COMPARATIVE ANALYSIS OF THE IMPACT OF SLOPE INCLINATION AND ALTITUDE ON LONG-TERM LAND USE CHANGES IN CZECHIA

PŘEMYSL ŠTYCH

Department of Applied Geoinformatics and Cartography, Faculty of Science, Charles University in Prague

ABSTRACT

The aim of this article is to compare the effects of altitude and slope inclination on the spatial distribution of selected categories of land use. This study is based on Czechia's LUCC database 1845–1948–1990–2000. The database contains nearly 9,000 basic territorial units (BTUs) and 8 LUCC categories that can be compared in all of the time periods mentioned. For the purpose of calculating the average altitude and slope inclination of all BTUs, a digital terrain model (DTM) of Czechia was created using interpolation methods. The average altitude and slope inclination of each BTU constituted the primary input variables for the correlation analysis. The strength of the relationship between these factors and the relevant categories was examined. Evidence concerning the increasing significance of inclination in the spatial distribution of arable land and grasslands after 1948 may be the most important finding. While in 1845, the first year in the database, altitude basically determined the location of arable land; after the World War II, there was a turn in this trend. Mainly in connection with the development of agro-industrial forms (the introduction of modern heavy machinery, the automation of modern cultivation methods, etc.), inclination became more important in determining the abandonment of arable land.

Key words: land use, land cover, Czechia, altitude, inclination

1. Objectives, data and methodology

The main objective of this article is to determine the level of significance of altitude and inclination for the years 1845–1948–1990–2000. Using correlation methods, this research intends to determine whether altitude has had more significant influence on land use changes than inclination. The primary research question is whether the correlation between the portions of observed land use categories and the average altitude of a BTU is more significant than the correlation between portions of observed land use categories and the average slope inclination, or vice versa? How did these correlations change over the period from 1845 to 2000?

The investigation was based on utilisation of the LUCC Czechia Database 1845–1948–1990–2000, which has been compiled by the research team at the Faculty of Science in Prague (detailed information about the database and its methodology has been published previously, e.g. Bičík (1991)). The database contains nearly 9,000 BTUs (average size 7 km^2), which are comparable for all the time periods. The database is divided into 8 LUCC categories (Table 1).

For the purpose of calculating the average altitude and inclination of all BTUs, a digital terrain model (DTM) of Czechia was created, using interpolation methods (Spline). A GIS layer of contour lines (50 meter interval) from ArcČR 500 datasets provided the basic information for the DTM. The average altitude and inclination of all BTUs were calculated using ArcGIS software. The territory of Czechia was divided into raster format (squares of 50 × 50 m) for the purpose of calculating average altitude. Inclination was calculated for a 250 × 250 m raster grid. The arithmetic average of all pixels located within the territory of a BTU represents its average altitude and inclination. Average values were calculated using the Zonal Statistics tool in ArcGIS. Figures 1 and 2 show the distribution of BTUs according to inclination and altitude.

Tab. 1 Land use categories in the LUCC Czechia database

Category	Arable land	Forest areas	Built-up areas
	Permanent cultures		Water areas
	Permanent grassland		Remaining areas
Group category	**Agricultural land**	**Forest areas**	**Other areas**

Source: LUCC Czechia database and the author's calculations

The statistical method of correlation analysis was used in this study. In a broad sense, the word "correlation" refers to the degree of association of two variables. Two variables are correlated (or associated) if certain values of one variable tend to occur together with certain values of the other variable. Correlation analysis examines the relationship of variables graphically, using various measures of dependence, which we call correlation coefficients (Hendl 2004). The linear correlation coefficient (R) was calculated between the values of the given characteristics and the portion of a given category within the total area of a unit. The Pearson correlation coefficient was used to describe the strength

