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Structural properties of agricultural and rural landscapes in river Bregalnica watershed

Структурни својства на земјоделските и руралните предели во сливот на реката Брегалница

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The human contribution in definition of the landscape character is most evident in agricultural and rural landscapes. The long-lasting human-nature interaction has had a distinctive role in nurturing secondary anthropogenic habitats which are significant for the preservation of biodiversity in contemporary environment, particularly in Europe. The shift in local people practices continuously reflects upon the landscape structure and its pattern. Assessment and subsequent management of landscape structural properties is crucial for preservation of the landscape functionality, especially in a region where there are ongoing conservation efforts.

Bregalnica river basin is a large region in eastern part of the Republic of Macedonia with a high potential for biodiversity conservation while significant portion of the basin is represented by agricultural and rural landscapes. Following, the aim of this study is to assess the structural properties of agricultural and rural landscapes in the river Bregalnica watershed and to assess the "nature friendliness" of agricultural and rural landscapes that were historically managed differently.

For this purpose, types and coverage of land cover classes in landscape types of both agricultural and rural landscapes groups have been assessed. Structural properties were assessed by calculating basic area-edge metrics, shape metrics, aggregation metrics and diversity metrics at the class and landscape level.

The results show that fragmentation levels vary from high in agricultural landscapes to moderate in rural landscapes clearly separating both landscape groups in their capacity to sustain biodiversity.

Key words: landscape structure, landscape metrics

Човековото влијание во обликувањето на пределниот карактер е највидливо во земјоделските и руралните предели. Долготрајната интеракција помеѓу човекот и природата, во овие предели, придонела кон развој на секундарни антропогените живеалишта кои се значајни за зачувување на биолошката разновидност, особено во Европа. Промената во локалните практики на искористување на земјиштето видливо се одразуваат врз структурата и образецот на пределот. Оттука, проценка и следствено управување со структурата на пределот е од клучно значење за одржување на функционалноста на пределот, особено во регион каде има тековни активности за зачувување и заштита на природата.

Брегалничкиот слив е голем регион во источниот дел на Република Македонија, со висок потенцијал за заштита на биолошката разновидност, а земјоделските и руралните предели заземаат значителен дел од сливот. Оттука, целта на оваа студија е да се проценат структурните својства на земјоделските и руралните предели во сливот на реката Брегалница и да се процени "природо-наклонетоста" на земјоделските и руралните предели, кои историски гледано, биле управувани на различен начин.

За таа цел, направена е проценка на типот и површината на различните класи на покровност на земјиштето во пределските типови од групата на земјоделски и рурални предели. Структурните карактеристики на пределите беа проценети со пресметување на четири групи на структурни мерливи на ниво на класа и предел.

Резултатите покажаа дека нивото на фрагментираноста се движи од високо во земјоделските предели кон умерено во руралните предели и јасно ги издвојува двете пределни групи во однос на капацитетот да подржуваат биолошка разновидност.

Клучни зборови: пределна структура, пределни мерливи

Introduction

The spatial patterns of the mosaic of landscapes that we perceive today results from perpetual "complex interactions between physical, biological and social forces" (Turner 1989). Landscapes are characterized by their heterogeneity i.e. landscape composition and its spatial configuration (Brown et al. 2004) that are the specific physical attributes which allow characterization of different landscape types (Wu et al. 2000). The spatial pattern of distribution of different patches of natural habitat(s) in a high to medium hemerobic landscapes may exert a strong influence on populations of birds, amphibians, reptiles and lepidopterans (McGarigal and McComb 1995; Atauri and De Lucio 2001). Furthermore, understanding and quantifying landscape structure is essential to the study of pattern-process relationships (Turner 1989) and landscape function and change (McGarigal and McComb

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1995). Understanding and quantifying landscape structure is also important for providing landscape approach while tailoring management practices in vast areas (Franklin 1993). For this reason, much emphasis has been placed on developing methods to quantify landscape structure (Kupfer 2012).

In spite of the prominence credited to landscape structure and its pattern worldwide, to date in Macedonia there are no published results in this field. However, the awareness of the importance of landscape diversity and their characteristics in the country is increasing and several studies and project reports (Melovski 2010; Slavkovik 2011; Melovski et al. 2010, 2015, 2016) on the subject have been prepared. A number of studies have raised the matter of land use/land cover changes (Redzovik 2011; Despodovska et al. 2012; Jovanovska and Melovski 2012) but still none of the afore listed studies has reflected the landscape pattern in particular.

