erosion from the Late Roman Period through the Medieval Islamic Period in the Lower Alentejo of Portugal. *Journal of Field Archaeology, 32,* 115–132.

Brázdil, R., & Kotyza, O. (1997). Kolísání klimatu v Českých zemích v první polovině našeho tisíciletí. *Archeologické rozhledy, 49,* 663–699.

Čapek, L. (2013). Využití dat leteckého laserového skenování ke studio středověké a novověké krajiny Velechvínského polesí, okr. České Budějovice. In: M. Gojda & J. John et al., *Archeologie a letecké laserové skenování krajiny*. Plzeň: Západočeská univerzita v Plzni.

Čapek, L. (in print). Lotniczy skaning laserowy i opuszczone średniowieczne wsie południowych Czech, In. M. Gojda (ed), *Lux Ex Caelo*. Warsaw: Archaeologica Hereditas – Prace Institutu Archeologii UKSW.

Čapek, L., John, J., & Stolz, D. (2013). Příspěvek leteckého laserového skenování k poznání dvou zaniklých středověkých vesnic mezi Líšnou a Točníkem. In: M. Gojda & J. John. et al., *Archeologie a letecké laserové skenování krajiny*. Plzeň: Západočeská univerzita v Plzni.

Černý, V. (1930). *Hospodářské instrukce. Přehled zemědělských dějin v době patrimonijního velkostatku v XV. – XIX. století*. Praha: Československá Akademie Zemědělská.

Černý, E. (1979). *Zaniklé středověké osady a jejich plužiny: metodika historicko-geografického výzkumu v oblasti Drahanské vrchoviny*. Praha: Academia.

Černý, E. (1982). Dosavadní výsledky a závěry historickogeografického výzkumu zaniklých středověkých osad a jejich plužin na Drahanské vrchovině. *Historická geografie, 20,* 89–112.

Černý, E. (1983). Vztah zaniklých plužin k rozloze lesů na Drahanské vrchovině v období vrcholného feudalismu. *Archaeologia Historica, 8,* 423–431.

Černý, E. (1992). *Výsledky výzkumu zaniklých středověkých osad a jejich plužin: Historicko-geografická studie v regionu Drahanské vrchoviny*. Brno: Muzejní a vlastivědná společnost.

Chapelot, J., & Fossier, R. (1985). *The village and house in the middle ages*. London: B. T. Batsford Ltd.

Cílek, V. (2012). Geodiverzita a paměť krajiny. In: I. Machar & L. Drobilová et al., *Ochrana přírody a krajiny v České republice. Vybrané aktuální problémy a možnosti jejich řešení*. 1. díl. Olomouc: Univerzita Palackého v Olomouci.

Curtis, D. (2014). *Coping with crisis: The resilience and vulnerability of pre-industrial settlements*. Farnham: Ashgate.

Doneus, M. (2013). Openness as visualization technique for interpretative mapping of airborne lidar derived digital terrain models. *Remote Sensing, 5,* 6427–6442.

Dotterweich, M. (2005). High-resolution reconstruction of a 1300 year old gully system in northern Bavaria, Germany: A basis for modelling long-term human-induced landscape evolution. *The Holocene, 15,* 994–1005.

Dotterweich, M. (2008). The history of soil erosion and fluvial deposits in small catchments of central Europe: Deciphering the long-term interaction between humans and the environment—A review. *Geomorphology, 101,* 192–208.

Dreibrodt, S., Lubos, C., Terhorst, B., Damm, B., & Bork, H.-R. (2010). Historical soil erosion by water in Germany: Scales and archives, chronology, research perspectives. *Quaternary International, 222,* 80–95.

Dugmore, A., & Buckland, P. (1991). Tephrochronology and late holocene soil erosion in south Iceland. In J. K. Maizels & C. Caseldine (Eds.), *Environmental change in Iceland: Past and present*. Dordrecht/Boston/London: Kluwer academic Publishers.

Dugmore, A. J., Church, M. J., Buckland, P. C., Edwards, K. J., Lawson, I. T., Mcgovern, T. H., et al. (2005). The norse landnám on the north atlantic islands: An environmental impact assessment. *Polar Record, 41,* 21–37.

Dugmore, A. J., Church, M. J., Mairs, K.-A., McGovern, T. H., Newton, A. J., & Sveinbjarnardóttir, G. (2006). An over-optimistic pioneer fringe? Environmental perspectives on medieval settlement abandonment in Þórsmörk, South Iceland. *Dynamics of Northern Societies: Proceedings of the SILA/NABO Conference on Arctic and North Atlantic Archaeology* (pp. 335–345), Copenhagen, May 10–14, 2004, Copenhagen: Aarhus University Press.