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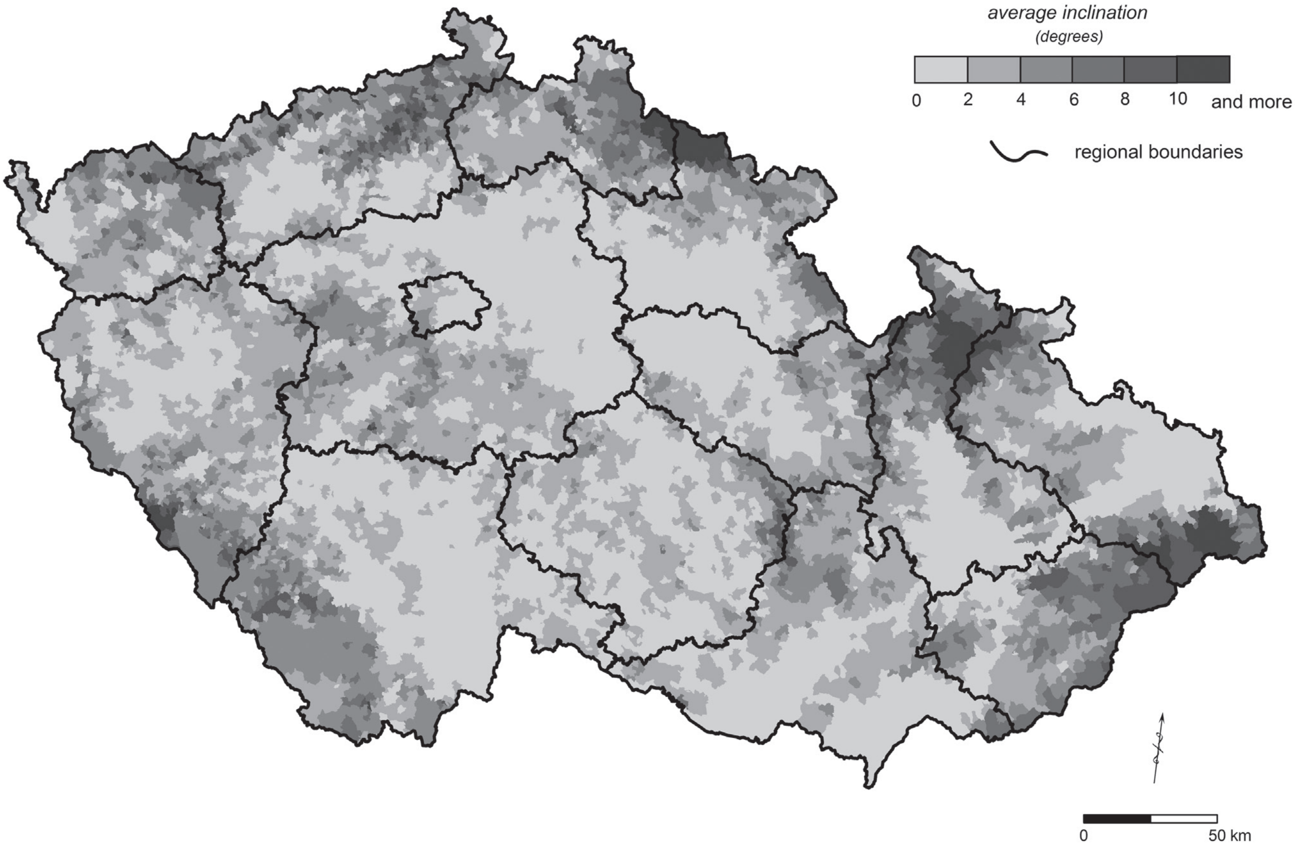

Fig. 1 Division of BTUs according to inclination
Source: LUCC Czechia database, ArcCR 500 and the author's calculations

