Land use/land cover changes of the Pálava PLA and proposed Soutok PLA in the years 1841 – 2006

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Abstract:

Paper deals with land use/land cover (LULC) changes in the Pálava Protected Landscape Area (PLA) and in the proposed PLA (pPLA) Soutok. LULC data were obtained from the maps of 2nd and 3rd Military Survey (years 1841 and 1876), black-and-white aerial photos from the year 1938 and orthophotographs from the year 2006. General trends in both study areas in the time span 1841 – 2006 are following: i) a distinct decrease of the grass-covered areas, ii) increase in the forested areas, iii) extensive change of the forest management (from the sparse low and middle-high forest to the continuous high forest), iv) representation of the agricultural areas by a mosaic of very small patches in the year 1938 as a result of land reform in 1919-1935, and v) increase in the linear vegetation corridors in 2006. For the Pálava PLA is typical gradual invasion of bush and forest into the grasslands (steppe biotopes) and increase in the built-up areas. In the proposed Soutok PLA, the most expressive changes were the channel regulations and adjustments, increase in the area of arable land and change of the forest management with substantive rise of the timber harvesting. Analysis of the forest age structure shows the unsustainability of the current timber harvesting rate, which represents serious danger for numerous protected species. Obtained results show a distinct change of the natural and cultural landscape structures in the study areas and can be used as a basis for management of the protected areas.

Shrnutí:

Změny využití krajiny/krajinného krytu v CHKO Pálava a navrhované CHKO Soutok v letech 1841 – 2006

Článek se zabývá změnou využití krajiny/krajinného krytu (LULC) v oblasti CHKO Pálava a navrhované CHKO Soutok. LULC data jsme získali z map II. a III. vojenského mapování (roky 1841 a 1876), z černobílých leteckých snímků z roku 1938 a z barevných ortofot z roku 2006. Hlavní trendy změn v období 1841 – 2006 společné pro obě studované oblasti jsou: i) výrazný pokles rozlohy trvalých travních porostů, ii) nárůst rozlohy lesa, iii) rozsáhlá změna lesního hospodaření z řídkého nízkého a středního lesa na zapojený les vysoký, iv) téměř úplné zastoupení zemědělské půdy v roce 1938 mozaikou velmi drobných ploch jako důsledek pozemkové reformy z let 1919 – 1935, a v) výrazný nárůst liniové zeleně v roce 2006. Pro CHKO Pálava je typické zarůstání travních porostů (stepí) křovinami a lesem a nárůst plochy urbanizovaných areálů. V navrhované CHKO Soutok byly nejvýraznějšími změnami regulace a úpravy vodních toků, nárůst plochy orné půdy a změna lesního hospodaření s nárůstem intenzity těžby dřeva. Analýza věkové struktury lesa ukazuje na neudržitelnost současného tempa těžby, což znamená vážné ohrožení pro mnohé chráněné organizmy. Získané výsledky ukazují značnou proměnu přírodních i kulturních struktur krajiny v zájmových oblastech a mohou sloužit jako podklad pro management zvláště chráněných území.

Key words: *Land use/Land cover, Multitemporal analysis, Landscape changes, Environmental protection, Pálava PLA, proposed Soutok PLA*

1. Introduction

Study of the changes of landscape structures and landscape development is both scientifically and practically usable field of research, widely practiced in various areas (e.g. Rembolt et al., 2000, Mendoza, Etter, 2002). For nature conservation, knowledge of changes in the area could answer the questions of biota changes, help with selection of area management methods and represent important argument for enforcing the selected management methods (Freeman et al., 2003, Wessels et al., 2004, Falcucci et al., 2006, Kintz et al., 2006, Goetz et al., 2009, Townsend et al., 2009, AOPK, 2010, Esbah et al., 2010, Mondal, Southworth, 2010). Both study areas (Fig. 1) belong to the longest settlement places in Czech Republic, so they are used and influenced by people in the long term. Area management changes due to agriculture intensification, political situation or declaration of protected areas and connected restrictions have had significant impact on the landscape. Area of the Morava and Dyje Rivers junction, called "Soutok", is a typical example. Due to deforestation of higher parts of both watersheds, which evocated periodical occurrence of floods in the past, lowland forests gradually turned into floodplain forests with abundance of many hydrophilic species (Vrška et al., 2006). Today, Soutok is one of the most valuable floodplain landscapes in Czech Republic, but even in the Central Europe region. Contemporary human activities have rather negative impact on it. To the most severe activities and processes belongs i) present intensity of timber harvesting (Vodka et al., 2009), ii) decrease of the grass-covered areas and iii) water resources management as canalization and regulation of watercourses (Šebela, 2002). For preservation of typical landscape character and biological values, it is necessary to accept arrangements towards sustainable usage of the area. Project of the declaration of this area as protected Landscape Area (PLA) comes from 1980s and nowadays is actual again, has not been accepted yet. In Pálava PLA, main current problem of nature conservation is forest and shrub invasion to semi-natural grasslands – steppe biotopes of many protected species (Miklín, 2007). Here the process of natural plant succession needs to be regulated by human activities.

Aim of the presented article is to quantify and evaluate changes of landscape composition, diversity and ecological stability in years 1841 – 2006 and to describe their causations and consequences. Outline of negative future human impact in the Soutok pPLA is represented by prognosis of timber harvesting intensity in the next 110 years. Results and conclusions of the study can be used in nature protection as resources for practical management of study areas.

2. Regional Settings

2.1. Pálava PLA

Pálava PLA (Fig. 1) was declared in 1979 with the area of 83 km^2 (AOPK, 2006). Natural and landscape values were appreciated also by enlistment to UNESCO Man and Biosphere program (Biosphere reserve), Ramsar site and Special Protection Area (SPA). There are 14 small protected areas within the PLA, including 5 in national categories (Čtyřoký et al., 2007).

Geologically, PLA is built of Jurassic limestone of Pavlovské vrchy Hills and Cenozoic sedimentary rocks of Milovická vrchovina Hills. Small portion of the area is occupied by floodplains with corresponding sediments (Grulich et al., 2002). The highest point is the Děvín Mt. with 550 m a. s. l. and the lowest point is the Dyje River outlet with 170 m a. s. l.

Whole area is relatively (compared with the rest of Czech Republic) hot and dry with the mean annual temperature 9.6 °C and mean annual rainfall 524 mm in Mikulov (Čtyřoký et al., 2007). Due to orographic barrier of Pavlovské vrchy Hills, there is very strong effect of windward and leeward slopes (Buček et al., 1990). Hydrologically, most important is the Dyje River at northeast border of PLA, accompanied by a few unimportant watercourses in the rest of area.

Due to the location in the Pannonian biogeographical province and close to the Hercynian biogeographical province, we can found many species here, which are very rare in the rest of Czech Republic. Typical ecosystems are grasslands (with porcupine grass, Aurinia saxatilis, Iris pumila, Iris humilis arenaria, endemic Dianthus lumnitzeri palaviensis etc.), thermophilic oak woods, scree woods a floodplain ecosystems (Buček et al., 1990, Grulich et al., 2002, Čtyřoký et al., 2007).

Area of Pálava PLA was settled long time ago, which illustrate i. e. archeological findings of mammoth hunters settlements from 34 to 25 ka BC, including famous sculpture of Věstonická Venuše. In the 1300 – 950 BC, fortifications on the Stolová hora, Kotel and Děvín Mts. were built (Grulich et al., 2002). After beginning of AD, Celts, Germans, Romans and Slavs have subsequently occupied the area (Grulich et al., 2002).

