Journal of Maps
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tjom20

Development of land use and main land use change processes in the period 1836-2006: case study in the Czech Republic

Hana Skokanová [a], Marek Havlíček [a], Roman Borovec [a], Jaromír Demek [a], Renata Eremiášová [a], Zdeněk Chrudina [a], Peter Mackovčin [a], Radovana Rysková [a], Petr Slavík [a], Tereza Stránská [a] & Josef Svoboda [a]

[a] Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Public Research Institute, Lidická 25/27, Czech Republic

Available online: 28 Mar 2012

To cite this article: Hana Skokanová, Marek Havlíček, Roman Borovec, Jaromír Demek, Renata Eremiášová, Zdeněk Chrudina, Peter Mackovčin, Radovana Rysková, Petr Slavík, Tereza Stránská & Josef Svoboda (2012): Development of land use and main land use change processes in the period 1836-2006: case study in the Czech Republic, Journal of Maps, 8:1, 88-96

To link to this article: http://dx.doi.org/10.1080/17445647.2012.668768

Journal of Maps
Vol. 8, No. 1, March 2012, 88–96

Routledge
Taylor & Francis Group

SCIENCE

Development of land use and main land use change processes in the period 1836–2006: case study in the Czech Republic

Hana Skokanová*, Marek Havlíček, Roman Borovec, Jaromír Demek, Renata Eremiášová, Zdeněk Chrudina, Peter Mackovčin, Radovana Rysková, Petr Slavík, Tereza Stránská and Josef Svoboda

Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Public Research Institute, Lidická 25/27, Czech Republic

(*Received 25 May 2011; Resubmitted 19 December 2011; Accepted 21 December 2011*)

Two different sets of maps, on a scale of 1:110,000, show the development of land use and main land use change processes in a 500 km^2 study area that occurred over the last 170 years. Analytical maps of land use were derived from old topographical military maps, as well as from base maps, using five time periods by the process of on-screen digitization. These analytical maps formed a basis for synthetic maps of land use change processes, number of changes, stably used areas and land use change trajectories. Maps of land use change processes record the spatial distribution of main processes that occurred between two adjacent time steps. The overall dynamics of land use changes are depicted in the map of land use change trajectories. The map of the number of changes shows how many times land use was changed in the given plot, while the map of stably used areas gives an idea of which land use categories did not change during the researched period.

Keywords: land use change; map; land use processes; Czech Republic; trajectories

1. Introduction

Besides studies that only consider land use from the most recent period (e.g. Campos & Priego-Santander, 2011; Chi, 2010; Di Lisio & Russo, 2010; Lopez-Garcia & Vega Guzman, 2010; Ramírez, Mirands, & Jiméne, 2007) there are a number of studies that research long-term development and changes in land use or land cover (e.g. Falťan & Bánovský, 2008; Levine & Kaufman, 2008; Olah, Bioltižiar, & Petrovič, 2006). These studies are of great importance because they help us to understand long-term dynamics of the landscape and fundamental transitions of land systems (e.g. forests – Kozak, 2003; Kozak, Estreguil, & Troll, 2007; or agricultural landscapes – Hamre, Domaas, Austad, & Rydgren, 2007; Lipský, 1995) as well as effects of past land uses on present landscape structure which is important in ecological research and nature conservation. Learning from the past via such long-term studies can be applied to landscape planning procedures in order to provide sound landscape management in the future (Jordan et al., 2005; Skalos et al., 2011). It is also fundamental for understanding a range of social, economic and environmental problems (Pelorosso, Leone, & Boccia, 2009).

Many land use change studies are based on cartographic documents, be it old maps (e.g. from the former Austrian-Hungarian Empire – Olah, 2000; Petek & Urbanc, 2004; Skokanová, 2008; Skaloš et al. 2011; Prussia – Haase, Walz, Neubert, & Rosenberg, 2007; Bender, Boehmer, Jens, & Schumacher, 2005; England – Swetnam, 2007, McLure & Griffiths, 2002; Italy – Agnoletti, 2007; Pelorosso et al., 2009; Norway – Hamre et al., 2007), aerial photographs (Fjellstad & Dramstad, 1999; Gerard et al., 2010) or satellite images (Milanova, Lioubimtseva, Tcherkashin, & Yanvareva, 1999; Weng, 2002). Advantages of using these sources lay mainly in the exact spatial distribution of landscape elements. On the basis of the cartographic documents it is also possible to identify gross changes (i.e. overall amount of land use change between two periods) and not only the net changes

*Corresponding author. Email: hskokan@email.cz

ISSN 1744-5647 online

http://dx.doi.org/10.1080/17445647.2012.668768
http://www.tandfonline.com

Table 1. Cartographic inputs and their characteristics.