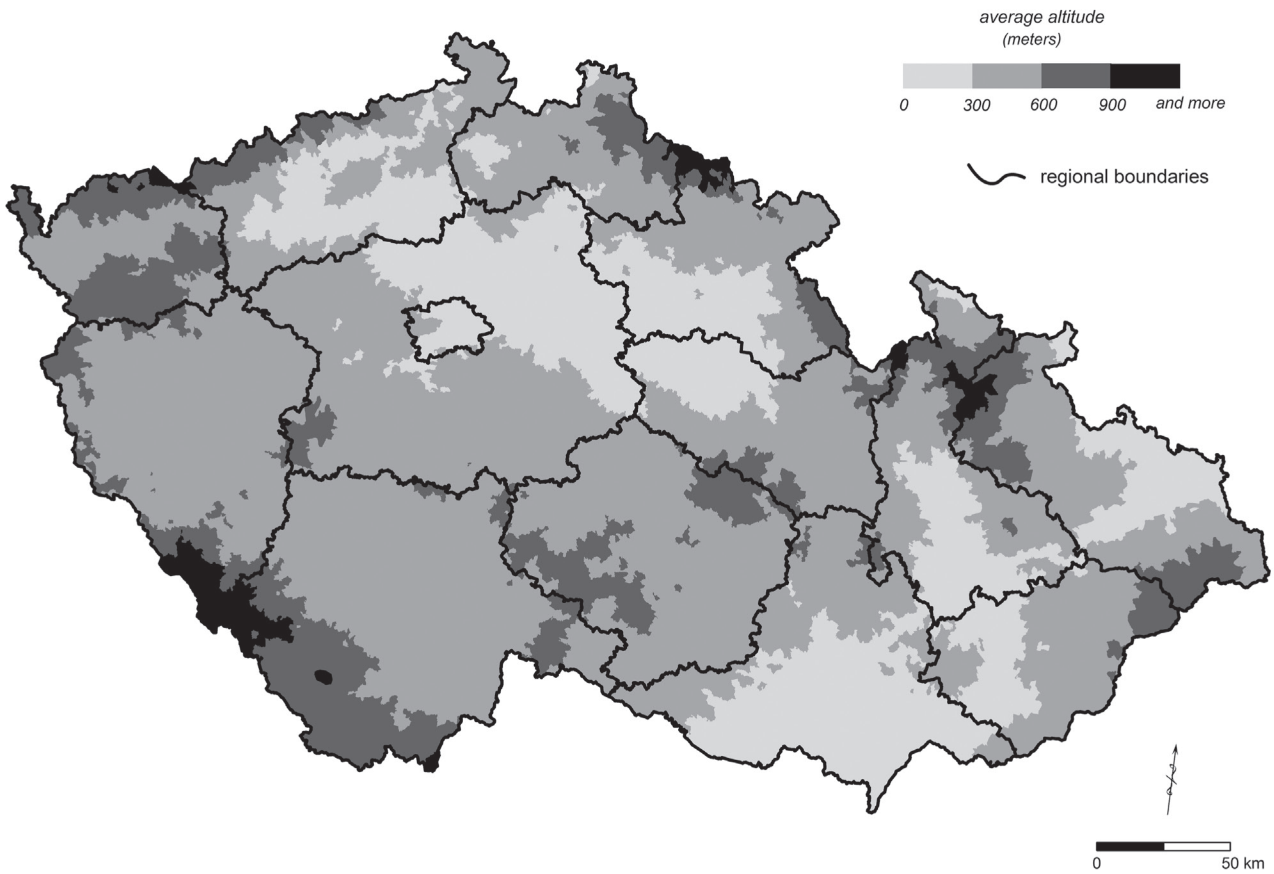

Fig. 2 Division of BTUs according to altitude
Source: LUCC Czechia database, ArcCR 500 and the author's calculations

of relationships. It acquires values from −1.0 to 1.0. R = 0.0 indicates independence, the closer the value R is to 1 or −1, the stronger the dependence is. Positive values indicate positive and negative values indicate negative impacts of the independent variable (factor) on the dependent variable (land use). The average altitude and inclination for each BTU are the primary input variables in the correlation analysis. The strength of the relationship between these factors and the relevant categories were examined. Portions of arable land, permanent grassland, agricultural land, forest and built-up areas in the total area of the Czechia were selected.

The purpose of the research was to ascertain the objective significance of any existing influence as well as how the significance of the two factors changed for the years 1845, 1948, 1990 and 2000. The large number of units used (over 8,900) made correlations statistically significant. The development of the correlation of both factors was evaluated by comparin values from these 4 time periods. According to Kabrda (2003), this method is more straightforward and statistically more reliable than using development indexes. The results presented in graphs show changes in the correlation coefficient (i.e. the degree of dependence) between the various factors and the spatial proportions of selected categories for the years 1845, 1948, 1990 and 2000. The research procedure was as follows: 1. define the degree to which land use categories depend on the given factor (degree of dependence), and 2. compare the degree of influence of both relief characteristics on the distribution of land use categories over time.