Dugmore, A., Newton, A., Larsen, G., & Cook, G. T. (2000). Tephrochronology, environmental change and the norse settlement of Iceland. *Environmental Archaeology, 5,* 21–34.

Dyer, C., & Jones, R. (Eds.). (2010). *Deserted villages revisited*. Hatfield: University of Hertfordshire Press.

Enters, D., Dörfler, W., & Zolitschka, B. (2008). Historical soil erosion and land-use change during the last two millenia recorded in lake sediments of Frickenhauser See, northern Bavaria, central Germany. *The Holocene, 18,* 243–254.

Gerrard, C., & Petley, D. (2013). A risk society? Environmental hazards, risk and resilience in the later Middle Ages in Europe. *Natural Hazards, 69,* 1051–1079.

Gissel, S., Jutikkala, E., Österberg, E., Sandnes, J., & Teitsson, B. (1981). *Desertion and land colonization in the Nordic Countries c. 1300–1600*. Stockholm: Almqvist & Wiksell.

Greipsson, S. (2012). Catastrophic soil erosion in Iceland: Impact of long-term climate change, compounded natural disturbances and human driven land-use changes. *CATENA, 98,* 41–54.

Hannon, G. E., Wastegård, S., Bradshaw, E., & Bradshaw, R. H. W. (2001). Human impact and landscape degradation on the Faroe Islands. *Biology and Environment: Proceedings of the Royal Irish Academy, 101,* 129–139.

Hildebrandt, H. (2004). Die spätmittelalterliche Wüstungsperiode aus der Sicht der Bodenerosionstheorie, betrachtet vornehmlich am Beispiel der Wüstung Horb im westlichen Steigerwald. *Bamberger Geographische Schriften Sonderfolge, 7,* 121–137.

Holata, L. (2013). Settlement patterns in Drahany Uplands (Czech Republic): GIS and quantitative methods based approach. In G. Earl et al. (eds.), *Archaeology in the Digital Era, vol. II. e-Papers from the 40th Conference on Computer Applications and Quantitative Methods in Archaeology* (pp. 636–644), Southampton, March 26–30, 2012, Amsterdam: Amsterdam University Press.

Holata, L., & Světlík, R. (2015). Detailed digital terrain models in the research of deserted settlements: Hydrological modelling and environment of settlement areas. In K. Růžičková & T. Inspektor (Eds.), *Surface models for geosciences*. Lecture notes in geoinformation and cartography, Amsterdam: Springer.

Houfková, P., Burnerl, J., Pospíšil, L., Karlík, P., Beneš, J., Bernardová, A., et al. (2015). Origin and development of long-strip field patterns: A case study o an abandoned medieval village in the Czech Republic. *CATENA, 135,* 83–91.

Hrádek, M. (2006). Odezva přírodního prostředí v okolí Bystřece na odlesnění krajiny. In L. Belcredi, *Bystřec. O založení, životě a zániku vsi*. Brno: Muzejní a vlastivědná společnost.

Hylmarová, L., Klír, T., & Černá, E. (2013). Kovové předměty ze zaniklého Spindelbachu v Krušných horách. K výpovědi detektorového průzkumu. *Archaeologia Historica, 38,* 569–609.

Jakobsen, B. H. (1991). Soil erosion in the Norse settlement area of Østerbygden in southern Greenland. *Acta Borealia, 8,* 56–68.

Janeček, M. (2002). *Ochrana zemědělské půdy před erozí*. Praha: Powerprint.

Jankovská, V. (2006). Pyloanalytický výzkum. In: Belcredi, L., *Bystřec. O založení, životě a zániku středověké vsi*. Brno: Muzejní a vlastivědná společnost.

Jankovská, V. (2011). The Middle Ages in pollen-analytical research on the territory of the Czech Republic. *Bulletin of Geography Physical Geography Series*, *4*, 47–70.

Klápště, J. (1978). Středověké osídlení Černokostelecka. *Památky archeologické, 69,* 423–475.

Klápště, J. (2005). *Proměna Českých zemí ve středověku*. Praha: Lidové noviny.

Klír, T. (2008). *Osídlení zemědělsky marginálních půd v mladším středověku a raném novověku*. Praha: Univerzita Karlova, Filozofická fakulta.