Period	Name	Date of creation	Scale	Positional error
1840s	Second Austrian military survey	1836–1852	1:28,800	11–30 m
1870s	Third Austrian military survey	1876–1880	1:25,000	13–30 m
1950s	Czechoslovak military topographic maps	1952–1955	1:25,000	10–15 m
1990s	Czechoslovak military topographic maps	1988–1995	1:25,000	10–15 m
	Czechoslovak topographic base maps (ZABAGED 2)	1982–1996	1:10,000	5–10 m
2000s	Czech topographic base maps (ZABAGED)	2002–2006	1:10,000	5–10 m

(i.e. difference in land use between two periods) that are captured in land use statistics (e.g. settlement expansion and agricultural abandonment in the same region can result in zero forest cover change).

The presented maps, on a scale of 1:110,000, are an example of the results from research conducted at the authors' workplace. This research targets quantitative analyses of landscape development within the whole of the Czech Republic (more than 78,000 km^2) over the last 170 years, which is why such a large scale was used even though the raster inputs are originally of the finer scale (see Table 1). The outputs of the analyses, alongside others, are represented by analytical as well as synthetic maps, at moderate scales (1:100,000–1:250,000). Analytical maps depict reclassified raster inputs according to defined land use categories (see below) while synthetic maps represent results of further analyses based on the analytical maps.

2. Study area

The area in the presented maps is 500 km^2, and is situated in the eastern part of the Czech Republic, located between 49°05' N and 49°17' N, and 17°36' E and 17°58' E (Figure 1). The regional centre of Zlín is situated here.

The study area has a hilly relief with its lowest elevation at 202 m, highest elevation at 726 m, and an average elevation of 385 m. It is drained by three rivers and their tributaries. The dominant geology is flysch – a variation of sandstone, clay and puddingstone. The dominant soils are cambisols. The climate is mild with an annual mean temperature of 6–9 °C and annual mean precipitation of 600–926 mm.

Figure 1. Location of the case study.

Apart from the city of Zlín, there are three major towns in the area: Vizovice and Slušovice in the north, and Luhačovice in the south. There are also many smaller villages. Recreation and tourism are the dominant sources of income. The main industry is the footwear industry in Zlín, and fruit production in Vizovice and Slušovice. Luhačovice is a well-known spa centre.

3. Materials and methods

3.1 *Cartographic inputs*

Both analytical and synthetic maps were based on old, medium- to large-scale topographic maps from five periods of time: maps from the second Austrian Military Survey; maps from the third Austrian Military Survey; Czechoslovak military maps from the 1950s and 1990s; and Czech topographic maps from the 2000s. The case study was covered by six map sheets from the second and third Austrian Military Survey respectively and by 12 maps from the 1950s and 1990s, respectively.

Maps from the first four periods were originally in analogue form. They were scanned using a large-format scanner at a resolution of 400 dpi. They were subsequently transformed into the Coordinate System of the unified Czech/Slovak trigonometric cadastral net (S-JTSK) and mosaiced. For the transformation predefined global transformation keys and non-residual Jungman transformation (for more detail see e.g. Čada & Vichrová, 2009; Čada, 2006) as well as control points (minimum 4, average 8–14) and polynomial transformation of the first order were used. The Czech base maps from the 2000s were derived from a digital vector model ZABAGED (already rectified), which was created at the Czech Office for Surveying, Mapping and Cadastre. The same applied for the Czechoslovak topographic base maps from the 1990s (ZABAGED 2), which were used as a complimentary source of the military topographic maps as these significantly underestimated the area of permanent grassland (Broušek, 2011).