The correlation coefficient method is transparent, but it has some negative aspects. For the sake of simplicity, linear correlation is used exclusively. In most cases, however, it does not fully capture the shape of the dependence. Like average or standard deviation, the correlation coefficient is highly influenced by outlying values. Above all, changes to the correlation coefficient may be influenced by various factors; different processes can hide behind visible change. For example, the increasing dependence of reforestation on altitude may be due to deforestation in the lowlands or to reforestation in hilly places, or both, etc. (Kabrda 2003). The existence of a correlation, no matter how strong, does not prove a causal relationship. It is important to note that factors enter into the evaluation separately. In the final evaluation we have to account for the fact that any change is caused jointly by a number of factors, both internal and external (see Bičík et al. 2001, or Bičík and Kupková 2002). If factors enter into the analysis separately, it is important to keep their interdependencies in mind, as well.

2. Results

Before presenting the results, it is necessary to comment on the mutual correlation of inclination and altitude. Results comparing the effect of both factors are strongly influenced by the fact that inclination and altitude show a relatively strong correlation with each other. The value of the correlation coefficient for inclination and altitude, for all BTUs, was calculated as 0.44.

Results concerning the correlation coefficient for agricultural land, arable land and permanent grassland are presented first. In the case of arable land it is interesting to compare the development of coefficient values in the observed years (Figure 1). In 1845, the coefficient approached −0.45 for both factors; it was slightly higher for inclination and slightly lower for altitude. By 1948, the strength of both negative correlations, inclination and altitude, had increased. The inclination coefficient decreased to almost −0.5, while the altitude coefficient decreased to −0.55. Parallel developments had been recorded until this year. After 1948, a significant reversal is evident in the development of the coefficient values. The Influence of inclination has increased drastically (the correlation coefficient dropped below −0.6), whereas the value of the altitude correlation has declined, again approaching −0.5. The development curves for inclination and altitude intersected one another. Therefore, it is possible to argue that, since 1948, inclination has, to a greater degree, determined the extent of arable land. Inclination has proven more significant than altitude as a factor encouraging the abandonment of arable land. The value of the correlation coefficient for altitude decreased over the 1948–1990 period. We can interpret this result to mean that the value of inclination had a greater impact on the spatial determination of loss of arable land, as recorded after 1948, than altitude. The significant decline of arable land has continued after 1990. Comparing correlation coefficient values between 1990 and 2000, both altitude and inclination values decrease with the coefficient of altitude decreasing more dynamically to fall below −0.55.

The correlation coefficient describing permanent grassland reached positive values in the observed years,

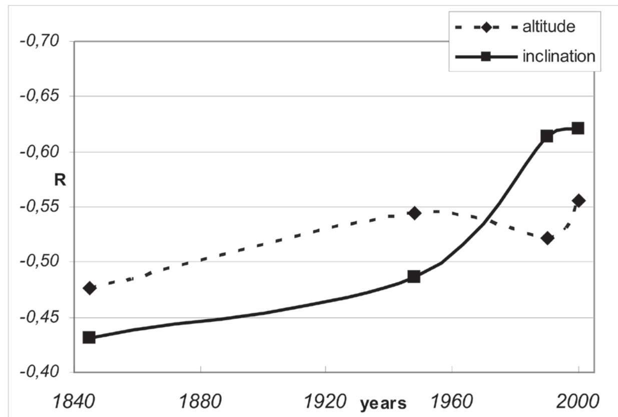

Fig. 3 The correlation R for arable land based on altitude and inclination in the years 1845, 1948, 1990 and 2000
Source: LUCC Czechia database and the author's calculations

both in terms of inclination and altitude (Figure 2). It is interesting to compare the development of values of the correlation coefficient between the examined factors. The results show that in the first examined year, 1845, altitude determined the extent of permanent grassland much more than inclination. The inclination coefficient is lower than 0.1, the altitude coefficient is close to 0.4. Over one hundred years later, in 1948, both the inclination and altitude coefficients had increased (altitude slightly more). The value of altitude grew to 0.5, inclination exceeded 0.1 and approached 0.2. As in the case of arable land, the breaking point in the development of the coefficient occurred during the 1948–1990 period. The value of the inclination correlation coefficient increased significantly (from 0.17 to 0.38), whereas the altitude coefficient decreased to 0.43. Since 1990, the values have begun to differentiate, with the altitude coefficient rapidly rising to 0.5 (thus initiating a return to the 1948 value). The value of the inclination coefficient also increased, albeit much more moderately.