2.2. Proposed Soutok PLA

Soutok pPLA's (Fig. 1) landscape is composed mainly by floodplain forests and meadows on the low reaches of Morava and Dyje Rivers, including their junction. Nowadays, area is declared as the Biosphere Reserve Dolní Morava (Lower Morava), which is overlaying partly with Sites of Community Interest (SCI) Niva Dyje (Floodplain of Dyje) SCI and Soutok-Podluží SCI. Area of pPLA is ~140 km^2.

Relief of the area is very flat, built of fluvial sediments. Area is used as dry polder for the flood catchment. Climatic characteristics of the area are very similar to Pálava PLA, with more equal portioning due to non-existence of orographic barrier.

Typical ecosystems are floodplain forests, watercourses and oxbow lakes (both permanent and periodical), or floodplain meadows (Grulich et al., 2002, Hrib, Kordiovský, 2004).

There are archeological findings of Great Moravian fortified settlements Pohansko and Mikulčice from the 6th – 10th century AD. Pollen analysis from this times (Opravil, 1978) shows prevalence of the Elm-Oak woods mixed with European beech (Fagus sylvatica), and, on the contrary, a small participation of soft floodplain woody species, e.g. alder and willow. This indicates drier conditions and non-existence of larger floods. It was probably supported by Slavonic agriculture, using mosaic of small fields planted by various types of crops (Lipský, 2000). Later, in the medieval times, rainfall raised and mountain areas were colonized and deforested. As a result, more intensive periodic flooding started, followed by the evolution of floodplain ecosystems and sedimentation of overbank deposits; their thickness is more than 4 meters (Vrška et al., 2006).

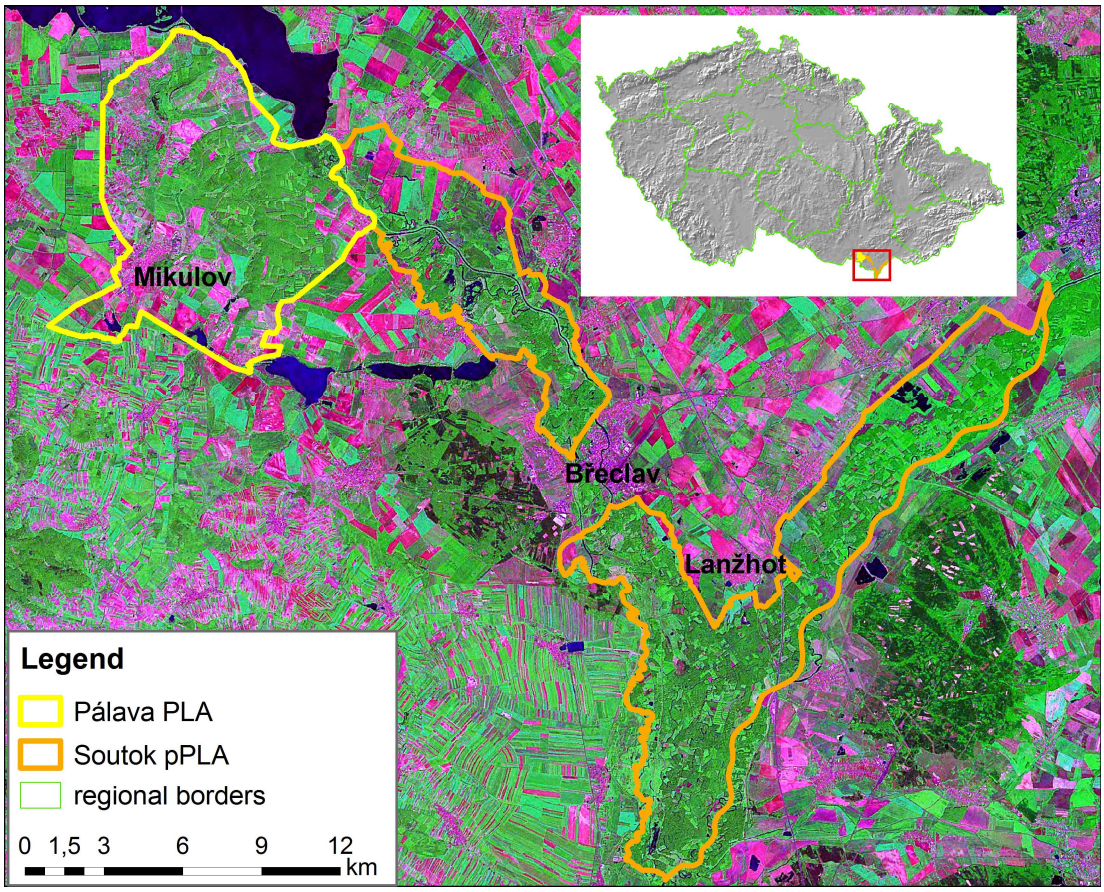


Fig. 1: : Localization of study areas in the Czech Republic

(source: SWIR GeoCover Landsat image, NASA 2000)

3. Material and Methods

As the source data we used historical maps from II. and III. military mapping (years 1841 and 1876), black-and-white aerial photographs from the year 1938 and color ortophotomap from the year 2006.

Land cover data from both historical maps were provided as vector shapefiles by the Silva Tarouca Research Institute for Landscape and Ornamental Garden. Thematic content is divided into 8 classes: Arable land, Grassland, Orchard, Vineyard, Forest, Water Area, Built-Up Area and Other (Tab. 1). Scale of vectorization was 1:25 000, line objects were not vectorized, and area of each polygon had to be one hectare at least.

1938-2006 Class	**1938-2006 Category**		**1841-1876 Class**
1. Urbanized Land	1.1	Continuous Built-up Area	Built-up Area
	1.2	Uncontinuous Built-up Area	
	1.3	Industrial, Commercial or Agricultural Zone	
	1.4	Mining Area	Other
	1.5	Urban and Suburban Vegetation	Orchard
	1.6	Recreational Area	Other
	1.7	Transportation, Communications and Utilities	
2. Agricultural Land	2.1	Arable Land	Arable Land
	2.2	Vineyard	Vineyard
	2.3	Orchard	Orchard
	2.4	Mosaic of Fields, Meadows, Vineyards and Orchards	Mosaic
	2.5	Permanent Grassland	Grassland
3. Forest Land	3.1	Forest	Forest
	3.2	Open Forest	
	3.3	Shrub	
	3.4	Clearcut Area	
	3.5	Afforested Clearcut Area or Young Forest	
	3.6	Linear Vegetation	Other
4. Barren Land	4.1	Exposed Rock or Bare Land	
5. Water and Wetland	5.1	Swamp or Marsh	Grassland
	5.2	Lake or Reservoir	Water Area
	5.3	Stream	Other
	5.4	Flood-plain Canal or Oxbow	

Tab. 1: Conversion between land use/land cover categories used in the study

Aerial photographs from the year 1938 were provided as scanned photos with resolution 1209 DPI (~0.4 m at ground) by Military Geography and Hydrometeorology Office in Dobruška. Real resolution depends on quality of every image and in most cases it is lower than 0.4 m. For the Pálava PLA 15 images were needed, while for the Soutok pPLA it was 39 images. We georeferenced all the images using identical points from ortophotomap, published at the map server of Czech Environmental Information Agency. The process of image georeferencing was affected by large elevation differences at the Pálava PLA (mean error at identical points ranged from 0.98 to

5.69 m per image), and by the absence of precise identical points (absence of infrastructure) at the Soutok pPLA (mean error at identical points ranged from 0.20 to 4.38 m per image).

