Zbornik gozdarstva in lesarstva 98 (2012), s. 39 - 49

GDK: 91+150:148.2(045)=111
Prispelo / *Received*: 03. 09. 2012
Sprejeto / *Accepted*: 23. 12. 2012

Izvirni znanstveni članek
Original scientific paper

LANDSCAPE CHANGES IN THE PIVKA AREA, SLOVENIA

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Abstract

Spontaneous afforestation is one of the biosystemic landscape change processes affecting landscape functioning. The process of overgrowing is highly dynamic, and the temporal dimension of changes in landscape structure can be of key importance for evaluating habitat suitability.

A detailed study was carried out in the area of 19.52 km^2 within the Pivka municipality, where land use is a mixture of traditional farmland, forests, and extended areas of abandoned former farmland with natural re-growth. In addition, this area is highly important for two bird species: the Barred Warbler (*Sylvia nisoria*) and the Red-backed Shrike (*Lanius collurio*). Both species are sensitive to forest spreading and prefer a mixture of extensive meadows with shrubs and hedgerows as their most suitable habitat.

Digital BW orthophotos from the 1975 – 2000 period and colour digital orthophotos from 2009 have been used for on screen digitizing of the EUNIS habitat classes. Indicators of landscape changes were derived from temporal based difference in the landscape structure (different structural indicators based on patch size, shape, distances and patch dynamics). All the details obtained were evaluated based on Earth observation data and GIS supported methods.

The most valuable parts of the area for both species are, from a biodiversity point of view, the core forest areas and mixture of meadows with shrubs and hedgerows.

Key words: afforestation, habitat analysis, EUNIS, landscape indices, Pivka

KRAJINSKE SPREMEMBE NA OBMOČJU PIVKE, SLOVENIJA

Izvleček

Spontano zaraščanje je eden izmed biosistemskih procesov sprememb, ki vplivajo na delovanje krajine. Zaraščanje je dinamično in časovna dimenzija sprememb v krajinski zgradbi je lahko ključnega pomena za ocenjevanje primernosti habitatov.

Podrobnejšo analizo smo izpeljali na 19,52 km2 izbrane površine v občini Pivka, kjer gre za prostor, kjer je raba zemljišč preplet tradicionalnih kmetijskih zemljišč, gozdov in obsežnih predelov zaraščajočih se kmetijskih površin. Poleg tega je to območje zelo pomembno za dve vrst ptic: pisano penico (Sylvia nisoria) in rjavega srakoperja (Lanius collurio). Obe vrsti sta občutljivi za širjenje gozda, saj je njun habitat preplet ekstenzivnih travnikov z grmičevjem in živicami.

Za zaslonsko digitalizacijo habitatnih razredov EUNIS smo uporabili digitalne črno-bele ortofoto posnetke iz obdobja 1975 - 2000 in barvni digitalni ortofoto iz leta 2009. Kazalce krajinskih sprememb smo izpeljali iz razlike v zgradbi krajine iz različnih let (različni kazalniki krajinske zgradbe, ki temeljijo na velikosti in obliki zaplat, medsebojnih razdaljah med njimi in časovni dinamiki). Vse pridobljene podatke smo ovrednotili na podlagi daljinsko pridobljenih podatkov v okolju GIS.

Najvrednejši deli prostora so jedrne cone gozdov in prepleti travnikov z živicami in grmovjem.

Ključne besede: zaraščanje, analiza habitatov, EUNIS, kazalci krajinske zgradbe, Pivka

INTRODUCTION
UVOD

Spontaneous afforestation is one of the biosystemic landscape change processes affecting landscape functioning. It is the result of a combination of structural, social and demographic reasons in several more or less remote areas in several EU countries (Kobler et al., 2005). In Central Europe, former abandoned agricultural land has been very often transformed entirely into forest matrix (Antrop, 2005; Čas and Adamič, 1998; Čas, 2006; Hladnik, 2005; Jongman, 2004;Van Eetvelde and Antrop, 2004).

According to EUROSTAT (statistical office of the European Union), the indicator "Change in traditional land-use practice" measures the potential maintenance of biodiversity by use of traditional as opposed to intensive land management and use practice. Changes in high value farming system frequently result in homogenisation of land use and loss of landscape elements, natural and man-made (Taylor, 2002). Yet in the case of spontaneous afforestation, another dimension of this indicator can be developed, namely one may measure the potential maintenance of biodiversity by use of traditional practice as opposed to abandoned land use. Such changes again result in homogenisation (of another type, as it means that the vegetational succession has been taking over)

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of land use and drowning of landscape elements (natural and man-made) in a forest matrix (as a climax land cover in the Central European conditions).

Traditional understanding of the Eurostat indicator "Change in land cover" (EUROSTAT 2010) should not be therefore considered just in one way, towards intensification of land use, but also the other way around, towards extensification (Osterman, 1998; Debussche et al., 1999).

In Slovenia, the rate of forest cover spread has been dramatic, starting as early as in the 19th century and continuing well into the end of the 20th century (Kobler, 2000). With introduction of aerial survey of Slovenia in 1973 (Hočevar, 1984), it was possible to follow land use changes and development of land abandonment through the end of the 20th century and beginning of the 21st century.