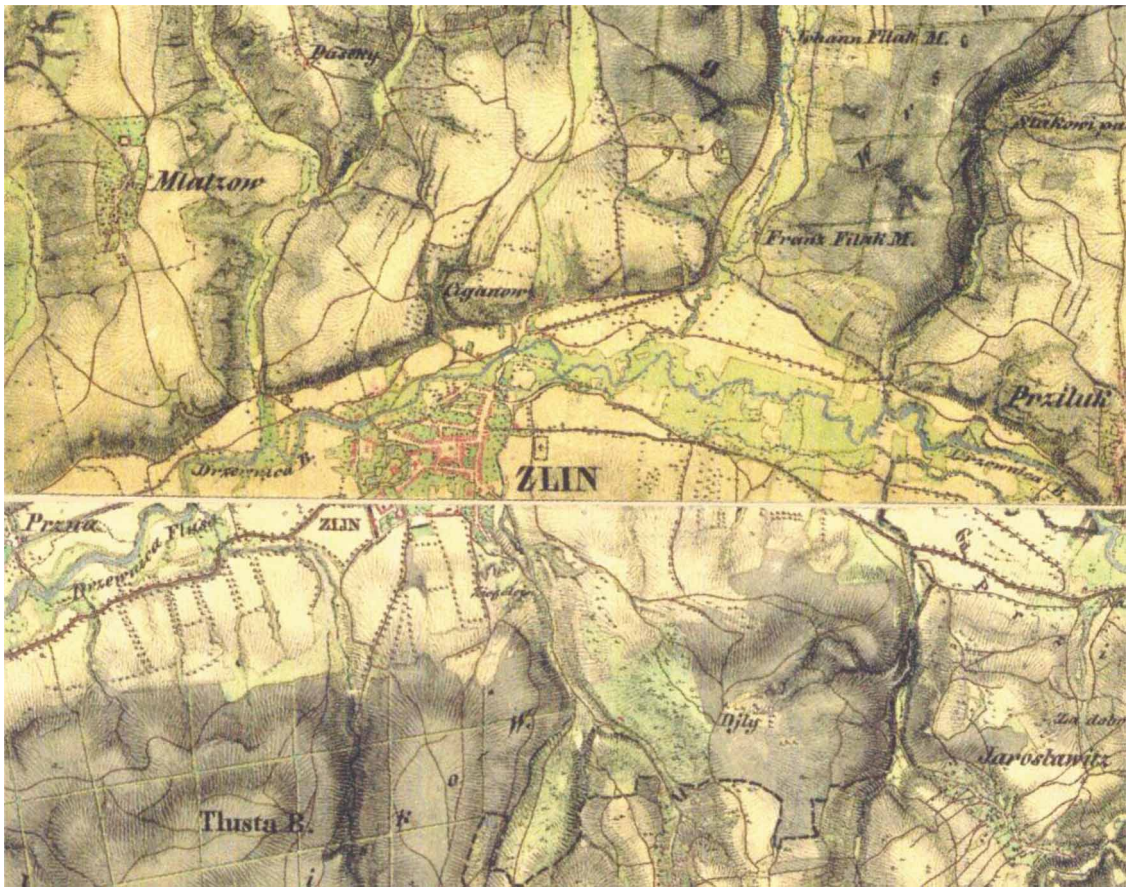

Figure 2. Example of second Austrian Military Survey map from year 1836 (Sources: Austrian State Archive/Military Archive, Vienna, Geoinformatics Laboratory, University of J. E. Purkyne, Ústí nad Labem).

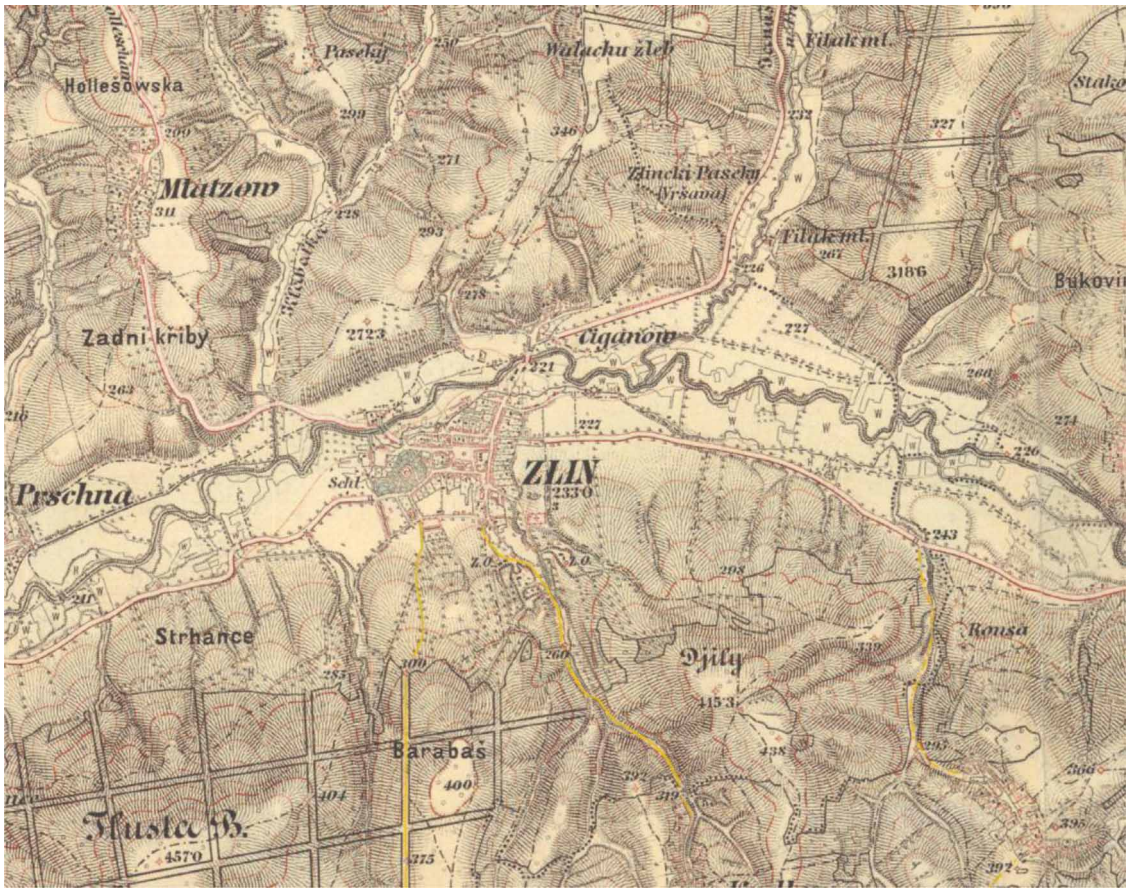

Figure 3. Example of third Austrian Military Survey map from year 1876 (Sources: Map Collection, Faculty of Science, Charles University in Prague, Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Pub. Res. Inst.).