For classification of landscape horizontal structure on aerial photographs we used a legend based on the CORINE Land Cover (Commission of the European Communities, 1994). Due to the specific needs of nature conservation, some categories (mainly urbanized land) were integrated, while others (i.e. wooden land) were divided using land use characteristics. Thus we speak about land use/land cover (LULC) classification. Final legend comprises 23 categories, grouped into 5 classes (Tab. 1). From both sets of aerial photographs, LULC data were obtained by visual photointerpretation in the scale 1:5000, practically without generalization.

Because of using two different sources of LULC data (maps and aerial photographs) data had to be arranged for mutual comparison. For general comparison of the whole studied period, categories from aerial photographs were joined to military mapping classes (Tab. 1). Some of them could not be converted unambiguously or at all (i.e. Transportation, Communications and Utilities or Linear vegetation). It is necessary also to consider another scale (generalization) of both data sets.

For the comparison of the landscape composition between years 1841-1876-1938-2006 we used differences in Class Area (ha) and in Percentage of Landscape (PLAND, %) after Leitão et al. (2006).

For evaluation of landscape diversity, ecological stability and its changes (Krebs, 1999, Lipský, 2000, Leitão et al., 2006), we computed two metric indexes.

For evaluation of ecological stability, we used Weighted Coefficient of Ecological Stability (C_{ES}) after Lipský (2000), defined as

$$C_{ES} = \frac{\sum (A_c \cdot C_{ESI})}{A_T}; \quad (1)$$

where A_C is area of class, C_{ESI} is coefficient of ecological significance of the class and A_T is total area. For each class, C_{ESI} were used after Lipský (2000) as follows: 0.1 Built-up Area; 0.3 Orchard; 0.14 Arable Land; 0.3 Vineyard; 0.65 Grasslands; 1 Forest; 1 Water Area and 0.2 Others. Value of C_{ESI} varies from 0.1 (the least ecologically stable area) to 1 (the most ecologically stable area). Lipský (2000) is not considering the Mosaic class (see Chapter 5.3.), which was specific in middle Europe for most of the agriculture land in the first half of 20th century. According to ecological significance of LULC types creating mosaic and to sensitivity tests of the equation (1) we decided to set the C_{ESI} value of Mosaic class to 0.25.

For evaluation of landscape diversity, we used Shannon Diversity Index (SHDI) after Shannon and Weawer (1949), defined as:

$$SHDI = -\sum (CAP \cdot \ln CAP); (2)$$

where CAP is the class area proportion (CAP=PLAND/100; Leitão et al., 2006). While C_{ES} we calculated from total study areas, SHDI we applied only to three characteristic 1 km^2 squares (two sq. from Pálava PLA and one sq. from Soutok pPLA) to avoid problems with different methodology of obtaining the LULC classes, especially influence of "Other" class.

4. Results

4.1. Relative and absolute LULC changes in Pálava PLA

Spatial distribution of LULC classes in studied years is presented in Fig. 2. The most striking increase was recorded in class Orchard, which at first (between years 1841 – 1876) decreased in area, but contemporary extent is 15x larger than in the year 1938 (Tab. 2). Built-up area follows with 73.7% increase in all municipalities (Tab. 2, Fig. 3a). Specific case, both for Pálava PLA and Soutok pPLA, is class Other (Tab. 2, 3, Fig. 3a, c), which relative increase is enormous due to zero area in the first year and due to different methods of LULC data obtaining (see Chapter 3). Significant relative decrease was observed by Water area, which extent is now nearly as low as half. Relatively important changes can be seen in Agricultural land class (Tab. 2, Fig. 3b). Highest relative decrease experienced Grassland, which is smaller by 75.8%. Area of Arable land is now by 17.5% smaller then in year 1841, whereas area of Vineyards increased slowly. Forests augmented by 19.1% (mainly at the expense of Grassland), which was the highest absolute increase (482 ha). The highest absolute decrease experienced Agricultural land (-1315.1 ha), mainly Grassland and Arable land (Tab. 2).

Class	**1841**		**1876**		**1938**		**2006**		**Difference 1841-2006**	
	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha	*%*
Built-up Area	283.50	*3.29*	289.00	*3.36*	338.62	*3.93*	492.62	*5.72*	**209.12**	***73.71***
Orchard	23.42	*0.27*	17.40	*0.20*	59.65	*0.69*	361.52	*4.20*	**338.10**	***1443.18***
Agriculture Area	5661.18	*65.73*	5848.14	*67.90*	5497.90	*63.82*	4346.13	*50.44*	**-1315.05**	***-23.25***
Forest	2521.61	*29.28*	2445.84	*28.40*	2600.79	*30.19*	3003.57	*34.86*	**481.96**	***19.08***
Water Area	123.69	*1.44*	11.72	*0.14*	3.60	*0.04*	70.02	*0.81*	**-53.67**	***-43.41***
Other	0.00	*0.00*	1.30	*0.02*	114.63	*1.33*	342.08	*3.97*	**342.08**	***a***
Total	**8613.40**	***100.00***	**8613.40**	***100.00***	**8615.19**	***100.00***	**8615.94**	***100.00***		
Agriculture Area:										
Arable Land	3250.25	*37.73*	3569.75	*41.44*	380.59	*4.42*	2682.26	*31.13*	**-567.99**	***-17.50***
Mosaic	0.00	*0.00*	0.00	*0.00*	4842.72	*56.21*	0.00	*0.00*	**0.00**	***0.00***
Vineyard	1323.33	*15.36*	1388.14	*16.12*	18.09	*0.21*	1400.37	*16.25*	**77.04**	***5.79***
Grassland	1087.60	*12.63*	890.25	*10.34*	256.50	*2.98*	263.50	*3.06*	**-824.10**	***-75.78***