In our study we have aimed to explore and understand spread of spontaneous afforestation in the Pivka region (southwestern Slovenia), where land abandonment has been recognized as a serious problem (Kobler et al., 2005). The aim of the study is to associate land use information with EUNIS habitat types and to evaluate land use transitions with certain landscape indices.

At the same time, the area remaining in grasslands (pastures or meadows) or arables is extremely important for at least two bird species, the Barred Warbler (*Sylvia nisoria*) and the Red-backed Shrike (*Lanius collurio*), as mentioned in the newest proposal for the revision of Special Protection Areas (SPA) in Slovenia (Denac et al., 2011). Both species are sensitive to forest spreading and prefer a mixture of meadows with shrubs and hedgerows as their most suitable habitat.

STUDY AREA AND METHODS
PODROČJE RAZISKAVE IN METODE

The detailed test site area of 19.52 km^2 lies in the Pivka municipality around the village of Palčje, south of Lake Palško. This is a typical karst region with predominating limestone and dolomite geology. Land use is a mixture of the traditional farmland, forests and extended areas of abandoned farmland with natural re-growth. Black and white (BW) digital orthophotos (DOF) from the 1975-2000 period and colour DOF (year 2009) with a resolution of 1m (year 1975) and 0.5m (2000 and 2009) were used as a backdrop for the on-screen digitizing of polygon boundaries, employing Cartalinx 1.2 software for this purpose. The minimum mapping unit was 100 m^2 (Figures 1 - 3).

GIS software package Idrisi Andes (Eestman, 2006) and FRAGSTATS 4.0 (McGarigal et al., 2012) were used for calculating different spatial metrics.

The EUNIS Habitat types classification is a comprehensive pan-European system to facilitate the harmonised description and collection of data across Europe through the use of criteria for habitat identification; it covers all types of habitats from natural to artificial, from terrestrial to freshwater and marine (eunis.eea.europa.eu/about.jsp).

Class D5.2 was delineated through comparison of DOFs and field examination. Class E1.5 was defined as typical for

Fig. 1: The study area in 1975

Slika 1: Študijsko območje v letu 1975

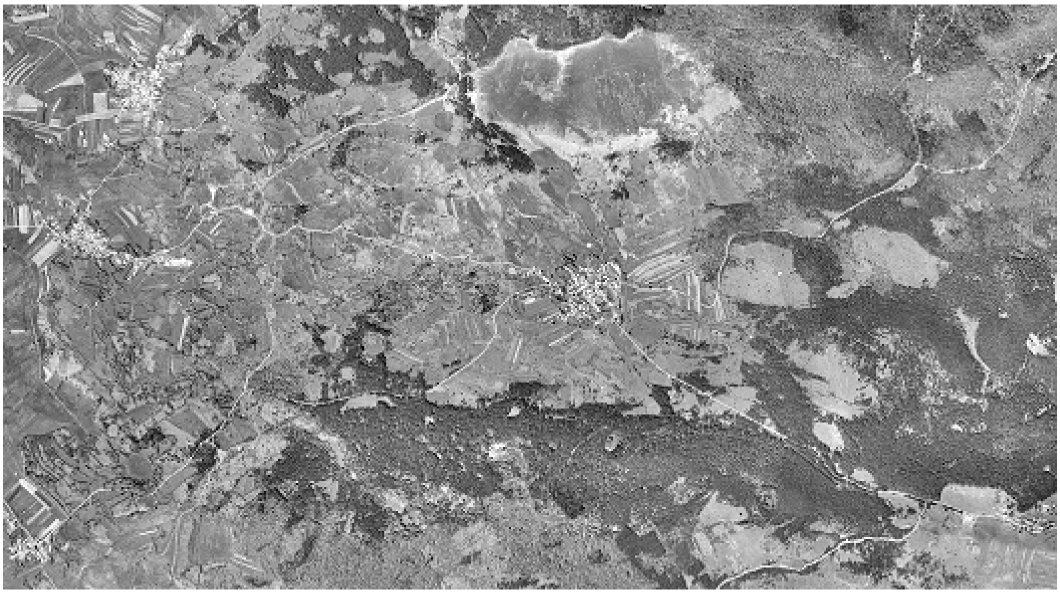

Fig. 2: The study area in 2000

Slika 2: Študijsko območje v letu 2000

Fig. 3: The study area in 2009

Slika 3: Študijsko območje v letu 2009

all pastures in the study area, where bedrock and soils prevent intensive farming (shallow soils, scrubs, limestone and dolomite outcrops on the surface). Class E2.2 was found on better soils often in the lowland, enabling more intensive agricultural land use (linear tracks of hay-mowing machinery can be sometimes traced even on DOFs). Class E3.4 was wet grassland found on the bottom of intermittent lakes (which are a specific feature of the local karst geology). Class F3.2 represented areas with early forest succession stages of *Corylus*, *Quercus*, *Ostrya* and *Pinus* species. Class F9.2 represented *Salix* species on the bottom of intermittent lakes, easily distinguished from *Pinus* species on all DOFs. FA were hedges, easily distinguishable on DOFs; they were either of linear or nonlinear shapes when following different objects like roads or small karst dolines and poljes. Classes G1.7 and G3.5 were thermophilous woodlands and black pine woods respectively, class G5.6 representing early-stage natural regrowth either of black pine or broadleaved trees or mixture of both, easily traced on DOFs. Class I were fields usually near the villages, while class J were main roads and villages. Beside the mentioned EUNIS classes, we decided to distinguish also a new class E1.5/FA where it was not possible to identify land cover clearly. We decided not to separate EUNIS E1.5 / E2.2 and FA when the ratio of a hedgerow width to the nearest ne-