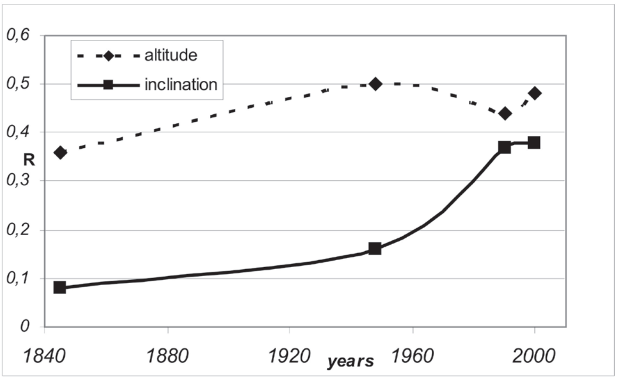

Fig. 4 The correlation R for permanent grassland based on altitude and inclination in the years 1845, 1948, 1990 and 2000
Source: LUCC Czechia database and the author's calculations

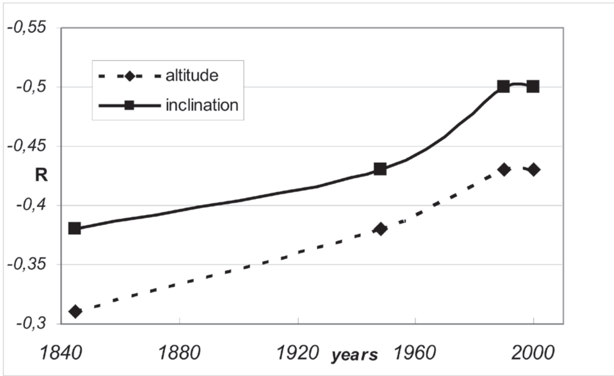

Fig. 5 The correlation R for agricultural land based on altitude and inclination in the years 1845, 1948, 1990 and 2000
Source: LUCC Czechia database and the author's calculations

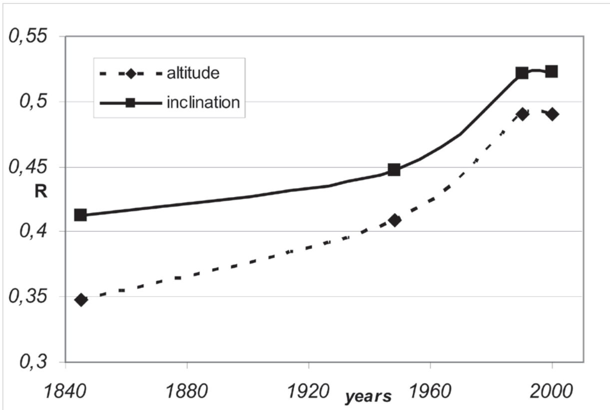

Fig. 6 The correlation R for forest areas based on altitude and inclination in the years 1845, 1948, 1990 and 2000
Source: LUCC Czechia database and the author's calculations

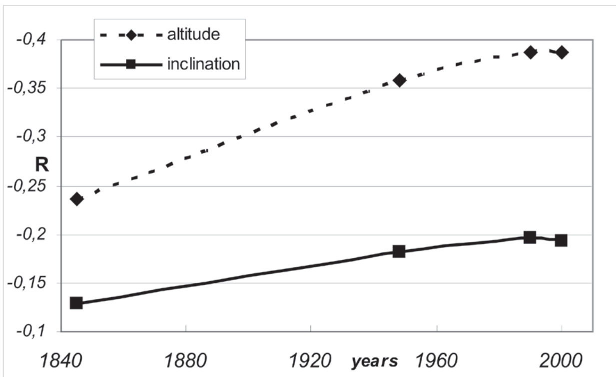

Fig. 7 The correlation R for built-up areas based on altitude and inclination in the years 1845, 1948, 1990 and 2000
Source: LUCC Czechia database and the author's calculations

In the case of agricultural land (Figure 3), an aggregate category consisting of arable land, grassland and permanent crops, growth of negative correlations for both factors can be seen. The decrease in coefficient values, during the period from 1845 to 2000, was almost identical for both of the factors (−0.15). Inclination proved to be a more significant factor than altitude for the duration of the monitored period. The separation between the two factors has remained de facto the same.