Tab. 2: Land use/land cover in Pálava PLA in 1841-2006

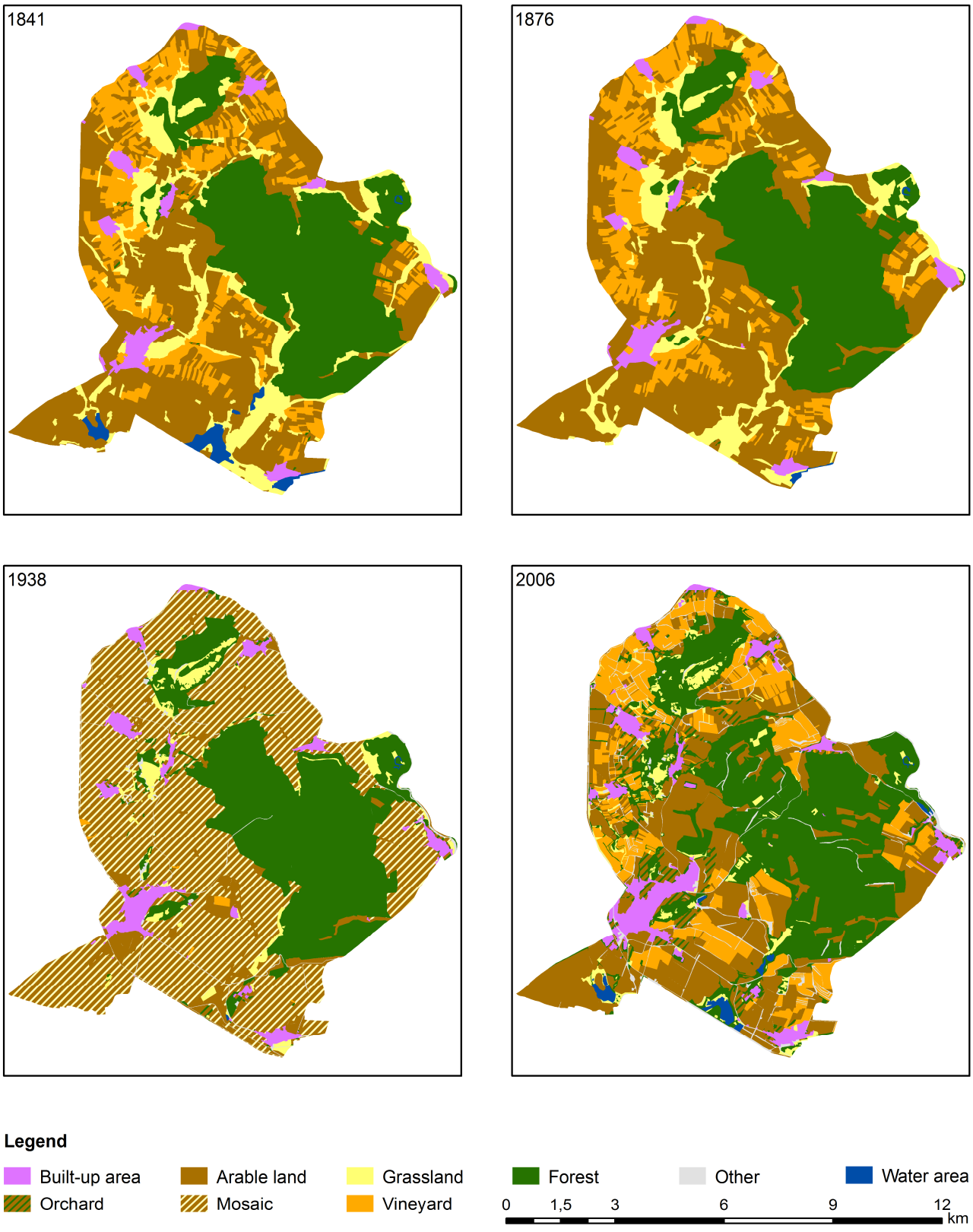


Fig. 2: Land use/land cover in Pálava PLA

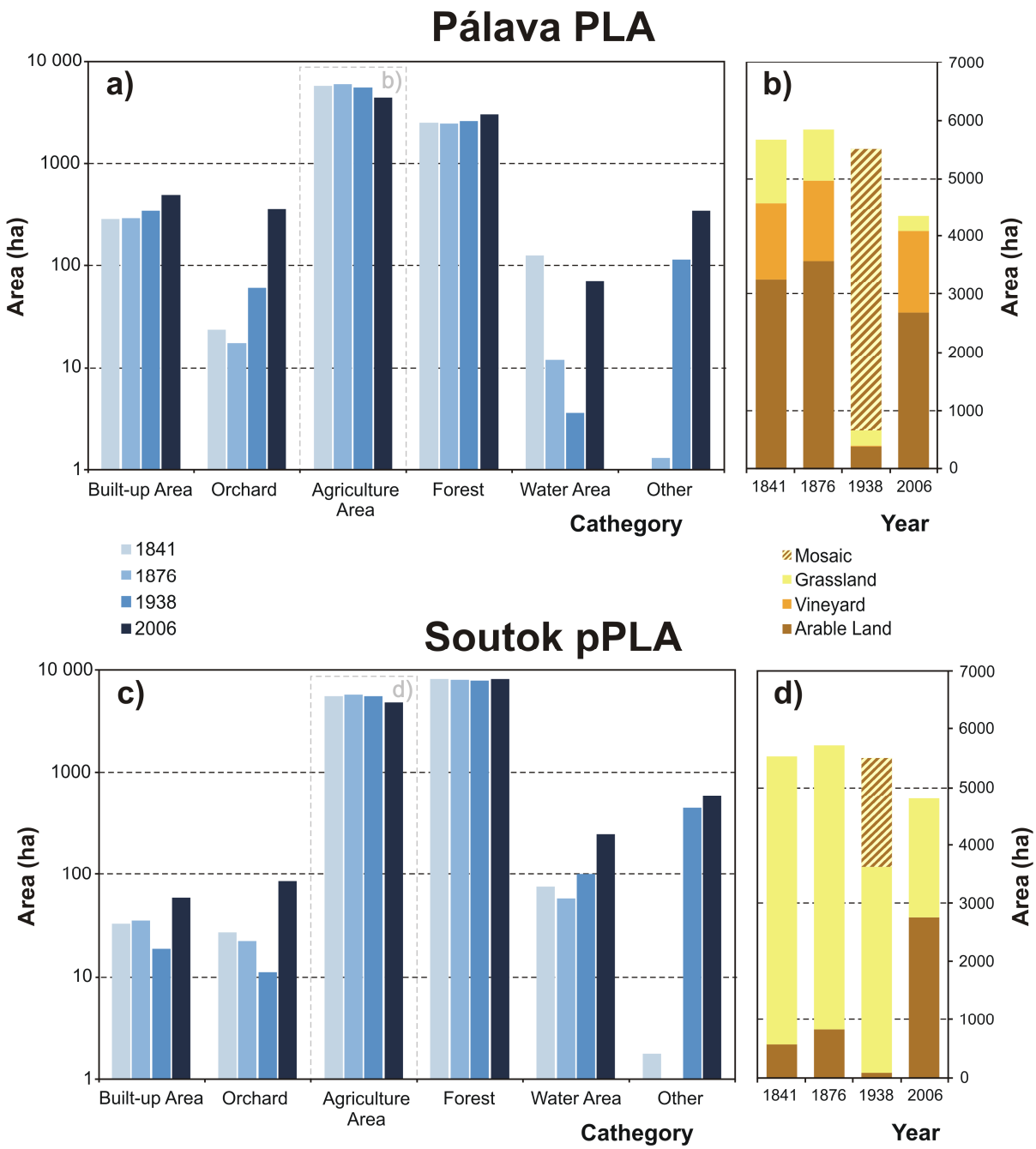


Fig. 3: Land use/land cover changes in Pálava PLA and Soutok pPLA in 1841-2006: a) all classes in Pálava PLA, b) agriculture areas in Pálava PLA, c) all classes in Soutok pPLA, d) agriculture areas in Soutok pPLA

4.2. Relative and absolute LULC changes in Soutok pPLA

Spatial distribution of LULC classes in studied years is presented in Fig. 4. The highest relative increase (despite of class Other) was recorded by Arable land, whose area increased between years 1841 – 2006 nearly five times (Tab. 3). High increase can be seen also by Water area and Orchards,