Table 1: EUNIS habitat classes in the Pivka study area

Preglednica 1: Habitatni razredi EUNIS v študijskem območju Pivka

Hab. class / *Habitatni razred*	**Scientific name / *Znanstveno ime***
D5.2	Beds of large sedges normally without free-standing water / *Površine šašev, praviloma brez stoječe vode*
E1.5	Mediterraneo-montane grassland / *Kraški pašniki*
E2.2	Low and medium altitude hay meadows / *Mezofilni travniki in pašniki na boljših tleh*
E3.4	Moist or wet eutrophic and mesotrophic grassland / *Vlažni, gospodarjeni travniki*
F3.2	Mediterraneo-montane broadleaved deciduous thickets / *Zaraščajoče se površine z grmovjem*
F9.2	[*Salix*] carr and fen scrub / *Zaplate vrbovja kot grmi in nizko drevje*
E/FA	A transition between E1.5 and FA, still more similar to E / *Prehodi med razredoma E1.5 in FA, več podobnosti z razredom E*
FA	Species-rich hedgerows of native species / *Omejki, bogati z domačimi vrstami*
G1.7	Thermophilous deciduous woodland / *Gozd termofilnih listavcev*
G3.5	*[Pinus nigra*] woodland / *Gozd črnega bora*
G5.6	Early-stage natural and semi-natural woodlands and regrowth / *Zaraščajoča se površina z mladovjem listavcev*
I	Regularly or recently cultivated agricultural, horticultural and domestic habitats / *Redno obdelovane kmetijske (njivske) površine*
J	Constructed, industrial and other artificial habitats / *Zgrajeni, industrijski in umetni habitati*

ighbour hedgerow distance was less than 1:5. In these cases, E1.5 with hedgerows was regarded as a single polygon and named E-FA class. When this ratio exceeded 1:5, the hedgerows were digitized separately to the class E1.5 or E2.2 in which they were “embedded”. We also decided not to separate E and FA where the distance exceeded the ratio 1:5, but at the same time we found FA in a very early stage, scattered or just indicated (especially in the DOF from 1975) so that in such cases we digitized them jointly . For the year 2009, all borders of EUNIS class polygons from 2000 were checked and corrected to situation based on digital colour DOFs from 2009. EUNIS classes were checked in the field and also by means of stereoscopic interpretation of black and white aerial photos. However, it turned out to be quite a challenge to distinguish E1.5 to E2.2. The decision was based on the mowing tracks, data of meadow quality and possible early shrub appearance where these sights of intensiveness / extensiveness helped us to distinguish both classes. Sometimes, however, it was not possible to distinguish these features especially in the 1975 DOF due to its poorer quality. Class identification errors in some cases therefore cannot be excluded. However, for each EUNIS class a randomly chosen set of 30 ground points within 100 m buffer zone along the roads was controlled to evaluate possible mistakes on EUNIS classes.

The polygon boundaries were delineated first in accordance with the distribution of EUNIS classes in the year 2000 DOF. These boundaries were compared with the year 1975 image and all the changes taken into consideration either through division of a primary established polygons into more than one sub-polygons (within the shape of original polygon) or through addition of new polygons. All polygons were assigned three polygon attributes, one representing EUNIS Class for the years 1975 and 2000 and another for the year 2009 respectively. Vector image produced in this way was exported into the environment of Geographic Information System Idrisi Andes and converted into the raster format with 1 m spatial resolution. With the use of different modules (Assign, Crosstab, Distance, Group, Reclass), three raster images with 1m resolution were produced for the years 1975, 2000 and 2009.

For the evaluation of land use transitions, certain indices of spatial metrics based on EUNIS classes concerning area, shape, dynamics, distances, edge and core areas were used as suggested by different authors (Riiters et al., 1995; Turner et al., 1989; Baker and Cai, 1992). Corrected shape index (Sh) is based on adjusted perimeter – area ratio and Area ratio index (Ar) is derived from Class area proportion (CAP) index (Leitão et al., 2006). All relations were calculated as follows:

$$SH = \frac{P}{2\sqrt{\pi}\,\sqrt{A}}$$

P = perimeter; A = area; Ei = EUNIS class “i” area

$$Ar = \frac{Ei}{(A - Ei)}$$

A = area; Ei = EUNIS class “i” area

In order to evaluate information regarding habitat structure at the landscape level, all EUNIS classes were aggregated into following four major land use classes:

- "Grassland": EUNIS classes D5.2, E1.5, E2.2, E3.4 E/FA;
- "Hedges": EUNIS class FA;
- "Afforestation": EUNIS classes F3.2, F9.2, G5.6;
- "Forests": EUNIS classes G1.7, G3.5.

For additional evaluation of habitat suitability, several spatial metrics based on area shape and distance relations were calculated for these aggregated classes. FRAGSTATS 4.0 software was used for the following equations (McGarigal et al., 2012).

CA – total class area;

$$CA = \sum_{j=1}^{n} a_{ij}\left(\frac{1}{10000}\right)$$

a_{ij} = area (m) of patch ij.

CA equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by 10,000 (to convert to hectares); that is, total class area.