Characteristics of the maps with positional errors are stated in Table 1. Examples of the original maps are shown in Figures 2–6.

3.2 *Analytical maps*

Analytical maps were created by on-screen digitization of cartographic inputs. Only polygons larger than 0.8 ha were digitized. This criterion was set with regard to output scale. A principle of generalization was applied owing to the output scale (e.g. at places where more polygons smaller than 0.8 ha were concentrated, a compact polygon of sufficient size should be created regardless of the actual boundaries of initial elements).

On the basis of legends to the cartographic inputs nine land use categories were distinguished (Mackovčin, 2009; Skokanová, 2009): arable land, permanent grassland, orchard, vineyard and hop field, forest, water area, built-up area, recreational area, and other area. These categories were then assigned to each digitized polygon according to the equivalent cartographic input.

3.3 *Synthetic maps*

Synthetic maps were derived from analytical maps by their overlay. By overlaying the analytical maps a geographic information system (GIS) database was created.

Maps of land use change processes were created by comparing land use change between two adjacent time periods. In total, nine types of processes were distinguished: transition into arable land, transition into permanent grassland, transition into orchard, transition into forest, transition into water area, transition into built-up area, transition into recreational area, transition into other area and areas in stable usage.

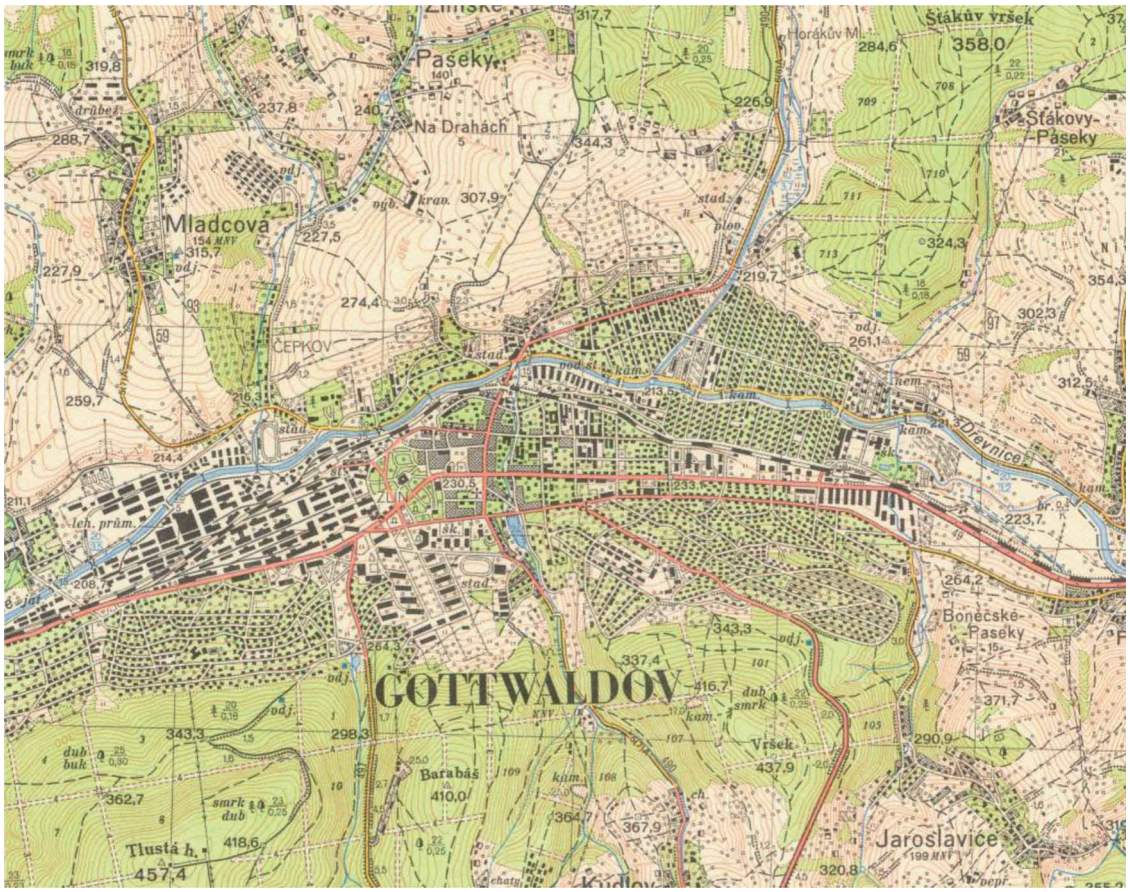

Figure 4. Example of Czechoslovak military topographic map from year 1956 (Sources: Department of Military Geography and Meteorology, University of Defence, Brno, Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Pub. Res. Inst.).