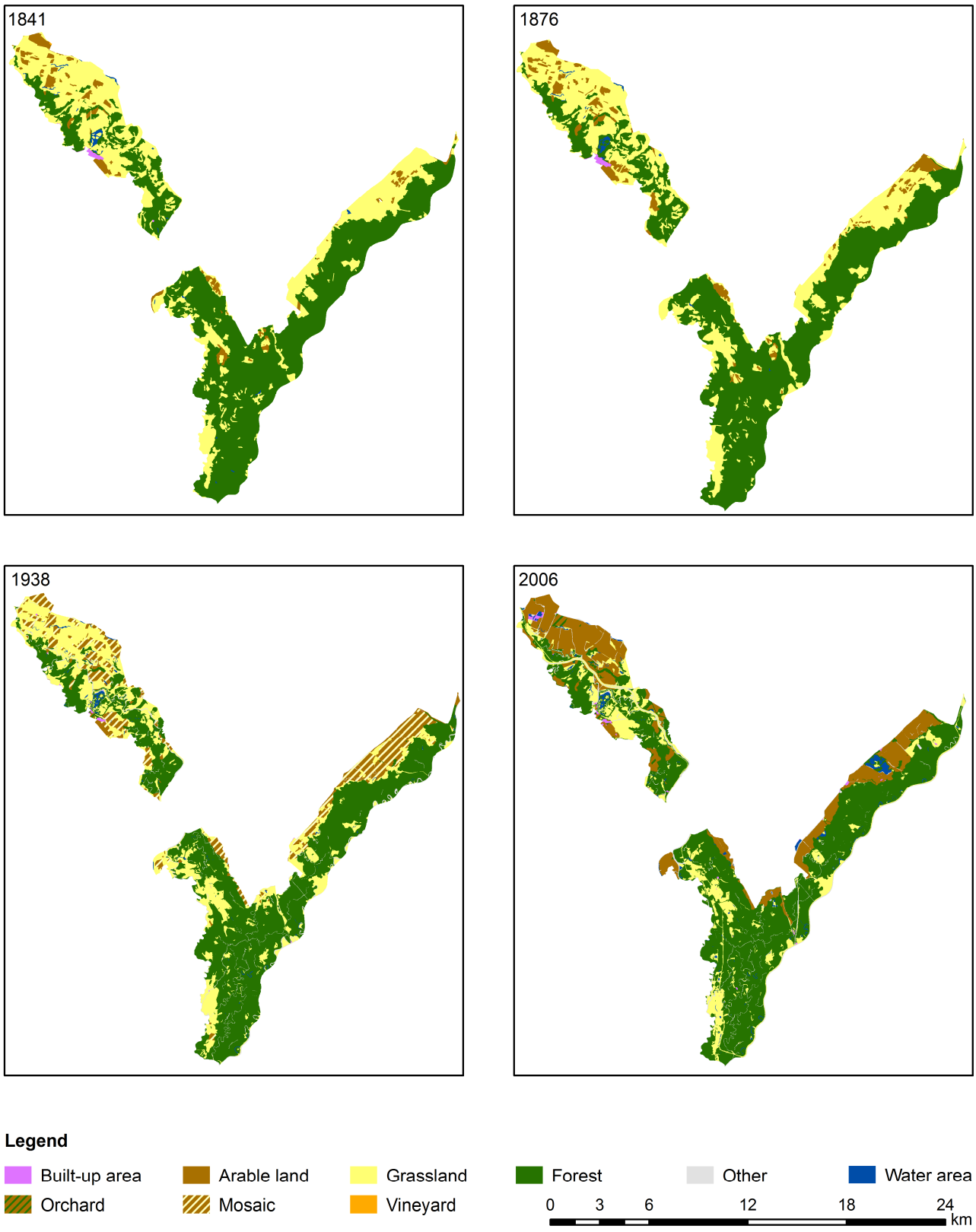


Fig. 4: Land use/land cover in Soutok pPLA

whose contemporary area is (compared to year 1841) more than three times larger. By 77.9% has increased Built-up area, whereas area of Grassland is half.

The highest absolute changes were recorded by Grassland (decrease by 2912 ha) and Arable land (increase by 2183.9 ha). Agricultural land extent decreased in total by 729.9 ha. High absolute increase occurred also in classes Other and Water area (by 589.3 or by 171.7 ha, respectively; Tab. 3).

Class	**1841**		**1876**		**1938**		**2006**		**Difference 1841-2006**	
	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha	*%*
Built-up Area	32.86	*0.24*	35.09	*0.25*	18.53	*0.13*	58.56	*0.42*	**25.70**	***77.88***
Orchard	27.20	*0.20*	22.47	*0.16*	10.87	*0.08*	85.13	*0.61*	**57.93**	***212.40***
Agriculture Area	5537.04	*39.94*	5715.88	*41.23*	5505.79	*39.64*	4807.19	*34.61*	**-729.85**	***-13.34***
Forest	8189.73	*59.07*	8032.64	*57.94*	7807.58	*56.21*	8100.81	*58.32*	**-88.92**	***-1.27***
Water Area	74.76	*0.54*	57.24	*0.41*	98.21	*0.71*	246.42	*1.77*	**171.66**	***229.00***
Other	1.74	*0.01*	0.00	*0.00*	448.16	*3.23*	591.03	*4.26*	**589.29**	***33804.12***
Total	**13 863.33**	***100.00***	**13 863.32**	***100.00***	**13 889.14**	***100.00***	**13 889.14**	***100.00***		
Agriculture Area:										
Arable Land	572.81	*4.13*	826.32	*5.96*	82.49	*0.59*	2756.71	*19.85*	**2183.90**	***380.37***
Mosaic	0.00	*0.00*	0.00	*0.00*	1878.02	*13.52*	0.00	*0.00*	**0.00**	***0.00***
Vineyard	1.74	*0.01*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	**-1.74**	***-100.00***
Grassland	4962.49	*35.80*	4889.56	*35.27*	3545.28	*25.53*	2050.48	*14.76*	**-2912.01**	***-58.76***

Tab. 3: Land use/land cover in Soutok pPLA in 1841-2006

4.3. Processes of the 1841 – 2006 LULC change

Comparison of single LULC classes between years 1841 and 2006 in both of areas determines general processes of landscape horizontal structure changes. We identified processes of urbanization (change from any of class to Built-up area), intensification (changes from Forest, Grassland or Water area to Arable land, Vineyard or Orchard, also from Vineyard and Orchard to Arable land), abandonment (change from Arable land, Vineyard or Orchard to Grassland), afforestation and irrigation. Other processes comprise i.e. changes from Arable land to Vineyard or Orchard. Values of inter-class changes are listed in Tab. 4 and 5. Share of LULC change processes (Fig. 5) is similar in both study areas. Without LULC change is 59.4% of the area of Pálava PLA, or 63.2% of the Soutok pPLA, respectively. Urbanized was 3.0% of Pálava PLA and 0.6% of Soutok pPLA area; this small value is related to delimitation of pPLA outside the built-up areas. Abandonment experienced 1.0% of Pálava PLA area and 0.5% of Soutok pPLA area, minimal extent has also irrigation (0.2% Pálava PLA, 1.6% Soutok pPLA). Relatively significant was afforestation: 9.2 % in Pálava PLA and 7.8% in Soutok pPLA. The most important process of 1841 – 2006 LULC change is intensification, which concerns 11.2% of the Pálava PLA area and 17.5%

of the Soutok pPLA area. Without adequate management of the Soutok area, ensured by status of PLA, we could expect acceleration of negative processes.

