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LONG-TERM LAND USE CHANGES IN RELATION TO SELECTED RELIEF CHARACTERISTICS IN WESTERN CARPATHIANS AND WESTERN PANNONIAN BASIN – CASE STUDY FROM HODONÍN DISTRICT (CZECH REPUBLIC)

Marek HAVLÍČEK & Zdeněk CHRUDINA

Department of Landscape Ecology and Geoinformatics, Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Publ. Res. Inst., Brno, Czech Republic; email: marek.havlicek@vukoz.cz

Abstract: This study examined the relationship between long-term land use changes and selected relief characteristics in the area of Hodonín District, Czech Republic, since the mid-19th century to the beginning of the 21th century. The analysis was based on five sets of old maps from 1836-1841, 1876, 1953-1955, 1991 and 2002-2006. Map layers of land use were applied to evaluate the number of changes in land use and its overall intensity. Altitude and slope were chosen as basic relief characteristics. Steady and significant increase in average altitude of permanent grasslands and steady and gradual decrease in average altitude of built-up areas, arable land and forests were the most important trends connected with altitude. Similar major trends in land use changes in relationship with steep gradient as those related to altitude were identified: significant increase in average slope of permanent grasslands and steady and gradual decrease in steepness of built-up areas, arable land and at first forests as well. These findings confirm gradual development of land use intensification primarily in low-lying flat terrain of floodplains in the Dolnomoravský úval Graben.

Key words: land use; altitude; slope; old maps; GIS; Western Carpathians; Western Pannonian basin; Czech Republic

1. INTRODUCTION

Human use of land has a long history, during which land was used in different ways and with different intensity. Contemporary intensive land use often arouses concern over its negative impacts on land functionality and stability. Studying historical development of land use is one of the keys to understanding ongoing processes and effective modelling of future trends in land.

Nowadays, old maps have been used increasingly for land change monitoring, primarily as a result of their accessibility in digital form that enabled to perform analyses over these map layouts in GIS environment. Detailed information about structure of land components is given mainly in large scale maps (cadastral maps). Using cadastral maps for land change studying can be found in studies from Norway (Hamre et al., 2007), Sweden (Skanes & Bunce, 1997) and other European countries. In countries of former Austria-Hungary, an extensive and detailed mapping was being performed in the first half of the 19th century and resulted in maps of so called stabile cadastre. In the Czech Republic, the maps of stabile cadastre were used e. g. by Lipský (1994, 1995) and later by authors from Jan Evangelista Purkyně University (UJEP) in Ústí nad Labem (Brůna et al., 2002; Brůna & Křováková, 2005; Brůna et al., 2005), now these maps have been used by Skaloš & Engstová (2010) and others. Middle scale topographic maps have enabled to monitor changes in land with relatively high position exactness since the half of the 19th century. The oldest map sets included in first and particularly second Austrian military mapping that can basically be used for this purpose were made available in digital format by the UJEP Laboratory of Geoinformatics (LG) in Most. The map set of third Austrian military mapping was transformed by the LG in cooperation with the Nature Conservation Agency of the Czech Republic, Centre in Brno, in the same way.

The advantage of middle scale topographic maps is that they can be used for studying changes of larger territorial units (Haase et al., 2007; Swetnam, 2007; Palang et al., 1998; Skaloš et al., 2011). In the Czech Republic, land use changes have been studied within administratively and naturally limited areas such as regions, districts, municipalities with extended competence, geomorphological units, river basins and protected areas (Demek et al., 2008, 2009, 2012; Eremiášová et al., 2007; Havlíček, 2008; Havlíček, 2008; Havlíček et al., 2009; Mackovčin, 2009; Skokanová, 2009; Stránská & Havlíček, 2008; Skokanová et al., 2012; Havlíček et al., 2012a,b).

Relationships between land use and relief characteristics have been studied e. g. by Štych (2011) and Havlíček et al., (2012a) in the Czech Republic and by authors as Falťan et al. (2011), Hrvatin & Perko (2003), Olah et al., (2006), Szilassi et al., (2006, 2010), Yu et al., (2008) and Zgłobicki & Baran-Zgłobicka (2012), abroad.

In this contribution, historical land use changes since the mid-19th century to the beginning of the 21th century in the area of Hodonín District in the Western Carpathians are described, with special emphasis on the relationship between land use changes and selected basic relief characteristics (altitude, slope).

2. METHODS

Changes in land were analysed using layers of spatial objects created by vectorization over sets of old maps in ESRI ArcGIS environment. A total of five map sets were used: second Austrian military mapping 1:28800 (1836-1841), third Austrian military mapping 1:25000 (1876), Czechoslovakian military topographic maps 1:25000 (1953-1955), Czechoslovakian military topographic maps 1:25000 (1991) and basic CZ maps (ZABAGED®) 1:10000 (2002-2006). The basic CZ maps were used for the reason that military topographic maps (1:25000) from the given period were not available in the time when vectorization of land changes was being performed. A method of Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Publ. Res. Inst., was used to prepare spatial data and do their analyses (Mackovčin, 2009; Skokanová, 2009). Nine basic land use categories are differentiated in this method: 1 – arable land, 2 – permanent grassland, 3 – garden and orchard, 4 – vineyard and hop field, 5 – forest, 6 – water area, 7 – built-up area, 8 – recreational area, 0 – other area. Since hop fields were not present in the district area within the examined time interval, only vineyards are stated here under the category 4.

Individual map layers of land use (a total of five) were created in ESRI shapefile format in the S-JTSK coordinate system. By overlapping of two subsequential maps, reference map layers with attribute tables containing land use categories from both relevant periods were always generated. From these layers, two basic GIS layers were then created: (1) number of changes in land and (2) areas used still the same way. Number of changes in land ranged from 0 (no change of land use category during the five examined periods) to 4 (the largest possible number of land use category changes during the five examined periods).

The analysis of overall land use intensity is based on methods used by Olah et al., (2006), Skokanová (2009) and Havlíček et al., (2009). The land use categories were classified according to intensity of human use in the following way: 5 - built-up areas and other areas (arisen as results of human activity), 4 – arable land, 3 – orchards and vineyards, recreational areas (particularly garden colonies), 2 – water bodies and permanent grasslands, 1 – forests. Overall land use intensity was calculated as a total of differences of land use intensity in particular periods (O1 – O5): $I = (I_{O2} - I_{O1}) + (I_{O3} - I_{O2}) + (I_{O4} - I_{O3}) + (I_{O5} - I_{O4})$. Intensity (I) has a whole number value in the range from -4 to 4. Positive values from 1 to 4 represent intensive land use (the larger value, the higher intensity), whilst negative values mean extensive land use (process of extensification). The value of 0 corresponds to balanced land use when either sites used still the same way (with no change of their land use category) are represented in an area, or intensification processes are outweighed by opposite ones (extensification). Number values were grouped into three basic categories: extensification, intensification and balanced intensity of land use changes.