Kotyza, O. (1992). Archeologické a přírodovědné prameny jako prameny historické klimatologie. *Archaeologia Historica, 17,* 449–459.

Kotyza, O., Pejml, K., & Sládková, J. (1990). Několik poznámek ke kolísání klimatu v Čechách 14. – 15. století. *Archaeologia Historica, 15,* 511–516.

Kuna, M., & Tomášek, M. (2004). Povrchový výzkum reliéfních tvarů. In M. Kuna et al., *Nedestruktivní archeologie*. Praha: Academia.

Lambrick, G. (1992). Alluvial archaeology of the Holocene in the Upper Thames Basin 1971–1991: A review. In S. Needham & M. G. Macklin (Eds.), *Alluvial archaeology in Britain*. Oxford: Oxbow Books.

Larsen, A., Robin, V., Heckmann, T., Fuelling, A., Larsen, J. R., & Bork, H.-R. (2016). The influence of historic land-use changes on hillslope erosion and sediment redistribution. *Holocene, 26,* 1248–1261.

Linke, M. (1983). Medieval deserted fields and deserted villages in the Lower Harz Mountains—An interim report. In B. K. Roberts & R. E. Glasscock (Eds.), *Villages, fields and frontiers. Studies in European Rural Settlement in the Medieval and Early Modern Periods.* Oxford: B.A.R.

Lom, F. (1973). Vývoj osevních postupů a soustav hospodaření v Českých zemích – Metodologická studie. *Vědecké práce zemědělského muzea, 13,* 215–263.

Malina, O. (2015). Hledání neviditelného. Relitky plužiny zaniklých středověkých vsí a možnosti jejich detekce a interpretace na datech LLS. *Zprávy památkové péče, 75,* 513–520.

Měřínský, Z. (1987). Příspěvek k možnostem rekonstrukce středověké krajiny, území zaniklých vesnic a typů sídlišť. *Archaeologia Historica, 12,* 111–128.

Míka, A. (1960). *Nástin vývoje zemědělské výroby v Českých zemích v epoše feudalismu*. Praha: SPN.

Nekuda, V. (1961). *Zaniklé osady na Moravě v období feudalismu*. Brno: Krajské nakladatelství.

Nekuda, R., & Jankovská, V. (2005) Mstěnice – zaniklá středověká ves, pyloanalytické zhodnocení přírodního prostředí v okolí středověkého vodního mlýna. In V. Hašek, et al. (Ed.), *Ve službách archeologie*. Brno: Muzejní a vlastivědná společnost.

Novotný, I., Žížala, D., Kapička, D., Beitlerová, H., Mistr, M., Kristenová, H., et al. (2016). Adjusting the CPmax factor in the Universal Soil Loss Equation (USLE): Areas in need of soil erosion protection in the Czech Republic. *Journal of Maps, 12,* 58–62.

Petr, L. (2008). Pylový rozbor zaniklých rybníčků a vývoj prostředí po zániku vesnic, In V. Dudková, et al. (Ed.), *Hledání zmizelého. Archeologie zaniklých vesnic na Plzeňsku*. Plzeň: Západočeské muzeum.

Petráň, J., & Petráňová, L. (2000). *Rolník v tradiční evropské kultuře*. Praha: Set Out.

Pohlendt, H. (1950). *Die Verbreitung der mittelalterlichen Wüstungen in Deutschland*. Göttingen: Geographisches Institut der Universität.

Postan, M. M. (1973). The economic foundations of medieval society. In M. M. Postan (Ed.), *Essays on medieval agriculture and general problems of the medieval economy*. London: Cambridge University Press.

Rippon, S. (2004). *Historic landscape analysis*. York: Council for British Archaeology.

Rippon, S. (2012). *Making sense of an historic landscape*. Oxford: Oxford University Press.

Robinson, M. (1992). Environment, archaeology and alluvium on the river gravels of the South Midlands. In S. Needham & M. G. Macklin (Eds.), *Alluvial archaeology in Britain*. Oxford: Oxbow Books.

Rösner, U., & Töpfer, C. (1999). Historische Bodenerosion *auf* Flurwüstungen im westlichen Steigerwald. *Mitteilungen der Fränkischen Geographischen Gesellschaft, 46,* 27–74.

Rybníčková, E., & Rybníček, K. (1975). Ergebnisse einer Paläogeobotanischen Erforschung. In V. Nekuda, et al. (Ed.), *Pfaffenschlag – Zaniklá středověká ves u Slavonic. Příspěvěk k dějinám středověké vesnice*. Brno: Blok.