PLAND – percentage of class in a landscape;

$$PLAND = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100)$$

P_i = proportion of the landscape occupied by patch type (class) i.

a_{ij} = area (m^2) of patch ij. A = total landscape area (m^2).

NP – number of class patches;

NP = n_i

n_i = number of patches in the landscape of patch type (class) i.

LPI – largest patch index;

$$LPI = \frac{\max\limits_{j=1\ to\ n}(a_{ij})}{A}(100)$$

a_{ij} = area (m^2) of patch ij.

A = total landscape area (m^2).

TE – total class edge;

$$TE = \sum_{k=1}^{m} e_{ik}$$

e_{ik} = total length (m) of edge in landscape involving patch type (class) i; includes landscape boundary and background segments involving patch type i.

TCA - total class core area;

$$TCA = \sum_{j=1}^{n} a_{ij}^{c}\left(\frac{1}{10000}\right)$$

a_{ij}^{c} = core area (m^2) of patch ij based on specified edge depths (m).

AREA_MN – average class patch area;

$$AREA_{MN} = \frac{\sum_{j=1}^{n} Xij}{ni}$$

MN (Mean) equals the sum, across all patches of the corresponding patch type, of the corresponding patch metric values, divided by the number of patches of the same type. MN is given in the same units as the corresponding patch metric.

n_i

GYRATE_MN – measure of class patch extent, distance from its centroid,

$$GYRATE = \sum_{r=1}^{z} \frac{h_{ijr}}{z}$$

h_{ijr} = distance (m) between cell ijr [located within patch ij] and the centroid of patch ij (the average location), based on cell centre-to-cell centre distance.z = number of cells in patch ij.

All these major land use classes were evaluated for the purpose of studying their temporal persistence or change. For this reason, urban land use was not evaluated. All indices tested in our research are well known and have been widely used for more than a decade for different ecological and landscape ecological purposes (Baker and Cai, 1992; Forman, 1995; Kienast, 1993; LaGro, 1991; Lang et al., 2002; McGarigal et al., 2012; Turner, 1989).

RESULTS
REZULTATI

Some indices of spatial metrics based on EUNIS classe area, shape, dynamics, distances, edge and core areas were evaluated giving following results, based on different landscape indices to evaluate what type of transitions and landscape changes have occurred in the study area.

Shape index is especially sensitive to changes of hedgerows as longitudinal landscape features.

Spatial stability is expressed as a percentage of each EUNIS class area in the year 2009 that has remained unchanged from the year 1975. Lower percentages indicate major changes.

As forest spreading was the most dominant land use change process during the last quarter of the 20th century in the study area, a more detailed evaluation was carried out.

Table 2: Patch shape (Sh) index of different EUNIS classes

Preglednica 2: Kazalec oblike zaplat (Sh) posameznih kategorij EUNIS

class /*razred* year / *leto*	D	E	F	E/FA	FA	G	R/S
1975	4.56	32.52	28.08	9.39	36.36	21.87	22.74
2000	5.45	40.11	25.53	10.49	49.29	22.56	22.86
2009	5.26	41.65	27.95	8.50	57.72	21.99	23.66

Table 3: Patch transitions of EUNIS classes between the years 1975 and 2009

Preglednica 3: Prehodi med zaplatami razredov EUNIS med letoma 1975 in 2009

EUNIS classes	meas. unit	D5.2	E1.5	E2.2	E3.4	F3.2	F9.2	E-FA	FA	G	I	J4.2	J1.2	Total 2009 *Skupaj 2009*
D5.2	ha	56.95	0	0	0	0	0	0	0	0	0	0	0	56.95
	%	100	0	0	0	0	0	0	0	0	0	0	0	100
E1.5	ha	0	221.03	0	0	23.07	0	0	0	5.66	0	0	0	249.76
	%	0.0	88.5	0.0	0.0	9.2	0.0	0.0	0.0	2.3	0.0	0.0	0.0	100
E2.2	ha	0	2.26	343.22	0	0	0	0	0	0.46	0	0	0	345.94
	%	0.0	0.7	99.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	100
E3.4	ha	0	0	0	28.9	0	0	0	0	0	0	0	0	28.9
	%	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
F3.2	ha	0	89.82	4.1	0	50.38	0	0	0	0.45	0	0	0	144.75
	%	0.0	62.1	2.8	0.0	34.8	0.0	0.0	0.0	0.3	0.0	0.0	0.0	100
F9.2	ha	3.45	0	0	0	0	11.55	0	0	0	0	0	0	15
	%	23.0	0.0	0.0	0.0	0.0	77.0	0.0	0.0	0.0	0.0	0.0	0.0	100
E-FA	ha	0	31.81	0	0	0	0	65.47	0	0	0	0	0	97.28
	%	0.0	32.7	0.0	0.0	0.0	0.0	67.3	0.0	0.0	0.0	0.0	0.0	100
FA	ha	0	8.42	3.61	0	1.03	0	0	26.72	0	0	0	0	39.78
	%	0.0	21.2	9.1	0.0	2.6	0.0	0.0	67.2	0.0	0.0	0.0	0.0	100
G	ha	0	28..05	0..86	0	182..69	0	0	0	712.96	0	0	0	924.56
	%	0.0	3.0	0.1	0.0	19.8	0.0	0.0	0.0	77.1	0.0	0.0	0.0	100
I	ha	0	0	1.2	0	0	0	0	0	0	0.49	0	0	1.69
	%	0.0	0.0	71.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	0.0	0.0	100
J4.2	ha	0	0	0	0	0	0	0	0	0	0	8.3	0	8.3
	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	100
J1.2	ha	0	4.12	3.92	0	0	0	0	2.64	0.24	0	0	30.45	41.37
	%	0.0	10.0	9.5	0.0	0.0	0.0	0.0	6.4	0.6	0.0	0.0	73.6	100
Total 1975 *Skupaj 1975*	ha	60.4	385.51	356.91	28.9	257.17	11.55	65.47	29.36	719.77	0.49	8.3	30.45	1954.28
	%	106.1	154.4	103.2	100.0	177.7	77.0	67.3	73.8	77.9	29.0	100.0	73.6	