The map of land use change trajectories is based on the methodology called stability mapping, which systematically identifies those areas that have been most prone to land use change (Swetnam, 2007). It is based on the calculation of three indices – similarity, turnover and diversity – and distinguishes six classes of land use change categories: stable, quasi-stable, stepped, cyclical, dynamic, and with no constant trend. A brief description of these categories is shown in Table 2. For more detail see Swetnam (2007) and Skokanová (2009).

The map of the number of land use changes is based on the index turnover, calculated within the stability mapping. Turnover records how many changes occurred between the periods/maps used for the analysis. It can be zero when there was no change to four when the land use category for the particular polygon changed in every period.

The map of land use categories in stable usage further extends the stable class of land use change trajectories because it shows the exact land use categories that did not change throughout the research period.

4. Discussion and conclusions

Five analytical maps of land use from the five time periods show the spatial distribution of land use categories in the study area. Arable land was the prevalent land use category until the 1950s, while forest was the second largest category. Since then, forest prevailed and arable land was the second most widespread category. Forest was concentrated in large forest complexes in the north-west, central and south-east areas. Permanent grassland showed a decrease in its area until the 1950s followed by a rapid increase. The built-up area showed an accelerated increase in its area since the 1950s, mainly in the surroundings of all three towns. Recreational area, which occurred first in the 1950s, is also concentrated in the surroundings of all three towns.

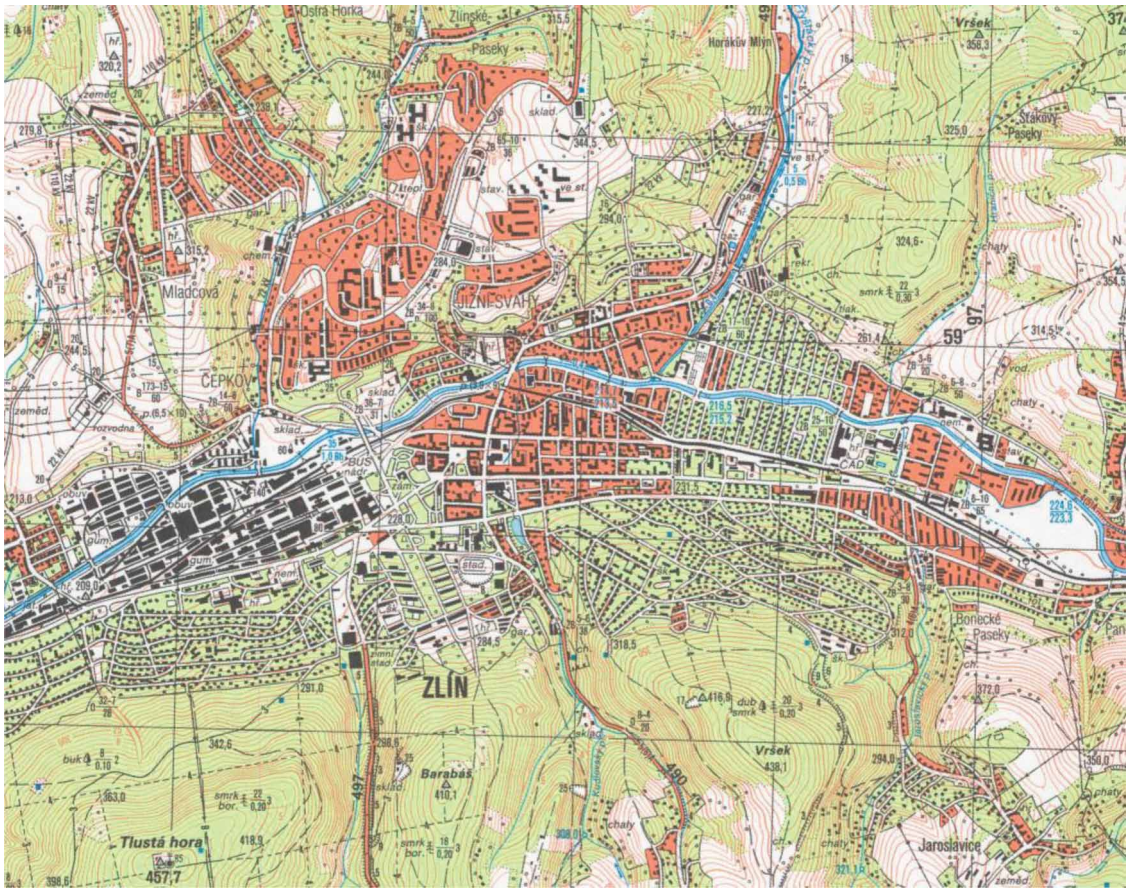

Figure 5. Example of Czechoslovak military topographic map from year 1991 (Sources: Military Geography and Hydrometeorology Office, Dobruška, Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Pub. Res. Inst.).