Altitude and slope were chosen as basic relief characteristics for the analysis of land use changes in Hodonín District. For determining these characteristics, current altimetry data from the Fundamental Base of Geographic Data of the Czech Republic (ZABAGED®) were used, particularly isolines (basic interval of 2 m) and spot heights in vector format. Based on these data, a thorough 3D model of the area with the resolution of 5 x 5 pixels was created using Spatial Analyst extension (Topo to Raster function) in ArcGIS environment. Average altitude, standard deviation altitude and average slope were calculated in ArcGIS environment (Spatial Analyst extension, Zonal Statistics as Table function) for each land use category in each examined period. Zonal statistic as Table summarizes the values of a raster within the zones of

another dataset and reports the results to a table (ESRI, 2006). Zones are defined as areas that have identical values. If the zone input is a raster, it must be integer. If the zone input is a feature class, the zone field must be integer. A character field is also acceptable. When the zone and value inputs are both rasters of the same resolution, they will be used directly. If the resolutions are different, an internal resampling is applied to make them match before the zonal operation is performed. Standard deviation (σ) shows how much variation or dispersion exists from the average (mean), or expected value. A low standard deviation indicates that the data points tend to be very close to the mean. High standard deviation indicates that the data points are spread out over a large range of values. To evaluate the relationship between land use changes and relief characteristics, ArcGIS Spatial Analyst extension tools were used (Reclassify for altitude intervals, Slope for slope). Eight altitude intervals (see Fig. 2) and six slope intervals (see Fig. 3) were created from the original 3D model of the Hodonín District area.

3. STUDY AREA

Hodonín District is located in southeast Moravia near the border with the Slovak Republic (see Fig. 1). Its overall area is 1,099 sq. km. According to current geomorphological regional division (Demek & Mackovčin, 2006), altogether seven geomorphological units involved in two geomorphological provinces extend into Hodonín District. The provinces of the Western Carpathians and the Western Pannonian Basin differ considerably in type of their relief. The largest part of the Hodonín District area (the central one) belongs to the Kyjovská pahorkatina Hilly land (32.3% of the District´s area) and the Dolnomoravský úval Graben (30.9%). The White Carpathians (16.7%) and the Vizovická vrchovina Highland (10.6%) extend into eastern part of the district and the Ždánický les Highland (7.1%), the Chřiby Highland (2.0%) and the Litenčická pahorkatina Hilly land (0.4%) extend only marginally into its northern part. The Dolnomoravský úval Graben is involved in the Western Pannonian Basin province, whilst all the other geomorphological units belong to the Western Carpathians province (Demek & Mackovčin, 2006).

Altitude. Spatial distribution of particular altitude intervals is shown in Fig. 2. The minimum altitude is 157 m (in the cadastre of the municipality Mikulčice near the Morava River), the maximum altitude is 835 m (spot height Durda in the White Carpathians), so the total altitude range reaches the value of 678 m. Approximately 92% of the Hodonín District area lies at an altitude lower than 399 masl.

Terrain slope. In Hodonín District, flat terrain (slope of 0.0-1.9°) prevails that is most often represented in the middle part of the district, mainly in the Dolnomoravský úval Graben. Very gentle slopes are found also in some parts of hilly lands and in floodplains of more important water streams. Flat and mildly undulating relief (partly rugged as well) with slopes of 2.0-4.9° and 5.0-9.9° is typical for hilly areas. Slopes over 10° occupy only less than 13% of the Hodonín District area. They are most common in highland and upland areas (the Ždánický les Highland, the Chřiby Mountains, the White Carpathians), but they can also be found in the highest part of the Kyjovská pahorkatina Hilly land (see Fig. 3).

4. RESULTS

4.1. Land use changes in relationship with altitude

An overview of trends in average altitude changes of areas belonging to particular land use categories since the mid-19th century to the beginning of the 21th century is presented in figure 4.

1836-1841. There were two land use categories in the zone of minimum average altitude under 200 masl – water area and other area. The reason is that larger ponds, sand pits and clay pits (more precisely mining sites) were then maintained particularly in the lowland region of the Dolnomoravský úval Graben near large water streams (ponds on the Kyjovka River belonged to the most important water bodies and brickyards near Hodonín were among the most important mining regions here). Most other categories were concentrated in the middle zone (about 200 – 300 masl), with buildings in its lowest part, vineyards in its highest part and arable land, permanent grasslands, and orchards and gardens between them. Areas populated over a long period of time and used intensively in farming were thus located primarily in these altitudes. In the upper zone, forests were found, although they occurred practically in the whole range of altitudes (from floodplain forest complexes of the Morava River to mountain forests in the highest locations of the White Carpathians) as well as permanent grasslands. The category recreational area did not yet exist in this period.

1876. Average altitudes of gardens and orchards as well as permanent grasslands changed most significantly compared with the previous period.