Given that the long lasting extensive human impact on the environment has played a significant role in shaping the highly diverse array of natural ecosystems in Macedonia, a high diversity of landscapes is apparent (Melovski et al. 2016). The human contribution in determination of the landscape character is most evident in agricultural and rural landscapes (Brady 2006; Špulerová and Petrovič 2012). This long-lasting human-nature interaction has had a distinctive role in nurturing secondary anthropogenic habitats (Harvey et al. 2008; Cevasco and Moreno 2013) which are significant for the preservation of biodiversity (Pimentel et al. 1992; Thies 1999; Atauri and De Lucio 2001; Falcucci et al. 2006). The change in local people practices continuously reflects upon the landscape structure and its pattern (Nassauer 1995; Natori et al. 2011; Jovanovska and Melovski 2012; Lausch et al. 2015). Assessment and subsequent management of landscape structural properties is crucial for preservation of the landscape functionality (Turner 1989; Kupfer 2012), especially in a region where there are ongoing conservational efforts.

Bregalnica river basin has high potential for biodiversity conservation while significant portion of the basin is represented by agricultural and rural landscapes. Following, the aim of this study is to assess the structural properties of agricultural and rural landscapes in the river Bregalnica basin in order to demonstrate to which level a landscape departs or conforms to a predefined landscape group as to assess the "nature friendliness" of agricultural and rural landscapes that were historically managed differently.

Material and Methods

Bregalnica watershed occupies relatively large territory of ≈4300 km^2 (Gaševski 1979) in the eastern part of the Republic of Macedonia (Fig. 1). The accrual of geomorphological characteristics and the complexity of climate varieties in river Bregalnica basin ensued a great diversity of habitats of different distribution and distinctive organization, described in details in Hristovski and Brajanoska (2015).

Continuously, throughout centuries, numerous and diverse activities have been practiced in the region. This has left a strong human imprint on plains, mountains and nature in general that throughout time led to significant diversity of landscapes too (Melovski et al. 2015). In river Bregalnica watershed 7 basic landscape groups can be