Four maps of land use change processes give a clearer insight into the changes of land use categories and which processes were dominant in which period. The map of land use change processes occurring between the 1840s and 1870s reflects transition into arable land as a part of agricultural intensification, which peaked in the second half of the nineteenth century, and the beginning of transition into forest, caused by the increased price of wood, together with changes in the understanding of forest functions (Bičík et al., 1996; Jeleček, 1995). Both processes can also be seen in the map from the following period. Transition into forest slightly prevails and is typical for the eastern part of the study area. The third significant process is transition into built-up area, which is concentrated around Zlín and Luhačovice. The map of land use change processes that occurred between the 1950s and 1990s shows a significant increase in area converted into permanent grassland, which is spread all over the study area. This process was strongly supported by environmental legislation, especially the introduction of the Landscape Care Programme. Transition into built-up area around Zlín continued and it also affected Slušovice. The fourth map of land use change processes shows continuing transition into permanent grassland, but the process is not as intensive as in the previous map.

The map of land use change trajectories represents the overall dynamics of land use changes. Areas of stable usage cover more than 48% and are expressed by large complexes of forest and arable land and cores of settlements. They are distributed more or less evenly throughout the study area, with the exception of the north-east (see also map of land use categories in stable usage). The second most common land use change trajectory is represented by the stepped class, occurring around Zlín, north of Luhačovice and in the north-east. Other classes do not show large clusters and are scattered all over the study area.

Land use categories usually only changed once or twice and the changes tended to be situated in river valleys, as is clear from the map of the number of changes.

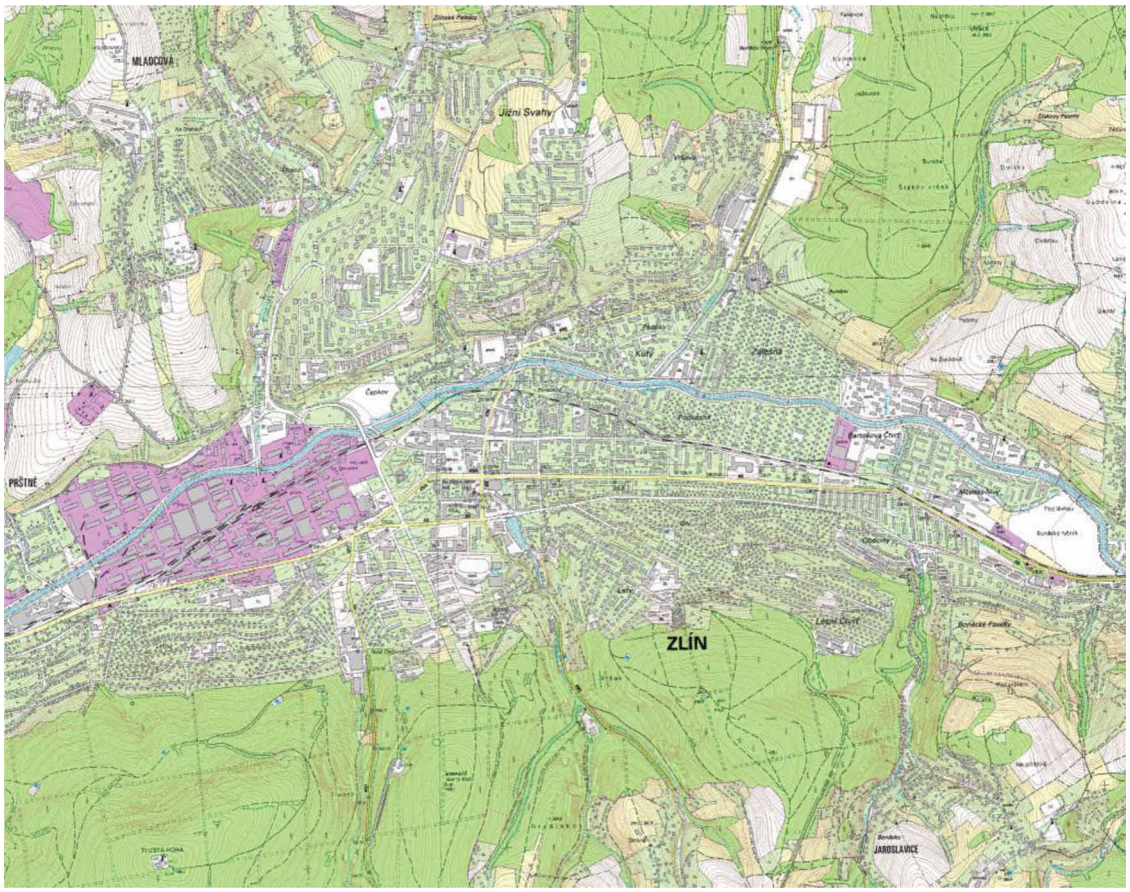

Figure 6. Example of Czech topographic base map from year 2006 (Source: Czech Office for Surveying, Mapping and Cadastre).