Table 4: Area ratio index (Ar)

Preglednica 4: Kazalec razmerja površine (Ar)

class / *razred* year / *leto*	D	E	F	E/FA	FA	G	R/S
1975	0.03	0.65	0.16	0.03	0.02	0.58	0.02
2000	0.03	0.47	0.09	0.05	0.02	0.90	0.03
2009	0.03	0.51	0.07	0.04	0.02	0.93	0.03

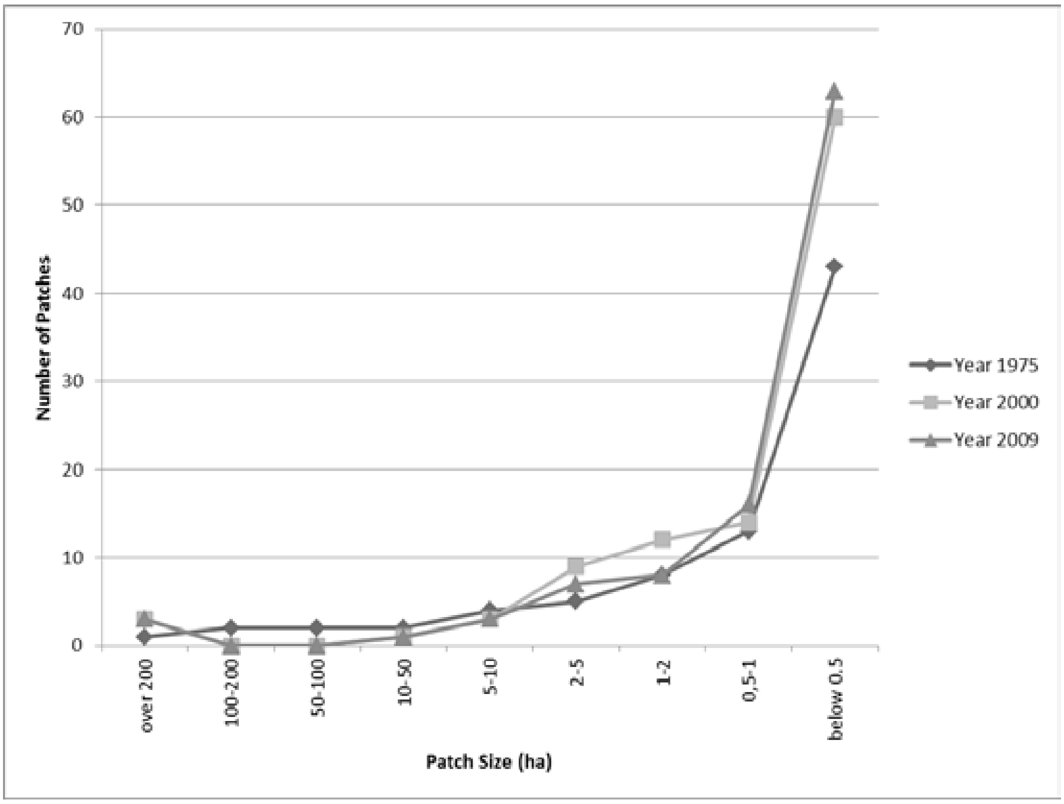

Fig. 4: Forest patch size dynamics

Slika 4: Spremembe površin gozdnih zaplat

Table 5: Forest and non-forest patch transitions related to distance from settlements (1975 – 2009)

Preglednica 5: Prehodi iz gozdnih in negozdnih zaplat v povezavi z razdaljo od naselij (1975 – 2009)

change *sprememba* / distance (m) *razdalja (m)*	G to E1.5 (ha)	G to E2.2 (ha)	G to F3.2 (ha)	G to J1.2 (ha)	E1.5 to G (ha)	E2.2 to G (ha)	F3.2 to G (ha)
0- 200	0.01	0.46			1.47		0.52
200-400	0.61				3.35	0.37	3.85
400-600	2.94				5.38		11.74
600-800	1.69			0.08	5.39		24.52
800-1000				0.16	3.82	0.37	31.94
1000-1200					2.03	0.03	49.07
1200-1400			0.45		3.92	0.09	35.14
1400-1600					0.68		10.20
1600-1800					1.16		5.19
1800-2000	0.41				0.49		4.38
2000-2200					0.17		2.91
2200-2400					0		1.11
2400-2600					0.14		2.02
2600-2800					0.04		0.08
2800-3000					0		
Total	5.66	0.46		0.24	28.05	0.86	182.69