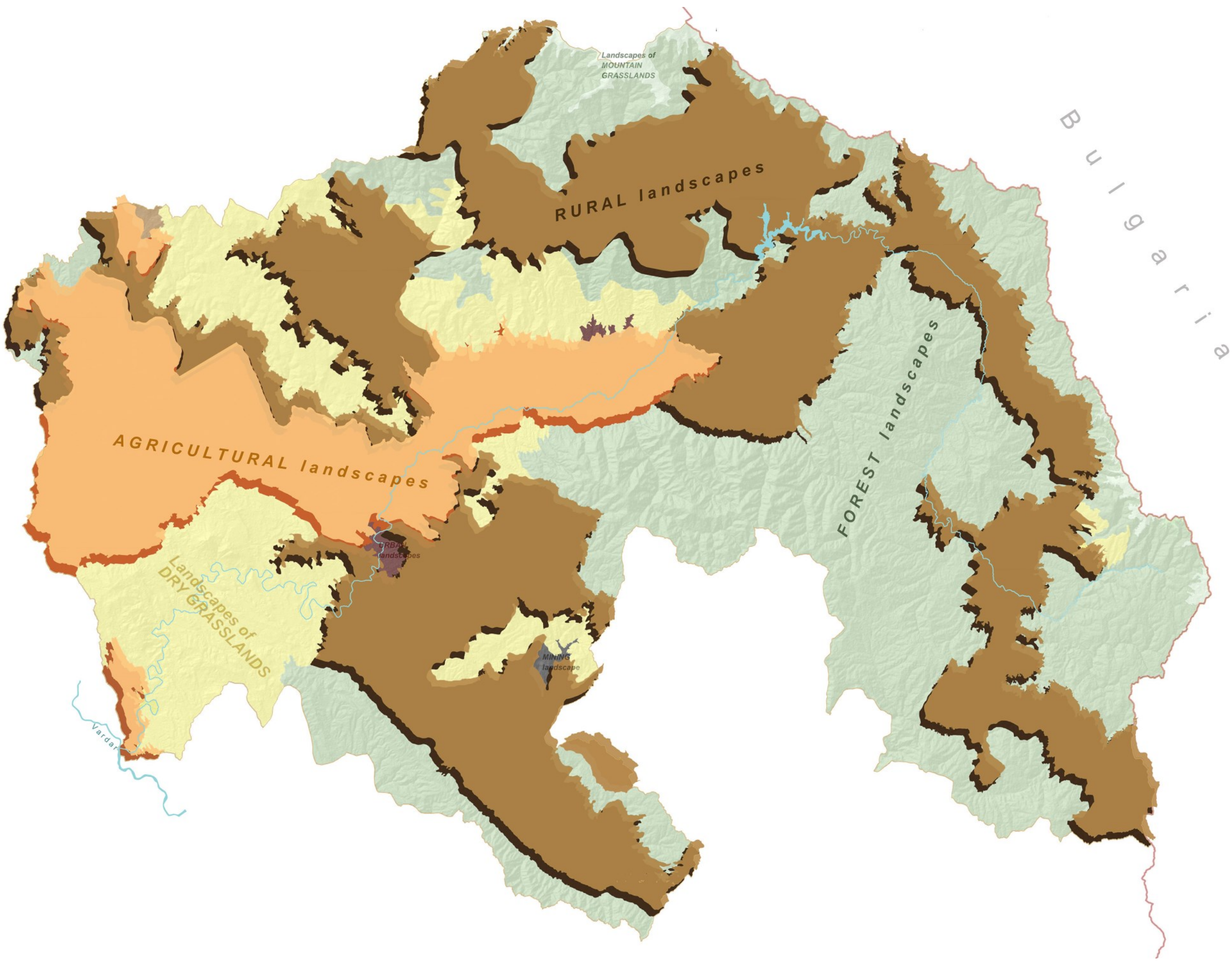

Figure 1. Landscape groups in river Bregalnica watershed. Landscape groups relevant for the analysis are visually outlined. Other landscape groups e.g. Landscapes of Dry grasslands, Forest landscapes etc. are only visually represented and are not subjected to the analysis

distinguished comprising even 20 landscape types (Melovski et al. 2015) and 70 landscape units in total.

In this study agricultural and rural landscapes' groups have been analyzed (Fig. 1). Agricultural landscapes group covers 4 agricultural landscape types (Agricultural flatland landscape on saline ground (Ovche Pole flatland landscape), Lowland rolling agricultural landscape (Ovche Pole lowland rolling landscape), Lowland rolling agricultural landscape with wind hedges (Ovche Pole lowland rolling landscape with wind hedges) and Flatland ricefield agricultural landscape (Kochani landscape)) comprising 7 landscape units in total. Rural landscapes group covers 7 rural landscape types (Lowland rolling agricultural rural landscape, Maleshevo-Pijanec rural agricultural landscape, Rolling rural landscape, Rolling rural landscape with hedges, Hilly rural landscape, Mountain rural landscape (Maleshevo mountain rural landscape) and Osogovo mountain rural landscape) comprising 19 landscape units in total.

To assess agricultural and rural landscapes structural properties we used landscape types in river Bregalnica watershed (Melovski et al. 2015) as a vector data. In order to analyze the landscape composition, CORINE Land Cover 2012 vector data set in UTM 34N/WGS 84 projected geographical coordinate system were rasterized with 50x50 m pixel size. Out of 23 land cover classes analyzed in total, 12 were dominant: 'Non-irrigated arable land' (Arable land-fields and acres i.e. Arable land), 'Complex cultivation patterns' (Complex cultivation), 'Rice fields', 'Land principally occupied by agriculture, with significant areas of natural vegetation' (Agricultural land with significant areas of natural vegetation i.e. Agricultural land with natural vegetation), 'Pastures', 'Vineyards', 'Discontinuous urban fabric' (Settlements), 'Transitional woodland-scrub', 'Coniferous forests', 'Broad-leaved forest', 'Natural grassland' and 'Mixed forests'. Land cover classes with less than 1% coverage were listed as "Other". For the purpose of this study, only land cover classes representing/covering natural habitat patches (Agricultural land with natural vegetation, Pastures, Transitional woodland-scrub, Broad-leaved forest, Mixed forest, Coniferous forest and Natural grassland) were elaborated in detail when discussing the structural properties of the agricultural and rural landscapes on both landscape and class level.