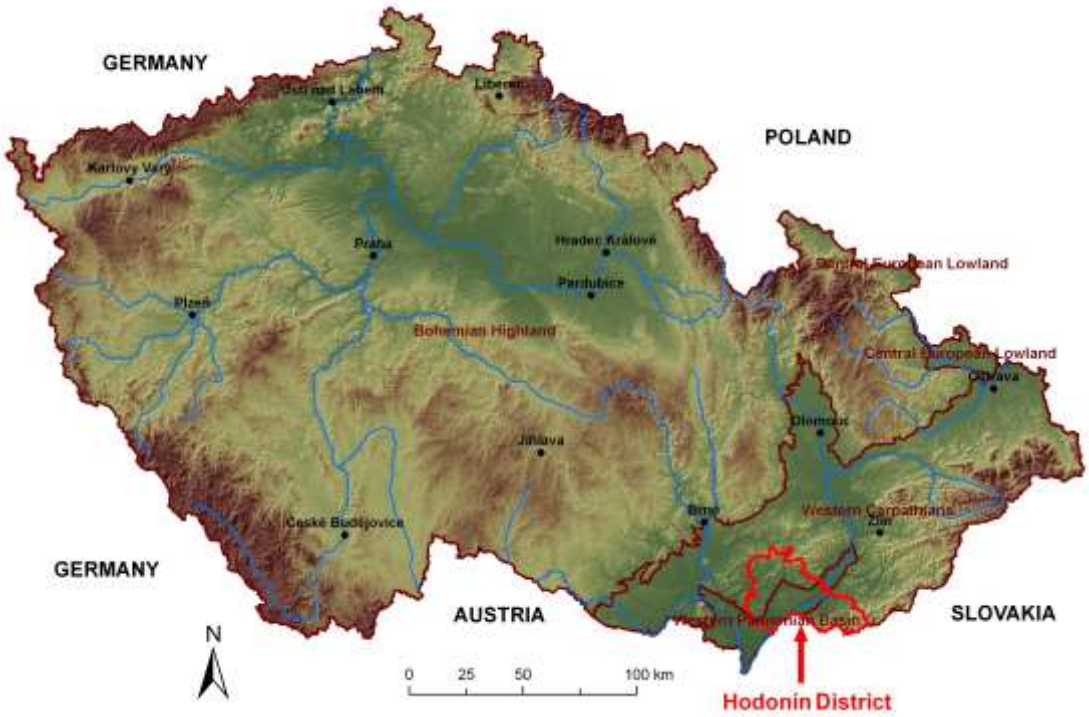

Figure 1. Study area

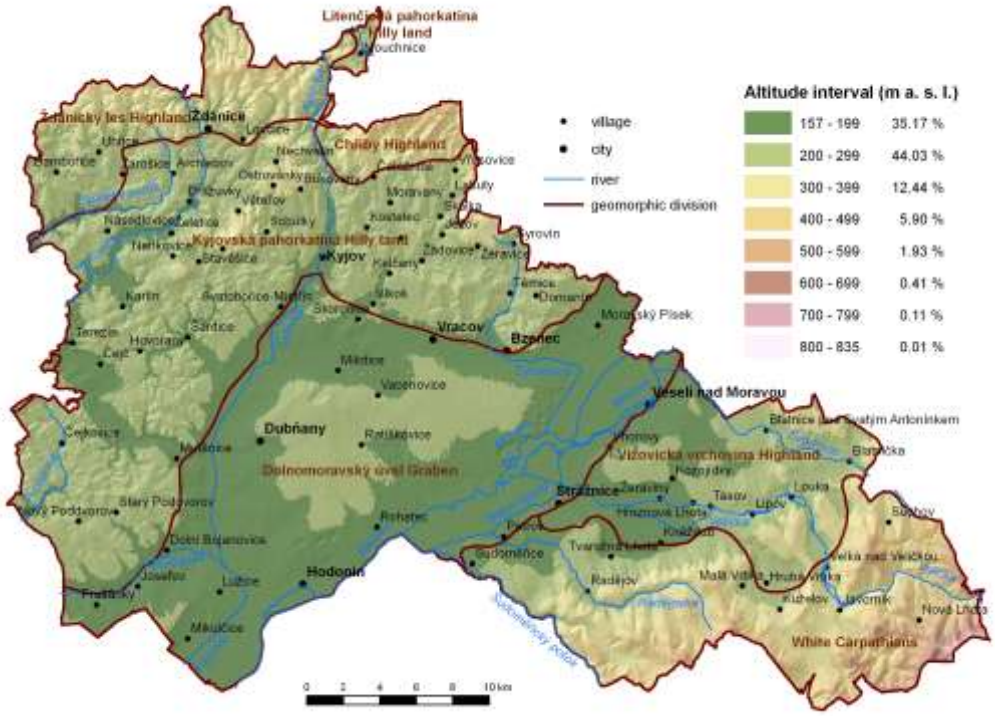

Figure 2. Altitude intervals and their percentage in the Hodonín District area.

Average altitudes of gardens and orchards got lower due to their movement into close proximity to settlements, whilst those of permanent grasslands increased because meadows and pastures nearby water streams were converted into arable land, which resulted in their significant losses in the lowland locations. Also, average altitudes of water bodies increased, for larger lowland ponds had already been defunct and converted into arable land that time.

By contrast, average altitude of arable land decreased due to these processes. In buildings, the decline of average altitudes was related to their