Table 2. Land use change trajectories – description and examples.

Land use change trajectory	Description	Example
Stable	same land use category in each time period	AAAAA
Quasi-stable	1 dominant category with 1 change	ABAAA
Stepped	1 change between 2 dominant categories	AAABB
Cyclical	frequent change between 2 categories	ABABA
Dynamic	frequent change among more than 3 categories	ABCDB
With no constant trend	variable change, some repetition can occur	ABBCA

The presented maps have several potential uses. Besides the fact that they give clear evidence of the major processes affecting landscape changes in the past which subsequently explain present landscape pattern, they can be used in spatial and environmental planning, or for modelling the possible development of land use in the future. These maps also allow identification of areas with potential higher biodiversity that are suitable for nature conservation or areas suitable for ecological restoration.

Software

For rectification of the maps from second and third Austrian Military Surveys, a programme MATCART developed at the Czech Technical University in Prague was used. Newer maps were rectified in the ESRI ArcGIS 9.2.

ESRI ArcView 3.3, ArcGIS 9.1, 9.2 and 9.3 were used for digitization. Synthetic maps were created using ESRI ArcGISInfo 9.2.

Acknowledgements

The research was conducted within research project MSM 6293359101, 'Research into sources and indicators of biodiversity in cultural landscape in the context of its fragmentation dynamics', supported by the Czech Ministry of Education, Youth and Sports.

References

Agnoletti, M. (2007). The degradation of traditional landscape in a mountain area of Tuscany during the 19th and 20th centuries: Implications for biodiversity and sustainable management. *Forest Ecology and Management*, *249,* 5–17, doi:10.1016/j.foreco.2007.05.032.

Bender, O., Boehmer, H.J., Jens, D., & Schumacher, K. (2005). Analysis of land-use change in a sector of Upper Franconia (Bavaria, Germany) since 1850 using land register records. *Landscape Ecology*, *20,* 149–163, doi:10.1007/s10980-003-1506-7.

Bičík, I., Götz, A., Jančák, V., Jeleček, L., Mejsnarová, L., & Štěpánek, V. (1996). Land use/land cover changes in the Czech Republic 1845–1995. *Geografie-sborník české geografické společnosti*, *101,* 92–109.

Břoušek, l. (2011). Šest desetiletí vojenského zeměměřictví v Dobrušce. . .a něco navíc [Six decades of military surveying in Dobruška. . . and something more]. *Vojenský geografický obzor*, 2, Vojenský geografický a hydrometeorologický úřad, 169. (*in Czech*).

Čada, V. (2006). Evaluation of positional and geometric accuracy of Second Military Survey elements georeferenced in the S-JTSK coordinate system. In R. Šimůnek (Ed.), Historická geografie [Historical geography], Supplementum I., 2006 Praha. Historický ústav, 82–105. (*in Czech*).

Čada, V., & Vichrová, M. (2009). Horizontal control for stable cadastre and second military survey (Franziszeische Landesaufnahme) in Bohemia, Moravia and Silesia. *Acta geodaetica et geophysica Hungarica*, *44,* 105–114, doi:10.1556/AGeod.44.2009.1.10.

Campos, M., & Priego-Santander, A. (2011). Biophysical landscapes of a coastal area of Michoacan state in Mexico. *Journal of Maps*, *6,* 42–50, doi:10.4113/jom.2011.1098.

Chi, G. (2010). Land developability: Developing an index of land use and development for population research. *Journal of Maps*, *6,* 609–617, doi:10.4113/jom.2010.1146.

Di Lisio, A., & Russo, F. (2010). Thematic maps for land use planning and policy decisions in the Calaggio Stream Catchment Area. *Journal of Maps*, *6,* 68–83, doi:10.4113/jom.2010.1105.

Falťan, V., & Bánovský, M. (2008). Changes in land cover in the area of Vyšné Hágy-Starý Smokovec, impacted by the wind calamity in November 2004 (Slovakia). *Moravian Geographical Reports*, *16,* 16–26.

Fjellstad, W.J., & Dramstad, W.E. (1999). Patterns of change in two contrasting Norwegian agricultural landscapes. *Landscape and Urban Planning*, *45,* 177–191, doi:10.1016/S0169-2046(99)00055-9.

Gerard, F., Petit, S., Smith, G., Thomson, A., Brown, N., Manchester, S., et al. (2010). Land cover change in Europe between 1950 and 2000 determined employing aerial photography. *Progress in Physical Geography*, *34,* 183–205, doi:10.1177/0309133309360141.

Haase, D., Walz, U., Neubert, M., & Rosenberg, M. (2007). Changes to Central European landscapes – Analysing historical maps to approach current environmental issues, examples from Saxony, Central Germany. *Land Use Policy*, *24,* 248–263, doi:10.1016/j.landusepol.2005.09.003.