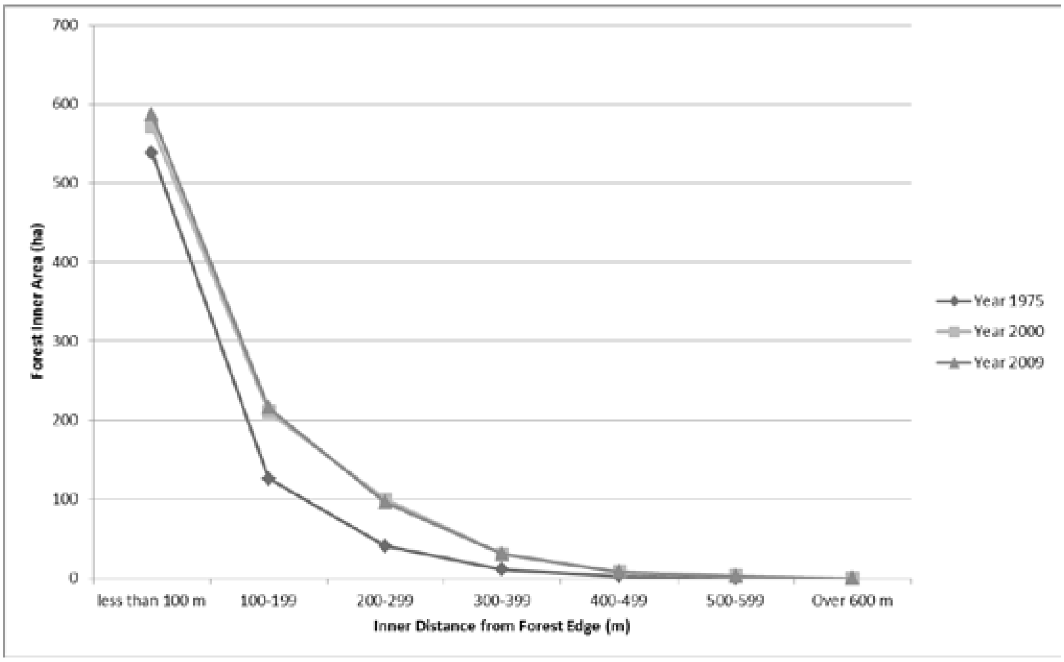

Fig. 5: Forest inner (core) area dynamics index

Slika 5: Kazalec spremembe površine notranjega gozdnega okolja

Table 6: Evaluation of major aggregated land use classes temporal changes in the years 1975 – 2000 – 2009

Preglednica 6: Kazalci sprememb glavnih združenih razredov rabe tal v letih 1975 – 2000 - 2009

year *leto*	land use *raba tal*	CA (ha)	PLAND (%)	NP (no.)	LPI (%)	TE (m)	AREA _MN (ha)	GYRATE _MN (m)	TCA (ha)
1975	grassland / *travišča*	894.73	45.85	216	18.22	301764	4.14	43.01	444.38
2000	grassland / *travišča*	776.55	39.78	307	11.87	353752	2.53	41.34	290.86
2009	grassland / *travišča*	786.59	40.30	310	9.57	378967	2.54	41.13	268.51
1975	hedges / *omejki*	29.36	1.50	86	0.29	69700	0.34	31.76	0.00
2000	hedges / *omejki*	39.79	2.04	109	0.40	110097	0.37	35.75	0.00
2009	hedges / *omejki*	45.82	2.35	243	0.33	138392	0.19	25.16	0.00
1975	afforestation / *zaraščajoče*	268.72	13.77	137	5.00	161722	1.96	46.45	74.94
2000	afforestation / *zaraščajoče*	159.75	8.18	103	1.42	113648	1.55	45.77	31.38
2009	afforestation / *zaraščajoče*	122.33	6.27	145	0.51	109073	0.84	37.22	10.54
1975	forests / *gozdovi*	720.25	36.90	104	10.86	208745	6.93	63.48	403.85
2000	forests / *gozdovi*	926.25	47.45	135	14.45	233043	6.86	53.79	600.24
2009	forests / *gozdovi*	941.94	48.26	114	15.18	228758	8.26	59.42	611.56

The number of large forest patches (over 200 ha) increases due to the natural afforestation or »fusion«. The number of middle forest patches decreases due to transition into a larger class, whereas the number of small forest patches increases due to fragmentation of forests near settlements.

The average patch area of the largest forest patch increases (from 212.34 ha to 278.24 ha), because smaller patches from the year 1975 are now fused into one large forest matrix. Former middle area patches (between 50 ha to 200 ha) practically disappeared, whereas smaller patches (less than 5 ha) are not significantly different.

Indices based on patch size and distances from the edge to the inner part of a forest are especially useful means of explaining increase of forest patch areas and their transitions into a forest matrix.

DISCUSSION AND CONCLUSIONS
RAZPRAVA IN ZAKLJUČKI

Abandonment can only effectively be measured through different temporal changes indicating this process. Indices should be easy to measure and also easy to understand.

The Corrected Shape Index is expressing one of such phenomena that we call “tide effect”, showing the simplifying of the border and “drowning” of non-forest areas near the edge. With more and more adjacent abandoned land under succession turning into forest the ratio between perimeter and area of forest patches is in decline. However, most striking results can be observed with FA (Hedges) EUNIS classes, since the hedges are long and narrow patches where a few meters of prolongation can change the perimeter to area ratio considerably. Straight hedges of trees over limestone walls distinguishing plots of agricultural land use are typical karst phenomena. They are the result of former clearing in order to provide better condition for agriculture. Managed areas of EUNIS class FA can be regarded therefore as a sight of still active cultivated land use.