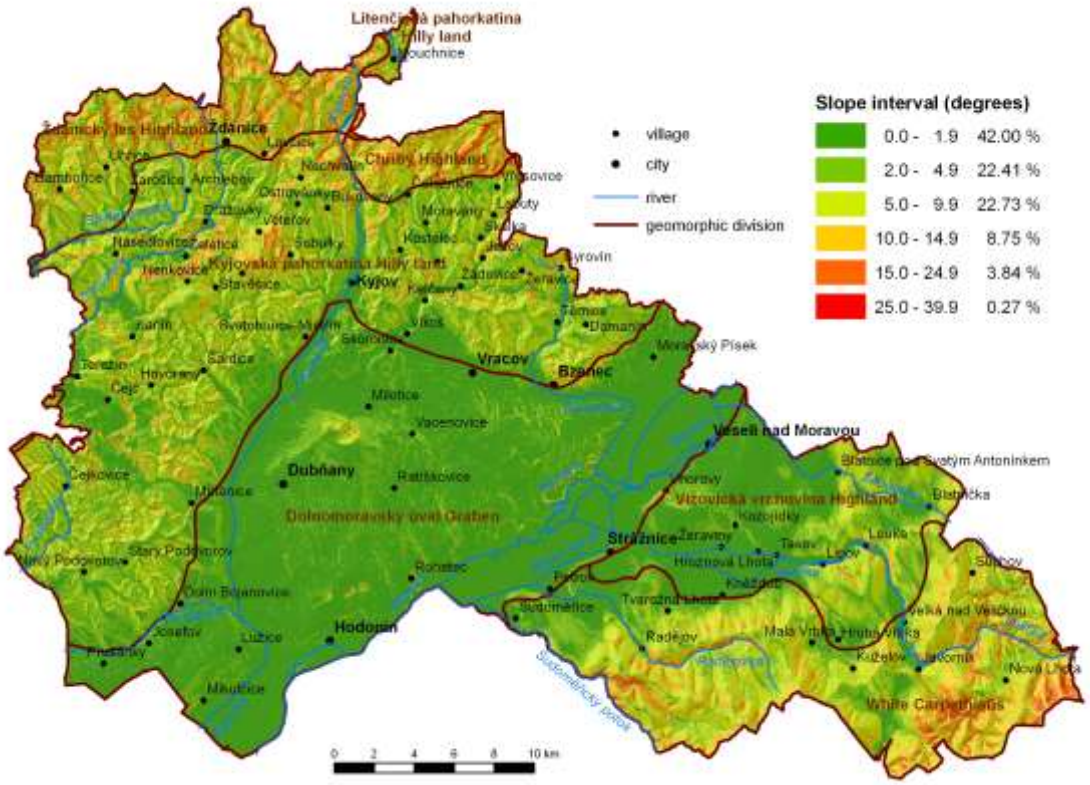

Figure 3. Slope intervals and their percentage in the Hodonín District area

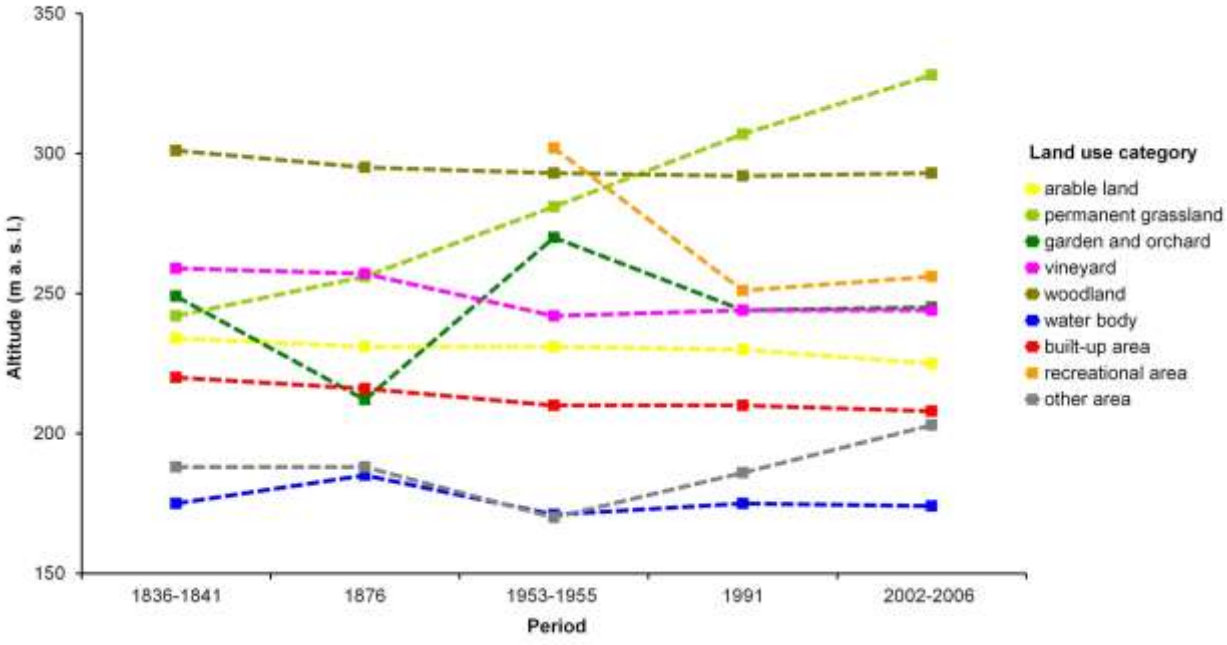

Figure 4. Average altitude changes of areas belonging to particular land use categories

expansion into lower locations (surroundings of floodplains or river terraces) where processes connected with development of industrial sites, transport infrastructure and residential areas were getting more intense. The fall of average altitudes of forests was a consequence of forest renewal in the Bzenecká doubrava Forest with altitude of about 200-220 masl.

1953-1955. Average altitudes of permanent grasslands and particularly of gardens and orchards

changed most significantly again. In permanent grasslands, further losses of meadows and pastures in lower locations were the main cause of the continuing trend. The trend in gardens and orchards turned into its opposite, mainly due to extending of intensively farmed orchards into higher locations with steeper slope (particularly at the base of the Ždánický les Highland and the White Carpathians, see also below) that occurred in regions with favourable conditions for orcharding when socialist agriculture was being implemented. The decline in average altitude of vineyards was linked to the implemetation of socialist agriculture, too. Continuing building development mostly in lower locations led to further decrease in average altitude of built-up areas. A new land use category, recreational area, showed the maximum average altitude. In this category, mainly newly built recreational and ski centres in a few smaller regions at the base of the White Carpathians and the Chřiby Mountain were included (see also below). The lowering of average altitude of water bodies compared with the previous period resulted particularly from renewal of ponds near the Kyjovka River close to Hodonín and Mutěnice. The same trend in the category other area arose from changes in mining sites (extending of areas for brick clay mining in surroundings of Hodonín and a sand pit next to Bzenec-Přívoz).

1991. Similar to the previous two periods, average altitude of permanent grasslands as well as that of gardens and orchards changed significantly, but the category in which average altitude changed the most was recreational area where rapid decrease occurred, for these areas were being developed as settlement facilities in lower locations. The last few permanent grasslands were concentrated mainly in higher parts of the White Carpathians. The pronounced movement of meadows and pastures into higher locations progressed continuously and their average altitude was already higher than that of forests. In forests, the moderately declining trend continued, partly due to reforestation of worse cultivable sites in lower altitudes that were being abandoned, partly also due to deforestation of submontane localities. The trend in gardens and orchards turned into its opposite again and their average altitude got lower, thus approaching that of vineyards, which was caused by changes in agriculture (terracing of orchards and vineyards in the 70´s and 80´s). The slight decrease in average altitude of buildings continued further and average altitude of arable land decreased, too. By contrast, the other areas moved to higher altitudes as a result of rubbish dump expansion near settlements that were spread out over the whole district, including higher locations.

2002-2006. The main reason that average altitude of permanent grasslands grew steadily also during this period was establishment and restoring of grass vegetation in the submontane zone. In the category other area, the distinctive increasing trend was maintained, which could be caused by the same process as in the previous period (see above), but not even an impact of different scale of used map layout can be excluded (see Methods): more smaller objects with the hectarage of about 0.8-1.0 ha (that could be included in the analysis) were plodded on the more thorough map. In buildings and arable land, the slight decline continued as a consequence of intensification development in lower locations within the whole examined period. No major changes occurred in the other categories but moderate growing in average altitude of recreational areas due to their expansion to the base of the White Carpathians.

In *arable land*, the standard deviation (SD) of altitudes (Table 1) was relatively balanced and reached mean values within the examined time interval. This indicates a rather equal distribution of altitudes with little variance in this category. SD of altitudes of *permanent grasslands* was among the highest (together with that in forests, see below). In values of the SD, an increase in average altitudes of these sites due to their losses in lower locations is reflected; only near the Morava River, a few remnants of permanent grasslands have been preserved whose average altitudes were already significantly different from those of other permanent grasslands in last years. By contrast, SD in *orchards and gardens* decreased, for the interval of their typical altitudes was becoming narrower. SD of altitudes of *vineyards* was among the lowest and did not change considerably because the interval of typical (optimal) altitudes is rather narrow (220-280 masl). Relatively high and steady SD of altitudes of *forests* is a result of that there are different types of forests in nearly all locations of the district, from floodplain forests in low-lying flat terrain and deciduous forests in lowlands and hilly lands to beech and needle forests of highland and upland areas. In *water areas*, SD of altitudes has ever been the lowest one, which arises from relatively narrow interval of altitudes in the largest pond systems in lowlands and river floodplains. SD of altitudes of *built-up areas* decreased gradually in connection with development of residential areas nearby water streams in lowland and hilly land locations. Significant increase in SD of altitudes of *recreational areas* is linked to building recreational

centres at the base of the White Carpathians and the Chřiby Mountains. In *other areas*, rapid increase in SD (with values getting closer to those of built-up areas) was caused by rubbish dump expansion into the proximity of the most urban areas. In previous periods, brickyards and sand pits were the most common other areas in lower locations.