Hamre, L.N., Domaas, S.T., Austad, I., & Rydgren, K. (2007). Land-cover and structural changes in a western Norwegian cultural landscape since 1865, based on an old cadastral map and field survey. *Landscape Ecology*, *22,* 1563–1574, doi:10.1007/s10980-007-9154-y.

Jeleček, L. (1995). Land use changes in the Czech Republic 1845-1995: Main trends and some broader consequences. *Sborník České gegrafické společnosti*, *100,* 276–291, (*in Czech*).

Jordan, G., Van, R.A., Szilassi, P., Csillag, G., Mannaerts, C., & Woldai, T. (2005). Historical land use changes and their impact on sediment fluxes in the Balaton Basin (Hungary). *Agriculture, Ecosystem and Environment*, *108,* 119–133, doi:10.1016/j.agee.2005.01.013.

Kozak, J. (2003). Forest cover change in the Western Carpathians in the Past 180 years. *Mountain Research and Development*, *23,* 369–375, doi:10.1659/0276-4741(2003)023[0369:fccitw]2.0.co;2.

Kozak, J., Estreguil, C., & Troll, M. (2007). Forest cover changes in the northern Carpathians in the 20th century: A slow transition. *Journal of Land Use Science*, *2,* 127–146, doi:10.1080/17474230701218244.

Levine, N.S., & Kaufman, C.C. (2008). Land use, erosion, and habitat mapping on an Atlantic Barrier Island, Sullivan's Island, South Carolina. *Journal of Maps*, *4,* 161–171, doi:10.4113/jom.2008.1016.

Lipský, Z. (1995). The changing face of the Czech rural landscape. *Landscape and Urban Planning*, *31,* 39–45, doi:10.1016/0169-2046(94)01034-6.

Lopez-Garcia, J., & Vega Guzman, A. (2010). Vegetation and land use 2009 Monarch Butterfly Biosphere Reserve, Mexico. *Journal of Maps*, *6,* 665–673, doi:10.4113/jom.2010.1123.

Mackovčin, P. (2009). Land use categorization based on topographic maps. *Acta Pruhoniciana*, *91,* 5–13.

McLure, J.T., & Griffiths, G.H. (2002). Historic landscape reconstruction and visualisation, West Oxfordshire, England. *Transactions in GIS*, *6,* 69–78, doi:10.1111/1467-9671.00095.

Milanova, E.V., Lioubimtseva, E.Y., Tcherkashin, P.A., & Yanvareva, L.F. (1999). Land use/cover change in Russia: Mapping and GIS. *Land Use Policy*, *16,* 153–159, doi:10.1016/S0264-8377(99)00011-3.

Olah, B. (2000). Možnostia využitia historických máp a záznamov pri štúdiu zmien využitia zeme [Possibilities of using historical maps and records in the research of land use changes]. *Acta Facultatis Ecologiae*, *7,* 21–26. (in Slovak).

Olah, B., Bioltižiar, M., & Petrovič, F. (2006). Land use changes' relation to georelief and distance in the East Carpathians biosphere reserve. *Ekológia (Bratislava)*, *25,* 68–81.

Pelorosso, R., Leone, A., & Boccia, L. (2009). Land cover and land use change in the Italian central Apennines: A comparison of assessment methods. *Applied Geography*, *29,* 35–48, doi:10.1016/j.apgeog.2008.07.003.

Petek, F., & Urbanc, M. (2004). The Franziscean land cadastre as a key to understanding the 19th-Century cultural landscape in Slovenia. *Acta Geographica Slovenica*, *44,* 89–113, doi:10.3986/AGS44104.

Ramírez, M.I., Mirands, R.R., & Jiméne, Z. (2007). Land cover and road network map for the Monarch Butterfly Reserve in Mexico, 2003. *Journal of Maps*, *2,* 181–190, doi:10.4113/jom.2007.60.

Skalos, J., Weber, M., Lipský, Z., Trpáková, I., Santrucková, M., Uhlírová, L., et al. (2011). Using old military survey maps and orthophotograph maps to analyse long-term land cover changes: Case study (Czech Republic). *Applied Geography*, *31,* 426–438, doi:10.1016/j.apgeog.2010.10.004.

Skokanová, H. (2008). Land use changes of river Dyje floodplain in reaches Nový Přerov-Brod and Dyjí and Nové Mlýny-Lednice, Czech Republic, in the period of 1830–2001 as a reaction to the river Dyje channel regulations. *Ekológia*, *27,* 82–98.

Skokanová, H. (2009). Application of methodological principles for assessment of land use changes trajectories and processes in South-Eastern Moravia for the period 1836–2006. *Acta Pruhoniciana*, *91,* 15–21.

Swetnam, R.D. (2007). Rural land use in England and Wales between 1930 and 1998: Mapping trajectories of change with a high resolution spatio-temporal dataset. *Landscape and Urban Planning*, *81,* 91–103, doi:10.1016/j.landurbplan.2006.10.013.

Weng, Q. (2002). Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modelling. *Journal of Environmental Management*, *64,* 273–284, doi:10.1006/jema.2001.0509.