Forests have shown trends similar to those observed for agricultural land. A positive correlation was documented for this category (Figure 4). As with agricultural land, inclination had a higher degree of dependency but, during the last reporting periods, the altitude coefficient began to approach the values of inclination.

Built-up areas were the last category examined. The results of the correlation analysis (Figure 5) show that, in 1845, altitude demonstrated a rate of dependency higher than inclination. The correlation of both factors had a negative character. During the examined years, the altitude coefficient decreased more dynamically. In 1845, it started with a value of −0.24, by 1990, it had decreased to −0.4. The value for inclination had decreased to −0.2 by 1990. A slight increase in coefficient values is documented for both factors, after 1990. The results show that, in both the initial and terminal year, altitude was a stronger factor in determining the spatial proportion of built-up areas than inclination, with a distinct trend of deepening differences.

3. Conclusion

The selected method monitored correlation values (the strength of the relationship) between both altitude and inclination and the selected variables (shares of land-use categories) in the examined years.

This evaluation of long-term land use change and its dependence on characteristics of relief provides some interesting results. The most important result may be evidence concerning the increasing significance of inclination on the spatial distribution of arable land and grassland, after 1948. While in the first year, 1845, altitude fundamentally determined the location of arable land, according to the Pearson correlation coefficient, after the World War II, this trend changed. Mainly in connection with the development of agro-industrial forms (the introduction of modern heavy machinery, the automation of modern cultivation methods, etc.), inclination became more important in determining the abandonment of arable land. Despite the tendency to utilise the maximum extent of arable land, during the communist regime, areas with high inclination saw reforestation and the renewal of grasslands. At that time, attention has focused on low inclination areas where ameliorative measures were applied; however, such efforts could not recoup the arable land lost in sloped areas. On the other hand, reductions in arable land and increases in grassland and forest areas were influenced by the marginalisation of mountainous and sub-mountainous areas and by the transfer of Czech Germans out of most of the borderlands, after 1945.

Undoubtedly, the character of relief has been a significant natural factor impacting the spatial distribution of socio-economic activities. Nevertheless, the weight of this factor has changed with the development of society. The general trend has been the concentration of the agrarian sector into favourable areas, despite the special subsidies and taxes to support the agrarian sector in the LFA from 1948 to 1990. Forest management can be mentioned as an example of concentration into unfavourable areas with higher inclination. Many places with high inclination and altitude are protected and governed by national parks or protected landscape areas. Human economic activities have been reduced in such locations. Areas have also shifted due to recreational use.

When the obtained results are compared with foreign, similarly oriented studies, several common trends can be seen. Hurbánek (2005) evaluates land use changes and the development of settlements in peripheral areas and reveals a significant correlation between depopulation and decrease of land use intensity in areas with a mountainous or sub-mountainous relief. Trends concerning the polarization of land use changes, related to the abandonment of agricultural land in less-favoured areas and the concentration of human activities in favourable (exposed) areas were demonstrated in the findings of Slovenian authors (Gabrovec and Kladnik 1997) and by research carried out in Austria (Krausman et al. 2003).

When critically assessing the chosen methodology of calculating the altitudes and the inclination for basic territory units, some negative points should be mentioned. Especially in the case of inclination, values are strongly averaged. Significant differences could have been scaled down. The selected range of the smallest square, 250 × 250 m, in the analysis raster surface for inclination also led to a reduction in the terminal values. The calculation of average values for unequal units influenced the output value. Despite these negative aspects, the methodology appears to be sufficient because a certain degree of generalisation of values for such a large area, the entire territory of Czechia, is desirable.

The results are consistent with basic theoretical concepts (Hampl 1998 and 2003). The main long-term trends in land use changes observed, i.e. the gradual concentration of built-up areas and arable land in exposed areas, with the decline of built-up areas and the growth of forest and grassland areas in locations with unfavourable natural conditions, correspond with the development of the integration of social organization, as well as with the development of the relationship between humans and nature and the significant shift from the exploration to the cooperative stage.