Summary. Steady and significant increase in average altitude of permanent grasslands and steady and gradual decrease in average altitude of built-up areas, arable land and forests were the most important trends connected with altitude in the area of Hodonín District since the mid-19th century to the beginning of the 21th century. These trends primarily reflect the development of land use intensification in low-lying floodplains of the Dolnomoravský úval Graben, from where extensive ways of land use were being pushed out gradually into higher altitudes (see also further).

4.2. Land use changes in relationship with altitude intervals

Two indicators were examined in relationship with altitude intervals in Hodonín District: number of land use changes (Table 2) and overall land use intensity (Figure 5).

Number of land use changes. There was no change identified in the area of almost 58,600 ha (about 53 % of the District area) within the examined time interval. The most hectarage of these areas was located in the two lowest intervals (about 76 % altogether) but mainly in the interval 200-300 masl (about 49 %), so in the zone that has been settled and used for agriculture over a long period of time. This finding corresponds well with average altitudes of particular land use categories, see Fig. 4. Distribution of areas with one land use change differed from the others in that the most hectarage of these areas fell into the lowest altitude interval. Reasons for this difference are to be found in abandonment of ponds and their conversion into arable land in the beginning of the examined time interval as well as in gradual ploughing up meadows and pastures. Both these important processes primarily ran in floodplains of lower courses of rivers, so in the lowest locations of the district.

In the interval from 300 to 400 masl, the hectarage of areas with more changes was not so much lower than in the other intervals, which was caused by alternation of some land use categories such as permanent grasslands, arable land, orchards and vineyards at the base of the White Carpathians and the Ždánický les Highland.

Table 1. Standard deviation of altitudes (m) in individual land use categories (1836-2006)

Land use category	**1836-1841**	**1876**	**1953-1955**	**1991**	**2002-2006**
arable land	55	56	58	60	51
permanent grassland	100	110	124	126	122
orchard	63	57	49	42	47
vineyard	37	36	31	37	34
forest	124	124	123	122	122
water area	12	11	12	22	19
built-up area	56	54	49	47	47
recreational area	-	-	44	82	82
other area	18	20	13	53	44

Table 2. Distribution of particular altitude intervals hectarage within various numbers of land use changes

Altitude (masl)	Total areas (ha) for various numbers of land use changes					Total area
	0	**1**	**2**	**3**	**4**	
157 - 199	16 210	14 642	5 525	2 049	266	38 692
200 - 299	28 470	10 633	6 604	2 250	421	48 377
300 - 399	7 810	2 932	1 899	790	166	13 597
400 - 499	4 082	1 596	569	216	27	6 489
500 - 599	1 596	359	125	36	5	2 122
600 - 699	378	47	24	4	0	453
700 - 799	113	3	3	1	0	119
800 - 835	4	3	0	0	0	7
Total area	58 663	30 215	14 747	5 345	886	109 856

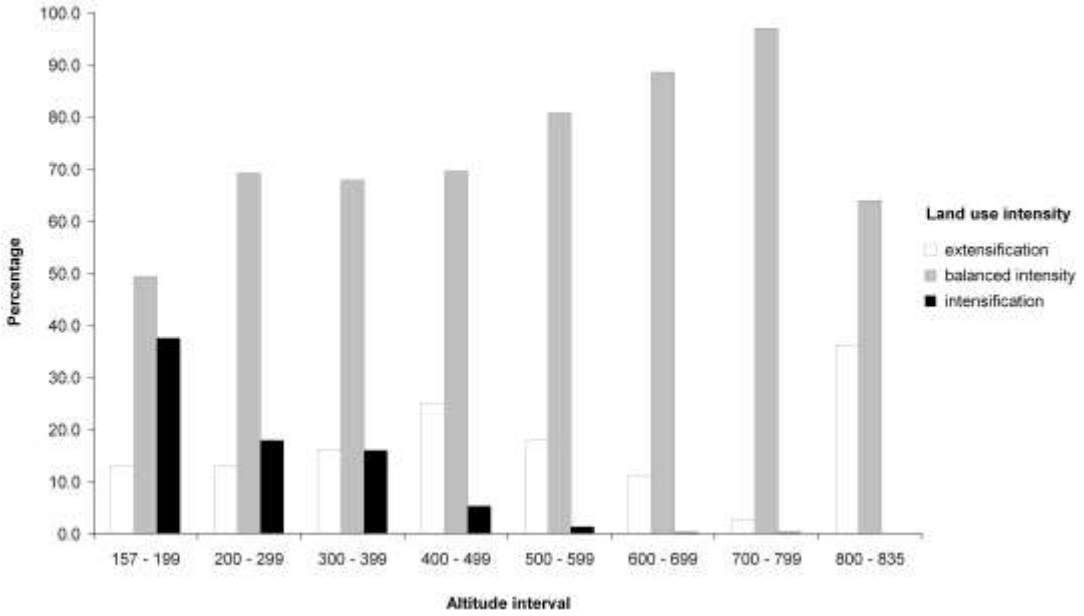

Figure 5. Distribution of areas percentage with different land use intensity within altitude intervals

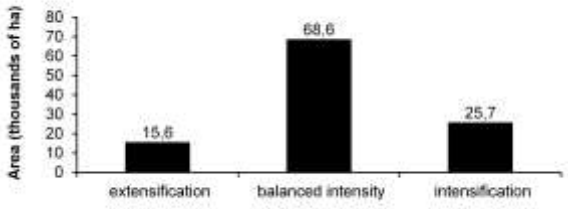

Figure 6. Land use intensity in the Hodonín District area

Overall land use intensity. Balanced land use prevailed in all intervals and its proportion grew with altitude in most cases. Intensification predominated over extensification in altitudes up to about 300 masl, particularly in the lowest interval. That corresponds rather well to landscape pattern in the area and the processes described in connection with number of land use changes (see above). In the zone of 300-400 masl, proportion of extensive and intensive use was quite balanced, which agrees with increased number of changes (different alternation of extensive and intensive ways of land use). Extensive and mainly balanced way of land use predominated significantly in the altitudes above 400 masl. Apparently, intensification processes decreased with increasing altitude in principle, whilst extensive use was concentrated in highlands and uplands. Even though balanced land use generally prevailed in the Hodonín District area, intensification predominated over extensification (Fig. 6).