The “drowning effect” can be presented using Area Ratio Index with interesting results only for regenerated patches (EUNIS F3.2) and forest (EUNIS G class) taking over the abandoned land in comparison with other EUNIS classes showing only slight differences.

Perhaps even more useful information is given with the Number of Forest Patches combined with their average size in different area classes. In our case, total number of forest classes is even increasing, due to some fragmentation processes near settlements, but more and more forests tied together in larger patches clearly indicate abandonment. As we see, the changes are not shifting in just one way; we are facing fragmentation and abandonment, yet fragmentation is small indeed and occurring more or less near the settlements, where farmers continue with their agricultural activities, and abandonment is taking over to a much larger extent and all around.

Figure 2 indicates that the Forest Inner Area dynamics is the best index showing the process of abandonment and drowning of non-forest land use in a forest matrix. The area of inner area forest (distance from the edge to the centre of the forest) is significantly increasing relatively and absolutely. One of the most important advantages of this index is that it can be easily understood even by non-ecologically educated final users, since we are operating in real meter based distances and not abstract numerical figures that are given by many other indices (e.g. fractal dimension based indices). This index is especially useful with transitions from non-forest EUNIS classes (E1.5, F3.2) or early stage forest classes (G5.6) into forest (G3.5 or G1.6 and G4.6 respectively in our case).

The analysis of aggregate land use evaluation has shown that even the simplest indices concerning classes, areas, perimeter and the number of class patches can effectively explain several processes (i.e. abandonment) at the landscape level. In case of bird habitat evaluation, the number of patches (NP) turned out to be extremely important for the “hedges” class in combination with four other indices (LPI, TE, AREA_MN, GYRATE_MN). It is of course possible to argue that the trend results for the year 1975 due to a rather poor quality of areal photos, which sometimes prevent accurate evaluation of small hedges and could lead to an underestimation of this class for this year. However, a comparison of the year 2000 with the year 2009 shows fragmentation (CA, PLAND, NP, TE are increasing while LPI, AREA-MN, GYRATE-MN are decreasing) of “hedges” in recent years probably resulting in intensification of agriculture. These indices provide quality information on habitat condition (areas and spatial distribution) for species requiring grasslands with shrubs and hedges.

Total core area index (TCA) gives useful information especially for forests, supporting our statement of forest matrix increasing in the area. The same is supported with a small decline in total forest edge decline. Of course the TCA index makes no sense in evaluating hedges or other similar long and narrow landscape elements without core areas.

In terms of spatial diversity it can be concluded that the most valuable parts of the space are areas, which are temporally stable in space and time. In our case, this is primarily a forest for forest core species and, if we ignore villages with road infrastructure, also the agricultural land to allow more intensive use close enough to (up to 1km) the edge of settlements. Karst rocky pastures are being gradually overgrown and their future depends partly on grazing, fires, and mostly on possible subsidies for the maintenance of cultural landscape. This process may affect species of forest edge and extensive agriculture.

However, one should not forget that indices based on EO data are expressing just the consequences of land abandonment. Beside natural capacities (relief slopes and expositions, soil types and remoteness from settlements) one should always consider social capacities (small plots, ageing ownership, uncertain future of agriculture in marginal agriculture areas…). Only natural and social based factors combined together can help to understand land use changes as a permanent process.

As far as deforestation for the needs of farming is concerned, areas used for farming before 1975 could be suitable if in accordance with the newest findings regarding habitat preservation. It is of key importance that small living forest patches and intertwinement of intensive and extensive meadows are preserved within the farming area. The preservation of these areas is additionally supported by the preposition for common agricultural policy,

where an important element is recognized »to enhance the overall environmental performance of the CAP through the greening of direct payments by means of certain agricultural practices beneficial for the climate and the environment« (Legal proposal for...2012)

POVZETEK

V Sloveniji se je zaraščanje z gozdom razširilo že v 19. stoletju in se je nadaljevalo tudi v konec 20. stoletja). V raziskavi smo analizirali spremembe rabe tal na izbrani površini 19,52 km^2, ki leži v občini Pivka, kjer gre za preplet tradicionalnih kmetijskih zemljišč, gozdov in območjih opuščenih kmetijskih površin z naravnim zaraščanjem. V raziskavi smo želeli oceniti spremembe glavnih habitatnih tipov EUNIS s pomočjo nekaterih kazalcev ocene krajinske zgradbe. Izbrano območje s pestro rabo tal je med drugim izjemno pomembno za vsaj dve vrsti ptic, in sicer za pisano penico in rjavega srakoperja. Obe vrsti sta občutljivi za širjenje gozda v kmetijski prostor, saj najraje prebivata v predelih, kjer se prepletajo ekstenzivni travniki z grmičevjem in živimi mejami Denac et al., 2011).