2006	Built-up Area		Orchard		Arable Land		Vineyard		Grassland		Forest		Water area		Other		***Total in 1841***
1841	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha
Built-up Area	**235.94**	***83.19***	28.59	*10.08*	1.48	*0.52*	4.50	*1.59*	1.40	*0.49*	7.18	*2.53*	0.00	*0.00*	4.51	*1.59*	**283.60**
Orchard	2.19	*9.35*	**2.25**	***9.60***	8.08	*34.49*	0.43	*1.84*	0.07	*0.30*	8.77	*37.43*	0.00	*0.00*	1.64	*7.00*	**23.43**
Arable Land	171.45	*5.27*	121.99	*3.75*	**1873.95**	***57.66***	652.67	*20.08*	55.89	*1.72*	228.63	*7.03*	4.35	*0.13*	141.32	*4.35*	**3250.25**
Vineyard	34.86	*2.63*	132.01	*9.98*	318.98	*24.10*	**642.14**	***48.52***	32.37	*2.45*	78.50	*5.93*	2.00	*0.15*	82.47	*6.23*	**1323.33**
Grassland	42.48	*3.91*	75.33	*6.93*	286.01	*26.29*	84.37	*7.76*	**92.26**	***8.48***	432.07	*39.72*	9.97	*0.92*	65.25	*6.00*	**1087.74**
Forest	1.93	*0.08*	0.62	*0.02*	184.25	*7.31*	16.19	*0.64*	61.54	*2.44*	**2215.33**	***87.85***	0.71	*0.03*	41.25	*1.64*	**2521.82**
Water area	3.19	*2.58*	0.76	*0.61*	8.58	*6.94*	0.01	*0.01*	19.49	*15.76*	32.92	*26.61*	**52.98**	***42.83***	5.76	*4.66*	**123.69**
Total in 2006	**492.04**		**361.55**		**2681.33**		**1400.31**		**263.02**		**3003.40**		**70.01**		**342.20**		**8613.86**

Tab. 4: Land use/land cover changes in Pálava PLA between 1841 and 2006

2006	Built-up Area		Orchard		Arable Land		Grassland		Forest		Water area		Other		***Total in 1841***
1841	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha	*%*	ha
Built-up Area	**9.86**	***30.02***	10.43	*31.75*	0.25	*0.76*	3.39	*10.32*	5.99	*18.23*	0.00	*0.00*	2.93	*8.92*	32.85
Orchard	0.99	*3.64*	**0.99**	***3.64***	10.70	*39.34*	5.86	*21.54*	2.71	*9.96*	1.07	*3.93*	4.88	*17.94*	27.20
Arable Land	14.08	*2.46*	15.96	*2.79*	**382.66**	***66.80***	40.98	*7.15*	89.01	*15.54*	14.76	*2.58*	15.37	*2.68*	572.82
Vineyard	0.00	*0.00*	0.00	*0.00*	1.74	*100.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	1.74
Grassland	25.82	*0.52*	54.22	*1.09*	2196.29	*44.26*	**1313.19**	***26.46***	964.47	*19.44*	143.52	*2.89*	264.98	*5.34*	4962.49
Forest	7.72	*0.09*	3.53	*0.04*	150.98	*1.84*	679.89	*8.30*	**7016.67**	***85.68***	57.81	*0.71*	273.12	*3.33*	8189.72
Water area	0.08	*0.11*	0.00	*0.00*	12.39	*16.57*	6.1	*8.16*	20.12	*26.91*	**29.1**	***38.92***	6.97	*9.32*	74.76
Other	0.00	*0.00*	0.00	*0.00*	1.70	*6.17*	1.07	*3.88*	1.84	*6.68*	0.17	*0.62*	**22.78**	***82.66***	27.56
Total in 2006	**58.55**		**85.13**		**2756.71**		**2050.48**		**8100.81**		**246.43**		**591.03**		**13 889.14**

Tab. 5: Land use/land cover changes in Soutok pPLA between 1841 and 2006

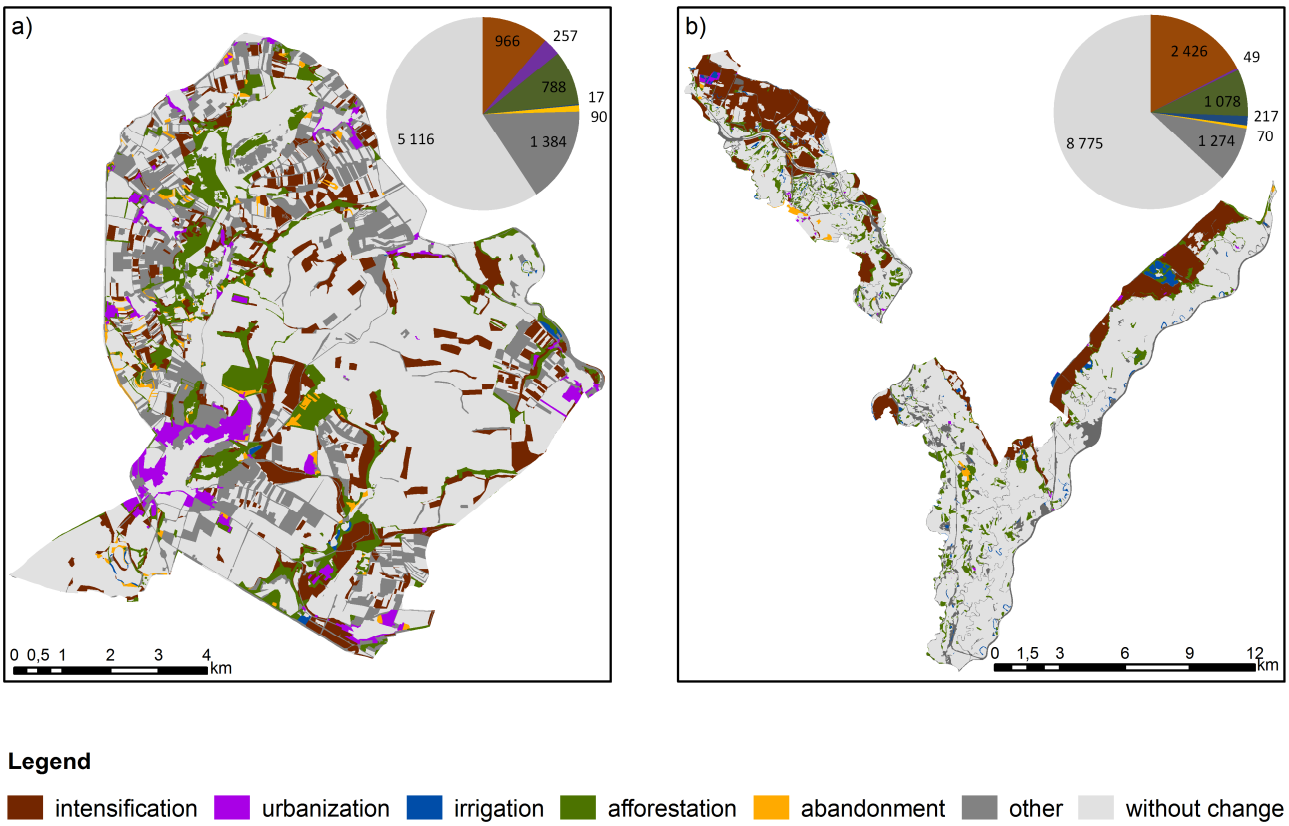


Fig. 5: Main processes of the 1841 – 2006 land use/land cover changes in a) Pálava PLA and b) Soutok pPLA

5. Discussion on causes of the LULC changes

LULC and landscape tending changes, observed in study areas, show both general trends typical for whole area of the Czech Republic (Lipský, 2000) and specific trends given by character of each study area.