4.3. Land use changes in relationship with terrain slope

The analysis of average slope changes completes properly the evaluation of average altitude development described above because it reflects some specifics of the Hodonín District area. For particular land use categories, similar trends were identified as in the analysis of changes connected to altitude, only more pronounced, but distribution of categories was slightly different. Water bodies were exluded from this analysis (water surface has no slope). An overview of trends in average slope changes of areas belonging to particular land use categories since the mid-19th century to the beginning of 21th century is presented in Fig. 7.

1836-1841. Similar to the case of altitude, the land use categories were distributed in three slope groups in this period. Built-up areas, meadows and pastures, arable land and other areas fell in the group with the lowest average terrain slope. Gardens and orchards showed medium average steepness, whilst the group with the highest values included forests and vineyards. Surprisingly, average slope of vineyards exceeded that of forests, which is unusual compared with other districts in the Czech Republic where the steepest average slope occurs typically in forests (see e. g. Havlíček et al., 2012a; Stránská & Havlíček, 2008; Skokanová et al., 2012).

1876. Average slope of gardens and orchards decrerased most significantly compared with the previous period (by almost 2°), which corresponds

to decline in their average altitude (cf. Fig. 4 and 7) due to their movement into close proximity to settlements. Average steepness of built-up areas, arable land and forests got lower, too, whilst that of vineyards and other areas increased slightly (as opposed to average altitude of these categories that declined): vineyards were maintained or being established in more appropriate sites with steeper slopes and among other areas greater number of brickyards as settlement facilities were represented that were also built on higher slopes. The decrease of average slope of forests resulted from renewal of the Bzenecká doubrava Forest in flat terrain of the Morava River fluvial terrace, whilst steepness of permanent grasslands grew due to ploughing up meadows and pastures in floodplains of water streams. Conversely, average slope of arable land fell as a result of this process (localities with gentle slopes became a part of arable land).

1953-1955. Average slope of gardens and orchards changed most significantly again, but this time their steepness increased by more than 4°. This change was caused by extending of intensively farmed orchards into sites with steeper slopes that occurred in regions with favourable conditions for orcharding when socialist agriculture was being implemented. In almost all other categories, the trend went in the opposite direction. The decline in slope of built-up areas was linked to expansion of their hectarage into flat terrain in lower locations, while that of arable land was a result of abandonment of problematic steeper sites and ongoing ploughing-up alluvial meadows and pastures (average slope of permanent grasslands increased, by contrast, due to these changes). Recreational areas occurred first time, built in localities with the highest average slope and altitude (cf. Fig. 4 and 7) - particularly recreational and ski centres in a few smaller regions at the base of the White Carpathians and the Chřiby Mountain.

1991. Average slope of built-up areas and arable land continued to decrease gradually due to processes mentioned above. Further increase in steepness of permanent grasslands was somewhat more significant than in the previous period, thus indicating accelerated disappearing of meadows and pastures in flat terrain. Terrain slope of vineyards as well as that of gardens and orchards fell quite significantly in relationship with changes in their distribution in cadastral districts where these plantasions were being aggregated into larger units located rather in lower altitudes (cf. Fig. 4 and 7) and terraced to be made accessible for agricultural mechanization. In recreational areas, average slope decreased, too, which resulted primarily from their development as settlement facilities.

2002-2006. The increasing trend continued in permanent grasslands, whose steepness approached closely to that of forests. This indicates that meadows and pastures had been maintained only in poorly cultivable steeper sites in lower locations and/or locations with higher altitudes above the forest limit. The category in which average slope increased the most compared to the previous period was other area, which was probably connected to rubbish dump expansion into proximity of settlements: these dumps were located in sites as ravines and terrain cuts that could hardly be used in another way as well as in mining sites. However, there is also a possibility the increase was highlighted by different, more thorough map layout used for the last assessed period (see methods).

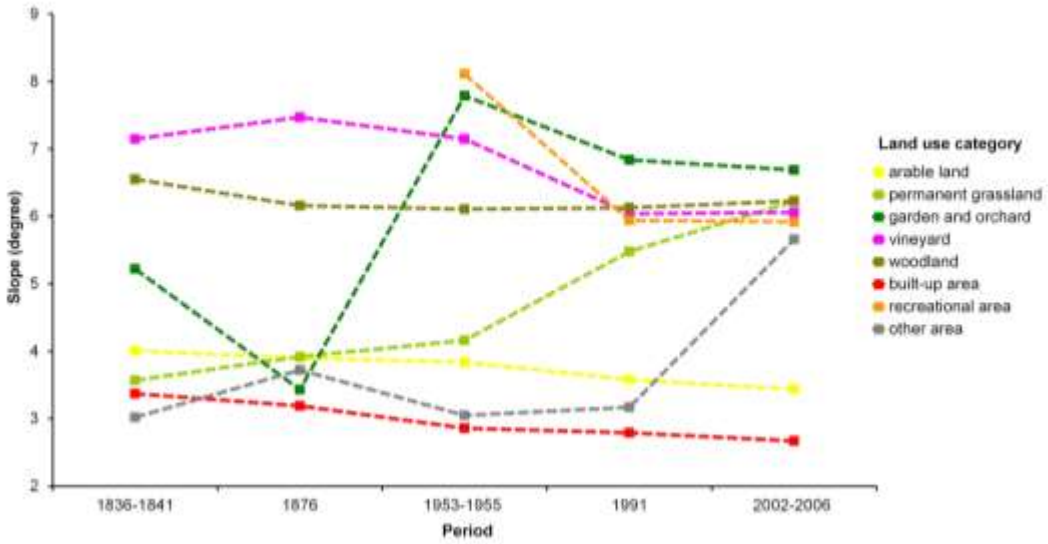

Figure 7. Average slope changes of areas belonging to particular land use categories

Summary. Similar major trends in land use changes in relationship with terrain slope as those related to altitude (see above) were identified in the area of Hodonín District since the mid-19th century to the beginning of the 21th century: significant increase in average slope of permanent grasslands and steady and gradual decrease in steepness of built-up areas, arable land and at first forests as well. These findings confirm advancing development of land use intensification mainly in low-lying floodplains of the Dolnomoravský úval Graben (including inappropriate building expansion in flood zones of lower courses of rivers, particularly the Morava River) and pushing out extensive ways of land use into steep sites and higher altitudes.

4.4. Land use changes in relationship with slope intervals

In relationship with slope intervals in Hodonín District, the same indicators were examined as those in altitude intervals, i. e. number of land use changes (Table 3) and overall land use intensity (Fig. 8).