Za ozadje zaslonske digitalizacije meja poligonov smo uporabili digitalne črno-bele ortofoto posnetke za leti 1975 in 2000 ter barvni DOF za leto 2009, z ločljivostjo 1 m (leta 1975) in 0,5 m (2000 in 2009). Digitalizacijo smo izpeljali z orodjem Cartalinx 1,2. Najmanjša enota kartiranja je 100 m2. Za izračune različnih kazalcev sprememb krajinske zgradbe smo uporabili GIS-programski paket Idrisi Andes (Eastman, 2006) in FRAGSTATS 4,0 (McGarigal et al., 2012). Vsak poligon je dobil tri atribute glede na določen EUNIS habitatni tip za leta 1975, 2000 in 2009. Za kontrolo zaslonske digitalizacije in ocene pravilnosti določenih habitatnih tipov smo za vsak EUNIS-razred naključno izbrali po 30 točk v 100 m dolgem pasu vzdolž cest, kjer smo primerjali vizualno pridobljeno oceno s situacijo na terenu.

Za oceno sprememb habitatov na krajinskem nivoju smo posamezne habitatne tipe združili v štiri glavne razrede (travniki, žive meje, zaraščajoče se površine, gozdovi) in ponovili analizo ocene krajinske zgradbe s kazalci v programu FRAGSTATS 4.0.

Rezultati kažejo, da se povečujeta število in povprečna velikost velikih gozdnih zaplat (večjih kot 200 ha), saj se le te zaradi zaraščanja površin zlivajo v gozdno matico. Iz istega razloga se zmanjšuje število srednjih gozdnih zaplat, medtem ko se število majhnih zaplat celo povečuje zaradi krčitev in presek v bližini naselij.

Kazalci, ki temeljijo na oceni oblike (shape index), lepo prikazujejo t.i. »učinek plime«, ki prikazuje poenostavljanje meje gozdnega roba; ta nastaja z zaraščanjem in s tem izginjanjem negozdnih otokov znotraj gozdov. Kazalci, ki temeljijo na obliki roba, so učinkoviti tudi pri analizi omejkov, saj so žive meje razporejene v obliki dolgih pasov; tam lahko nekaj metrov podaljšanja spremeni razmerje med površino in obsegom take zaplate.

Morda še bolj uporabno informacijo daje število gozdnih zaplat v povezavi z njihovo povprečno velikostjo v različni oddaljenosti od naselij. V našem primeru se je skupno število gozdnih zaplat v bližini naselij zaradi fragmentacije celo povečalo, toda že omenjeno zlivanje zaplat v enovito matico jasno kaže vpliv zaraščanja v bolj oddaljenih predelih.

V oceni sprememb rabe na krajinskem nivoju, kjer smo ocenjevali zgradbo habitatov za že omenjeni ptici, je pri oceni omejkov zelo pomemben kazalec število zaplat (NP), kar ni presenetljivo, vendar ga je treba ocenjevati tudi v povezavi še z nekaterimi drugimi kazalci (LPI, TE, AREA_MN, GYRATE_MN). Seveda je mogoče trditi, da so rezultati nezanesljivi za leto 1975 zaradi dokaj slabe kakovosti letalskih posnetkov, zaradi katere včasih ni bilo mogoče dovolj zanesljivo oceniti majhnih skupin živic. Vendar pa primerjava leta 2000 z letom 2009 kaže razdrobljenost omejkov (CA, PLAND, NP, VE se povečujejo, medtem ko se LPI, AREA-MN, GYRATE-MN zmanjšujejo). Te spremembe so verjetno posledica bolj intenzivnega kmetovanja v zadnjih letih. Zato lahko z uporabo teh kazalcev pridobimo kakovostne informacije o stanju habitatov (območja in prostorska razporeditev) za vrste, ki jim ustrezajo prepleti ekstenzivnih travnikov z grmovjem in živimi mejami, kot sta rjavi srakoper in pisana penica.

Kazalec jeder notranjega okolja (TCA) daje koristne informacije, predvsem za gozdove, in podpira ugotovitve o povečanju gozdne matice na tem območju. Seveda pa je ta kazalec praktično neuporaben pri ocenjevanju živic in drugih podolgovatih ozkih omejkov brez notranjega okolja.

Z vidika prostorskega raznolikosti lahko sklepamo, da so najbolj dragoceni tisti deli ohranjenega prostora, ki so v prostoru in času razmeroma stabilni. V našem primeru so to

predvsem predeli jedrnih con gozdov za vrste, ki potrebujejo veliko gozdno matico.

Glede habitatov rjavega srakoperja in pisane penice je ključnega pomena, da ohranimo preplet manjših gozdnih zaplat, grmičevja, omejkov in ekstenzivnih travnikov v kmetijski krajini. Ohranjanje teh območij bi bilo smiselno podpreti s predlogi prenovljene skupne kmetijske politike, ki priznava pomembne krajinske elemente »za povečanje splošne okoljske uspešnosti SKP z okolju prijaznejšimi neposrednimi plačili s pomočjo nekaterih kmetijskih praks, ki ugodno vplivajo na podnebje in okolje« (Legal proposal for...2012).

ACKNOWLEDGEMENT
ZAHVALA

Predstavljeno delo je nastalo v okviru projekta CRP V4 – 1144 "Kriteriji za presojo izvedbe krčitev gozdov", ki ga financirata Ministrstvo za kmetijstvo in okolje ter Javna agencija za raziskovalno dejavnost RS. Avtorja se zahvaljujeva tudi obema recenzentoma za koristne pripombe ter dopolnila.

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