5.1. Built-up areas and orchards

Not only for the Czech Republic is typical distinct increase in built-up areas during the 20th century (Lipský, 2000). Increase in Built-up area is comparable in both study areas (~75%). The highest rate of increase was observed here between years 1938 and 2006 (Tab. 2, 3). Built-up areas increased mainly at the expense of Arable land and Grassland (Tab. 4, 5), which corresponds with general trend of occupation of agricultural land by urban development.

Orchards extent decreased between 1841 and 1876 in both study areas. In Soutok pPLA, this decrease continued till 1938, while in Pálava PLA orchard´s area increased in this period, probably because of bigger proportion of urbanized areas, to which orchards are closely related. Common for both areas is jump increase in orchards area between 1938 and 2006. This is caused by existence of

agricultural mosaic in the year 1938. Small fields of mosaic, including also fruit trees, adjoined with built-up areas directly, while nowadays are residential parts buffered by zone of orchards and gardens. Additionally, agricultural management changes after the Second World War – consolidation of agricultural land – meant multiple increases in large-area orchards.

5.2. Grassland

Development of grasslands, experiencing both absolute and relative decrease, confirms negative trends mentioned by other authors (Miklín, 2007, AOPK, 2010). In both areas, the decrease is caused mainly by intensification (change to arable land – 286 ha, i.e. 26.3% in Pálava PLA and 2196.3! ha, i.e. 44.3%! in Soutok pPLA – Tab. 4, 5) and by afforestation (432.1 ha, i.e. 39.7%! in Pálava PLA and 964.5 ha, i.e. 19.4% in Soutok pPLA – Tab. 4, 5). There are more causes for afforestation of grasslands. The main causal factor in both areas was the limitation of traditional management of grasslands, i.e. pasture and grass-cutting. Declaration of Pálava as a PLA in 1979 had a great influence because of prohibition of agricultural management (pasture and grass-cutting) due to that time consensus of nature conservation (no management and leaving nature to its "natural" development – Kostkan, 1996). In Soutok pPLA, intentional afforestation played its role, but important effect had also an existence of state border area – the Iron Curtain, which was buffered by a wide zone of forbidden entry. Starting with shrubs and continuing with trees, afforestation was spontaneous. Grasslands, considering both steppe biotopes in Pálava and floodplain meadows in Soutok, are thus ecosystems requiring active management for its preservation. In Soutok pPLA, meadows are mechanically cutted. Some last decades, mechanical and chemical disposal of self-sowing wood species and pasture of sheep and goats has been realized in Pálava PLA (AOPK, 2006). Because of shortage of money and presence of tenacious invasion plants (i.e. Robinia pseudoacacia or Ailanthus altissima) it is an infinite fight and afforestation could be only retarded, not stopped.

5.3. Agricultural mosaic

Very interesting is condition of agricultural land in 1938 (Fig. 2c, 3b, 3d, 4c). Despite a few exceptions, there was mosaic of very small, elongated fields, with temporal changes of use (i.e. arable land, grassland, accompanied with orchards, vineyards and solitary trees). Origin of the mosaic is most probably connected with Czech Land Reform, which took place in 1919 – 1935 (Balcar, 2000). During the reform, 30.34% of land, held mainly by aristocracy or by the Church, was parceled to small landowners (Pavel, 1938). To illustrate internal structure of mosaic, we

vectorized all of the partial fields in several representative areas (delimited by orientation of fields or paths). We calculated an average area of one part of mosaic as 0.444 ha in Pálava PLA, or 0.478 ha in Soutok pPLA respectively. Considering 4842.7 ha as total area of mosaic in Pálava PLA in year 1938, the number of partial fields could be expected as high as 11 000. In the year 2006, there were 2332 fields (in Agricultural land class) on the area of 1938´s mosaic, which constitutes 21.3% of the number of fields in 1938. Similar situation is in Soutok pPLA, where area of mosaic in 1938 was 1878 ha and thus the total number of partial fields was nearly 4000. In 2006, there were 469 fields (11.9%).

5.4. Vineyards

In Pálava PLA, there were no large-area vineyards in 1938, but vineyards were included as small patches in agricultural mosaic (Fig. 2c). As the main cause we consider the decrease of wine consumption in the second half of 19th century (Kraus et al., 1999). According to the industrial revolution, drinking of beer and spirits began more common. Also after abolition of customs frontier between Austria and Hungary and together with railways development, Moravian wines lost their competitive strength and industrial plants were produced instead of wine (Jílek et al., 1984). Lapse of wine and large vineyards in southern Moravia was finished by massive spreading of vine fretter and other wine diseases in the break of 19th and 20th century (Doležal, 2001) and also – before mentioned – Land Reform. For small farmers and land owners, vineyards were less attractive due to low profitability and impossibility of crop alternating on areas covered by vineyards (Jílek et al., 1984).

Small extent of vineyards persisted until 1960s, when restoration of vineyards accelerated due to founding of new, mechanically accessible vineyards and using new methods of cultivation (Kraus et al., 1999). The highest increase in vineyard´s area was in the 1990s, before accessing the European Union. Contemporary area of vineyards is slightly higher than in 1841 (Tab. 2).

5.5. Forests

Important observed change is the transformation of forest management. Traditional ways of forest management near settlements were cattle pasture and keeping forest as coppice or coppice-with-standards woodland (Vera, 2000). It means structured, open-canopy and sunny stand with coppice trees and standard trees – mainly very old and colossal oaks (Konvička et al., 2005). Forest pasture was officially prohibited in 1754, but in the floodplain forest of Soutok area had persisted until 1873 at least (Vrška et al., 2006). From this time, transformation of coppice forest into even-aged

stands with closed canopy and clear-cutting management started. Such change inside of Forest class could be observed only from aerial photographs, not on historical maps. In 1938, open woodland occupied area of 1301.6 ha (even 300 ha more than closed canopy forest) in Pálava PLA, or 651 ha in Soutok pPLA, respectively. Nowadays, area of clear-cuts is more than twice (1221.2 ha) compared to 1938 (629.1 ha) in Soutok pPLA and open woodlands do not exist in both study areas. Moreover, decrease of number of the solitary trees (mainly oaks) in meadows is connected with forest management changes. The number of solitary trees decreased from 1329 pieces (year 1938) to 644 pieces (year 2006), i.e. less than a half. Forest character changes (even-aged stands, clear-cutting management, decrease of number of standard and old trees) have negative effect on many of endangered and protected species, such as Hermit beetle (Osmoderma barnabita), the Great Capricorn beetle (Cerambyx cerdo), the Jewell beetle (Eurythyrea quercus) and others (Vodka et al., 2009, Čížek, Hauck, 2008, Čížek, Zábranský, 2009).