Number of land use changes. The most percentage (less than 37 % of the Hodonín District area) of localities where there was no land use change identified belonged to the lowest steepness interval. The areas used still the same way were also highly represented in the second and third lowest interval (about a quarter in both cases), so almost 86% of unchanged sites were located in terrain with slope less than 10º. An interpretation of this is to be similar to that of change number in relationship with altitude interval (see above). The most areas of Hodonín District that have been settled and used for agriculture over a long period of time show steepness 0.0-9.9º. Distribution of sites with one land use change did not differ so much from that with no change, only the hectarage of areas with the lowest slope interval was somewhat higher (less than 54%, so more than a half of the district). This reflects conversion of ponds into arable land in flat sites of the Dolnomoravský úval Graben, ploughing up meadows and pastures in floodplains of lower courses of rivers as well as expansion of buildings into localities with the gentlest slope and renewal of the Bzenecká doubrava Forest. Areas with more changes occupied the most hectarage in land with medium average slope (5-9º), which was a consequence of alternation of some land use categories on highland hillsides and particularly at the base of the White Carpathians and the Ždánický les Highland.

Overall land use intensity. Although balanced land use prevailed in all slope intervals, quite expected inverse dependence of intensification level on steep gradient is evident in figure 8. Predominance of intensification over extensification in sites with slopes less than 10º (that show lower altitude as well) refers to dynamic development of these localities. The lower predominance of intensification processes in slope interval 5.0-9.9º is a result of more land use changes on highland hillsides and at the base of the White Carpathians and the Ždánický les Highland, as they are mentioned above. High proportion of extensification in steeper areas is caused by grassland establishment, conversion of arable land into orchards and vineyards and replacement of not used meadows and arable land with forests.

4.5. Slope orientation of selected land use categories

The slopes most represented in Hodonín District are southwest facing ones (with proportion of 15.36%), which are found primarily nearby Dubňany and Hodonín and in the White Carpathians and the Ždánický les Highland. The proportion of west slopes (13.08%) and southeast slopes (12.96%) is high, too. East slopes (10.76) and north slopes (10.99%) are least represented.

Vineyards. Hodonín District is among the most important wine regions in the Czech Republic. The greatest proportion of vineyards has ever been situated on southwest and south slopes that are considered to be the most favourable for growing grapes.

Table 3. Distribution of particular slope intervals hectarage within various numbers of land use changes

Slope	Total areas (ha) for various numbers of land use changes					Total area
	0	**1**	**2**	**3**	**4**	
0.0 – 1.9°	21 466	16 273	5 962	2 150	282	46 133
2.0 – 4.9°	14 656	5 764	3 167	887	144	24 618
5.0 – 9.9°	14 203	5 594	3 615	1 319	252	24 983
10.0 – 14.9°	5 594	1 827	1 402	648	137	9 608
15.0 – 24.9°	2 553	686	601	309	66	4 215
25.0 – 39.9°	191	71	0	32	5	299
Total area	58 663	30 215	14747	5 345	886	109 856

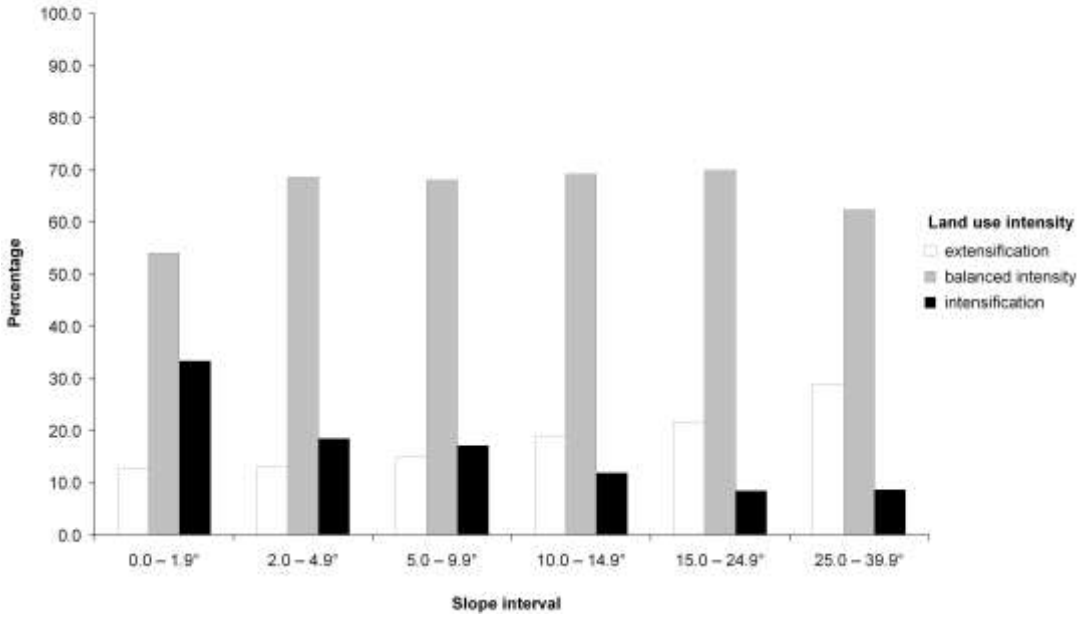

Figure 8. Distribution of areas percentage with different land use intensity within slope intervals.

That also refers to areas with continuous vineyards, although many of them are found on west slopes as well. The lower proportion of southwest oriented vineyards and the higher proportion of vines on north slopes in the period 1953-1955, or 1991, was a result of land consolidation at the time of socialist large-scale agricultural production when too much attention was not paid to appropriate site selection. After transition to market economy (2002-2006), the proportion of southwest oriented vineyards reached its maximum, whilst that of north oriented vineyards fell to a minimum (Table 4).

Permanent grasslands. West, northwest and northeast slopes are most common in the White Carpathians. There are the greatest areas of original and newly established permanent grasslands on these slopes.