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REFERENCES

BIČÍK, I. (1991): K metodice hodnocení využití ploch. In: Geografie zemědělství II. Katedra sociální geografie a regionálního rozvoje Přírodovědecké fakulty Univerzity Karlovy, Praha, p. 76–87.

BIČÍK, I., JELEČEK, L., ŠTĚPÁNEK, V. (2001): Land-Use Changes and their Social Driving Forces in Czechia in the 19th and 20th Centuries. Land Use Policy, 18, n. 1, p. 65–73.

BIČÍK, I., KUPKOVÁ, L. (2002): Long term changes in land use in Czechia based on the quality of agricultural land. In: I. Bičík et al. (eds.), Land Use/Land Cover Changes in the Period of Globalization. Proceedings of the IGU-LUCC International Conference Prague 2001, Prague, p. 31–43.

GABROVEC, M., KLADNIK, D. (1997): Some new aspects of Land Use in Slovenia. Geografski sbornik – Acta Geographica 37, p. 7–64.

HAMPL, M. (1998): Realita, společnost a geografická organizace. Hledání integrálního řádu. Univerzita Karlova, Praha, 110 p.

HAMPL, M. (2003): Diferenciace a zvraty regionálního vývoje Karlovarska: unikátní případ nebo obecný vzor? Sborník ČGS, n. 3, Praha, p. 5–16.

HENDL, J. (2004): Přehled statistických metod zpracování dat. Portál, Praha, 584 p.

HURBÁNEK, P. (2005): Vývoj a nové prístupy v interpretáciách vidieka: priestorový aspekt, perifémosť a koncentrovanosť systému osídlenia. In: Spišiak, P. et al.: Agrorurálne štruktúry Slovenska po roku 1989. Geo-grafika, Bratislava, p. 95–114.

KABRDA, J. (2003): Faktory ovlivňující vývoj využití ploch v kraji Vysočina od poloviny 19. století. Magisterská práce. KSGRR PřF UK, Praha, 112 p. + addendum.

KRAUSMANN, F., HABERL, H., SCHULZ, N. B., ERB, K., DARGE, E., GAUBE V. (2003): Land-use change and socio-economic metabolism in Austria – Part I: driving forces of land-use change: 1950–1995. Land Use Policy, 20, n. 1, p. 21–39.

RNDr. Přemysl Štych, Ph.D.
Charles University in Prague
Faculty of Science
Department of Applied Geoinformatics and Cartography
Albertov 6
128 43 Prague 2
Phone: + 420 221 951 406
E-mail: stych@natur.cuni.cz

RÉSUMÉ

Komparativní analýza vlivu sklonitosti a nadmořské výšky na dlouhodobé změny krajiny Česka

Hlavním cílem tohoto článku bylo porovnat vliv nadmořské výšky a sklonitosti na prostorovém rozmístění vybraných kategorií land use v období 1845–2000. Pomocí korelačních metod bylo hodnoceno, zdali nadmořské výšky měly větší vliv na změny land use než sklonitost. Základním zdrojem dat o vývoji změn využití ploch v časových horizontech 1845, 1948, 1990 a 2000 byla LUCC Czechia databáze. Údaje o průměrných nadmořských výškách a průměrných sklonitostí zkoumaných ZÚJ byly vypočteny v GIS z digitálního modelu terénu. Užitá statistická metoda byl výpočet lineárního korelačního koeficientu (R) mezi hodnotou dané reliéfní charakteristiky a podílem dané kategorie využití ploch na celkové rozloze. Za nejdůležitější výsledek možno považovat důkaz o evidentním zvýšení významnosti sklonitosti na prostorové rozložení orné půdy a trvalých travních porostů po roce 1948. Zatímco v prvním sledovaném období 1845–1948 nadmořská výška zásadněji určovala výskyt orné půdy, po druhé světové válce došlo k obratu. Převážně v souvislosti s rozvojem industriální formy agrokomplexu (zavedení moderní těžké mechanizace, automatizace moderních pěstebních postupů…) se sklonitost stala více určující pro opouštění orné půdy a růstu zatravněných ploch.