Šarapatka, B. (2012). Zemědělská krajina a biodiverzita. In I. Machar & L. Drobilová, et al. (Eds.), *Ochrana přírody a krajiny v České republice. Vybrané aktuální problémy a možnosti jejich řešení. 1. díl.* Olomouc: Univerzita Palackého v Olomouci.

Schreg, R. (2009). Development and abandonment of a cultural landscape—Archaeology and environmental history of medieval settlements in the northern Black Forest. In J. Klapste & P. Sommer (Eds.), *Medieval rural settlement in marginal landscapes*. Ruralia VII. Turnhout: Brepols.

Schreg, R. (2011). Feeding the village—Reflections on the ecology and resilience of the medieval rural economy. In J. Klapste & P. Sommer (Eds.), *Processing, storage, distribution of food. Food in the medieval rural environment*. Ruralia VIII. Turnhout: Brepols.

Schreg, R. (2014). Ecological approaches in medieval rural archaeology. *European Journal of Archaeology, 17,* 83–119.

Silva-Sánchez, N., Schofield, J. E., Mighall, T. M., Martínez Cortizas, A., Edwards, K. J., & Foster, I. D. L. (2015). Climate changes, lead pollution and soil erosion in south Greenland over the past 700 years. *Quaternary Research, 84,* 159–173.

Smetánka, Z. (1988). *Život středověké vesnice. Zaniklá Svídna.* Praha: Academia.

Smetánka, Z., & Klápště, J. (1981). Geodeticko - topografický průzkum zaniklých středověkých vsí na Černokostelecku. *Památky archeologické, 72,* 416–458.

Štěpánek, M. (1967). Plužina jako pramen dějin osídlení (Příspěvky k dějinám osídlení 1). *Československý časopis historický, 15,* 725–746.

Štěpánek, M. (1969). Strukturální změny středověkého osídlení II. *Československý časopis historický, 17,* 649–679.

Sveinbjarnardóttir, G. (1991). A study of farm abandonment in two regions of Iceland. In J. K. Maizels & C. Caseldine (Eds.), *Environmental change in Iceland: Past and present*. Dordrecht/Boston/London: Kluwer Academic Publishers.

ÚHUL. (2013). *Přehled lesních typů a souborů lesních typů v ČR*. Brandýs nad Labem: Ústav pro hospodářskou úpravu lesů.

van Andel, T. H., Zangger, E., & Demitrack, A. (1990). Land use and soil erosion in prehistoric and historical Greece. *Journal of Field Archaeology, 17,* 379–396.

Vařeka, P., Aubrechtová, A., Hnízdilová, P., Novák, R., Rožmberský, P., & Veselá, R. (2006). *Archeologie zaniklých středověkých vesnic na Rokycansku I.* Plzeň: Ing. Petr Mikota.

Vařeka, P., Holata, L., Přerostová, H., & Švejnoha, J. (2008). Zaniklé středověké vesnice na Blovicku (Plzeňský kraj). *Archaeologia Historica, 33,* 85–100.

Vařeka, P., Holata, L., Rožmberský, P., & Schejbalová, Z. (2011). Středověké osídlení Rokycanska a problematika zaniklých vsí. *Archaeologia Historica, 36,* 319–342.

Vermouzek, R. (1985). Vyplavené vesnice na Tišnovsku a jižní Moravě. *Vlastivědný věstník moravský, 1,* 68–75.

Williamson, T. (2004). *Shaping medieval landscapes: Settlement, society, environment.* Macclesfield: Windgather Press.

Wischmeier, W. H., & Smith, D. D. (1965). *Rainfall-erosion losses from cropland east of the rocky mountains: Guide for selection of practices for soil and water conservation (Agricultur.).* Washington: U.S.Governmental Printing Office.

Wischmeier, W. H., & Smith, D. D. (1978). *Predicting rainfall erosion losses: A guide to conservation planning*. U.S. Department of Agriculture Handbook No. 537 (Agricultur.). Washington: U.S. Governmental Printing Office.

Zakšek, K., Oštir, K., Pehani, P., Kokalj, Ž., & Polert, E. (2012). Hill-shading based on anisotropic diffuse illumination. *GIS Ostrava 2012—Surface models for geosciences* (pp. 283–297), Ostrava, January 23–25, Ostrava: VŠB—Technical University of Ostrava.

Žemlička, J. (1980). *Vývoj osídlení dolního Poohří a Českého Středohoří do 14. století*. Praha: Academia.