Table 4. Slope orientation of vineyards in Hodonín District (individual periods and continuous vineyards, percentage)

Slope orientation	1836-1841	1876	1953-1955	1991	2002-2006	Continuous vineyards
north	4,81	4,86	6,62	5,24	3,97	5,00
northeast	6,98	6,69	9,29	5,83	4,83	3,05
east	8,19	7,95	8,57	7,84	8,03	4,10
southeast	14,88	14,67	13,92	14,31	13,99	11,57
south	17,83	17,29	16,59	18,05	18,01	17,34
southwest	24,52	25,71	22,64	25,22	26,91	26,99
west	12,99	12,48	12,00	14,32	14,97	16,04
northwest	9,81	10,36	10,37	9,19	9,28	15,90

Table 5. Slope orientation of permanent grasslands in Hodonín District (individual periods and continuous permanent grasslands, percentage)

Slope orientation	1836-1841	1876	1953-1955	1991	2002-2006	Continuous grasslands
north	12,16	12,70	13,60	13,99	12,68	12,77
northeast	11,69	12,22	12,16	13,89	15,66	14,87
east	10,09	8,97	6,21	6,55	8,81	5,79
southeast	12,32	11,34	8,66	7,43	7,02	5,09
south	12,06	11,45	10,25	8,43	7,22	7,08
southwest	15,31	15,31	16,49	14,75	12,52	16,43
west	13,20	13,94	16,40	17,38	18,31	20,40
northwest	13,17	14,07	16,23	17,56	17,79	17,56

The proportion of southeast, south and east oriented permanent grasslands (including continuous plots of them) decreased significantly within the examined time interval, particularly in floodplains of the Kyjovská pahorkatina Hilly land and the Dolnomoravský úval Graben as well as in higher locations of the Kyjovská pahorkatina Hilly land and the Ždánický les Highland. South and southeast slopes were used very often to starting vineyards and orchards. Continuous permanent grasslands are most common on west and northwest slopes and least represented on southeast and east ones (Table 5).

5. DISCUSSIONS

Relationships between land use and relief characteristics were studied e. g. by Olah et al., (2006). In the study, changes in land use in the biosphere reserve Eastern Carpathians between 1949 and 2003 were examined. The authors assessed development of land use in relationship with altitude (that ranges from 200 to 1,200 masl in this part of the Carpathians), steep gradient and slope orientation, focusing on forests and arable land. The research revealed gradual expansion of arable land into steeper sites, which was a trend in the opposite direction to that found out in Hodonín District, but overall land use change intensity was comparable in both areas. In the Eastern Carpathians, land use intensification reached its highest levels in the zone of 200-400 masl, while extensification prevailed in altitudes of 400-800 masl. However, localities used still the same way predominated overall in the biosferic reserve, too, and their proportion grew significantly at altitudes over 600 masl.

Štych (2011) used correlative methods to perform comparative analysis of slope and altitude effect on long-term land cover changes in the Czech Republic. The study was based on land use statistics for years 1845, 1948, 1990 and 2000 in LUCC database. The aim of the analysis was to find out whether altitude had greater effect on land use changes than steep gradient. It was proved by the analysis that spatial distribution of arable land and permanent grasslands was affected by slope rather than altitude after 1948. Although altitude was determining before 1948, its importance began to decrease when industrial agriculture was developed (implementation of heavy machinery, using of modern automated cultivation techniques) and effect of slope on arable land abandonment and expansion of building became more important (Štych, 2011). This trend was similar to that in the Hodonín District area where average slope of permanent grasslands increased gradually (particularly in the second half of the 50´s), while steepness of arable land declined.

Zgłobicki & Baran-Zgłobicka (2012), who studied the impact of relief on different types of land uses in loess areas, concluded that there is the apparent connection between relief (primarily slope) and deforestation: long-term deforestation (followed by cultivation) occurred mainly in flat terrain (in high plains or gentle slopes with lower altitudes). That corresponds to higher average slope of forests in Hodonín District, although lowland forest complex Bzenecká doubrava was renewed in the flat fluvial terrace of the Morava River.

Hrvatin & Perko (2003) examined current relationship between relief and land use in Slovenia. Their findings relating to altitude and steep gradient with respect to some land use categories (which were defined in a rather different manner) have some differences from those in our study. In Slovenia, the lowest average altitude (of about 260 masl) was identified in vineyards, followed closely by arable land, and there was a quite great difference in average slope between the two categories (less than 3º in arable land compared to less than 11º in vineyards). Average altitude of gardens and orchards (more precisely orchards alone) was about 100 m higher than that of vineyards and orchard steepness was somewhat lower compared with vineyard one. Meadows, pastures and particularly forests showed relatively high average altitude as well as steep gradient. In Hodonín District, by contrast, average altitude of vineyards was moderately higher than that of arable land and a difference in their average slope was not so great. Altitude of gardens and orchards did not differ substantially from that of vineyards in the last two periods and steepness of gardens and orchards was slightly higher than slope of vineyards. Permanent grasslands (meadows and pastures) had higher average altitude than forests in the last periods, while slope of both categories was similarly steep compared to that in Slovenia. Probably the most significant difference between both regions was identified in built-up areas: in Slovenia, not only their average altitude was higher than that of arable land, but also their steepness, while there was a smaller difference in slope between the two categories in Hodonín District (where built-up areas showed the lowest average slope among all the land use categories in the last periods). Explanation of these differences is to be based on differences in ladscape pattern of both regions – nevertheless, it is questionable to compare the whole area of Slovenia with the Hodonín District one.

Like in Slovakia (Lieskovský et al., 2013), continuous vineyards in Hodonín District were small-scale plots which did not change during collectivisation and are not considered to be traditional agricultural landscape structures.

Yu et al., (2008) compared results of two case studies conducted in regions of Hubei province, China. A direct impact of terrain characteristics to land use was proved in the study: agricultural use of land, together with more intense land destruction and greater homogeneity of landscape structure, predominated in flat terrain, whilst in mountain regions, forest was the prevailing landscape element. This overall conclusion corresponds well to findings from the Hodonín District area where proportion of intensive land use declined successively with growing altitude.

6. CONCLUSIONS

The analysis of the relationship between long-term land use development and selected basic relief characteristics – altitude and slope – enabled a better understanding of spatial differentiation in land use changes in the Hodonín District area since the mid-19th century to the beginning of the 21th century.

Steady and significant increase in average altitude of permanent grasslands and steady and gradual decrease in average altitude of built-up areas, arable land and forests were the most important trends in land use changes in relationship with altitude. These trends primarily reflect the development of land use intensification in low-lying floodplains of the Dolnomoravský úval Graben, from where extensive ways of land use were being pushed out gradually into higher altitudes. In the zone of 300 – 400 masl, proportion of extensive and intensive land use was balanced and different land use categories altered (arable land, vineyards, orchards and gardens, forests).

Similar major trends in land use changes in the relationship with terrain slope as those related to altitude were identified in the assessed area: significant increase in average slope of permanent grasslands and steady and gradual decrease in steepness of built-up areas, arable land and at first forests as well. Although balanced land use prevailed in all slope intervals, inverse dependence of intensification level on steep gradient was proved. Predominance of intensification over extensification in sites with slopes less than 10 ° refers to dynamic development of these localities where land uses changes were concentrated (abandonment of ponds and permanent grasslands, urbanisation).

The evaluation of land use changes with respect to selected basic relief characteristics completes properly basic analyses of long-term land use development in larger territorial units.

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