5.6. Water areas

Development in Water area class follows some general trends. In Pálava PLA we observed mainly changes of fishponds (Fig. 3a). In 1841, size of water areas was the largest in studied period (123.7 ha). During next one hundred years, almost all fishponds have been dried and changed into the agricultural land (meadows, arable land) – as documented in 1938, when Křivé jezero Lake (3.6 ha, Tab. 2, Fig. 2c) was the only water area in Pálava PLA. During the second half of 20th century, almost all ponds were renewed, but not in their original size (their contemporary area is less by 43.4%, compared with 1841). Soutok pPLA was affected mainly by water-resources control, canalization and regulation of watercourses; from 1938 to 2006, Dyje and Morava Rivers were shortened by 4.6% (Dyje) and 39.6%! (Morava). Many of former river meanders changed into the slacking water (increase by 150.9%).

5.7. Landscape stability and diversity

We evaluated ecological stability, landscape diversity and its changes in the study areas using landscape metric indexes C_{ES} (Lipský, 2000) and SDHI (Shannon, Weawer, 1949). Results are shown in Table 6.

According to C_{ES} values, area of Soutok pPLA is more ecologically stable then Pálava PLA, which is caused by proposing of PLA to non-urbanized and less agriculturally managed areas. Trends of C_{ES} are different in each of areas (tab. 6).

	Coefficient of ecological stability		Shannon diversity index		
	Pálava PLA	**Soutok pPLA**	**Pálava sq. 1**	**Pálava sq. 2**	**Soutok sq. 1**
1841	0.492	0.835	0.924	1.203	0.872
1876	0.463	0.822	0.672	0.954	0.689
1938	0.478	0.777	0.258	1.202	0.704
2006	0.495	0.736	1.081	0.704	0.740

Tab. 6: Coefficient of ecological stability and Shannon´s diversity index in 1841-2006

In Pálava PLA, there is decrease of C_{ES} between 1841 and 1876, caused mainly by decrease of Water area and Grassland and increase of area of Arable land. Since 1876, there is slow increase of C_{ES} until 2006. Main reasons are: decrease of area of all forms of agriculture land, renewing of ponds and increase of forest area. We must mention the paradox that afforestation, a process which according to C_{ES} methodics increases ecological stability of an area, is perceived as major negative process in the context of nature conservation in Pálava PLA.

In Soutok pPLA, value of C_{ES} constantly decreases in the studied time span. There act two main processes against each other: afforestation as positive effect and intensification (turning grasslands into arable land) as negative effect, which was stronger.

Values of SHDI show relatively common trend in all sample squares (tab. 6). SHDI in Pálava sq. 1 (covering area of one of the ponds and its vicinity with agricultural land) decreased from 1841 due to drainage of pond, intensification of agriculture and which resulted to the lowest index value in 1938. Value of SDHI in 2006 is highest because of renewal of the pond and change of agricultural mosaic into distinct units of arable land and grassland.

Pálava sq. 2 (covering area of Tabulová National Nature Reserve and its vicinity with arable land and vineyards) represents relatively stable area, with small changes in proportion of both agricultural (mosaic, vineyards, arable land) and natural (grasslands and forest) classes.

Soutok sq. 1 (covering typical mosaic of forest, grassland and water courses) shows also relatively stable natural area with small changes.

5.8. Analysis of timber harvesting intensity in next 110 years in Soutok pPLA

Amount of timber harvesting is one of the most discussed themes of Soutok pPLA. We analyzed forest age-structure, assuming that area of forest with certain age is usable for prognosis of timber harvesting in given decennium. The analysis was based on forestry maps from the year 2009.

Acquired results (Fig. 6) clearly show, that forest age-structure is very uneven and percentage of area occupied by each age interval vary between 2.75% to 14.27%. As threshold of equable portion

(concerning 15 age intervals) can be used arithmetic mean – 6.66% of area per decennium (red line in the Fig. 6). Portion of clear-cuts and forests less than 10 years old (i.e. timber harvested in last decennium, between 1999 and 2009), is 14.27%, it means more than twice to equable portion and shows alarming amount of timber harvesting in this decennium.

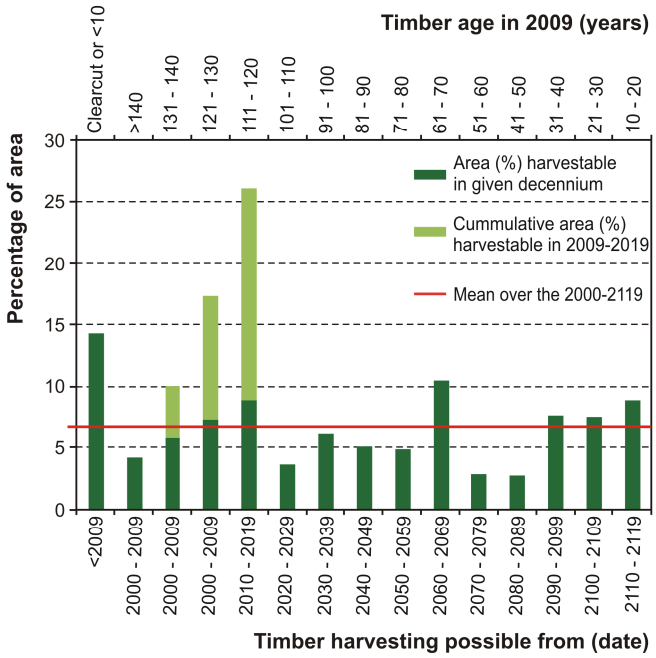


Fig. 6: Timber age structure and harvesting prognosis in Soutok pPLA for the next 120 years

Portion of forest achieving exploitable age in next decennium is 26.1% (determining species is oak with exploitable age 120 years). This means (even in case of reduced timber harvesting in next four decenniums) rapid decrease of old stands, necessary for many endangered and protected fauna species (Miklín et al., 2010).

Concerning other negative practices, such as exceptions from size of clear-cuts or use of full-area soil preparation (milling of clear-cuts), the present status of nature conservation of this extremely biologically valuable area is insufficient and means failure of controlling state administration.

6. Conclusions

The most important changes of LULC, discovered in study areas of Pálava PLA and Soutok pPLA in the years 1841 – 2006, were as follows: i) decrease of grasslands due to intensification of agriculture (changing grasslands to arable land) and afforestation; ii) increase in forest area; iii) specific representation of agriculture land (arable land, vineyards, orchards, meadows and pastures) in 1938 as a mosaic of very small and elongated fields, without large-scale vineyards; iv) change of forest management from open, pasture woodlands (coppice forests with standards) to clear-cut management.

Most serious problem (from nature conservation point of view) of Pálava PLA, afforestation of natural grasslands, is now solved by the set of management measures by PLA Administration, but forest spreading is too fast, also because of spread of invasive species.

Contemporary management and processes in Soutok pPLA, as recorded not only by LULC or C_{ES} changes are in the face of area´s biodiversity preservation unsuitable. Amount of forest timber harvesting in last decennium highly exceed sustainability, and (concerning age structure of forest stands) contemporary forest management means direct endangering of many unique species. Contemporary protection of area as SCI is in practice insufficient and many of rulings of competent organ (South Moravian Regional Authority) are in conflict with principles of SCI conservation. In the interest of preservation of species and biotopes of this area, it is necessary to ensure real and effective conservation and sustainable management of the area, i.e. by declaring Soutok area as PLA.

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