Data preparation, data processing and mapping were performed in ArcGIS 10.2. Landscape structure analyses have been performed with Fragstats 4.2, by which basic area-edge, shape, aggregation and diversity metrics that quantify landscape configuration in terms of the complexity of patch shape at the class and landscape level were computed.

Results and discussion

The general overview of the landscape composition shows that agricultural landscapes group is characterized by a dominance of agricultural land cover classes of *arable land, complex cultivation, rice fields and agricultural land with natural vegetation*. The landscapes in this group are characterized by a matrix composed of *arable land* that clearly dominates the landscape(s) (56% coverage on average). Conversely, the rural landscapes group matrix is not perceptibly distinctive. The rural nature of the landscapes is ascribed to the combined share of the both *agricultural land with natural vegetation* and *complex cultivation* classes (41%) and characterized by a considerable share of *broad-leaved forest* (18%) and *transitional woodland-scrub* (15%) classes. General representation of the landscape composition by land cover types and coverage for both landscape groups is presented on Fig. 2.

Structural properties of agricultural and rural landscapes group at a landscape and class level

At a landscape level **patch density** is higher (1.37) in rural landscapes than in agricultural landscapes (0.75) group indicating that rural landscapes are characterized by disjoined dispersion of patches. **Patch richness** in rural landscapes is higher (21) than in agricultural landscapes (16). The percentage of the landscape covered by the **largest patch** is much greater (43.91%) in agricultural landscapes (which clearly defines the matrix) than in rural (5.17%) landscapes.

When analyzed on a class level in regard to matrix composition, agricultural landscapes matrix (*arable land*) consists of only 43 units, while the land cover class that has the largest share (22%) in rural landscapes (*agricultural land with natural vegetation*) consists of even 317 units. The **patch density** of the land cover class that dominates rural landscapes - *agricultural land with natural vegetation* is higher (0.19) than the **patch density** of the land cover that composes the matrix in agricultural landscapes – *arable land* (0.07). This shows that the matrix of the agricultural landscapes is more fused (aggregated) opposed to that in rural landscapes. When considering the **total edge** on a class level, in the rural landscapes the largest **total edge** value is recorded for land cover classes representing natural habitat patches (*broad-leaved forest*, 2569.7 km) and *transitional woodland-scrub*, 2531.4 km). Though the *arable land* represents the matrix in agricultural landscapes, the **total edge** (930.4 km) is exceeded by the **total edge** of *arable land* cover category in rural landscapes (1045.8 km). On a class level, the largest **proximity index** in agricultural landscapes is exhibited in the matrix of *arable land* (4678.08), then in the *rice fields* (332.71), *complex cultivation* (49.00) and *agricultural areas with natural vegetation* (19.43). The largest **proximity index** in the rural landscapes is recorded in the *broad-leaved forest* (355.09) then in the *complex cultivation* (119.83) and *agricultural areas with natural vegetation* (183.27), followed by *arable land* (113.68), *transitional woodland-scrub* (51.55) and *pastures* (27.30). This shows that agricultural landscapes are more uniform in land cover classes that form complex cluster of larger patches than rural landscapes.

Structural properties of agricultural and rural landscape types on a landscape level

In order to provide more detailed overview of the landscape structure of individual landscape types, the structural properties of each landscape type from both agricultural and rural landscapes groups have been analyzed separately. The results are presented in increasing order of the naturalness of individual landscape types, as perceived by the authors, i.e. before calculation of the structural metrics. The discussion follows the same pattern. Detailed representation of the landscapes structure calculated on a landscape level is presented in Tab. 1.

The landscape metrics calculated for each landscape type on a landscape level in general demonstrates that the **number of patches** (Tab. 1) typically follows on the landscape extent. When observing the **number of patches** and **total area** ratio of landscapes from both groups, the **number of patches** per landscape area in rural landscapes' group surpasses the **number of patches** per landscape area in agricultural landscapes (the highest ratio is observed in Lowland rolling agricultural rural landscape and Maleshevo-Pijanec rural agricultural landscape, while the lowest ratio is observed in the Ovche Pole flatland Landscape due to the domination of *arable land* class). In rural landscapes, more significant decline in this ratio is noticeable in Osogovo mountain rural landscape, but due to the domination of *broad-leaved forest* land cover class.

Patch density (Tab. 1) shows that the **number of patches** per ha is considerably lower in agricultural landscapes. **Patch density** generally declines from Hilly rural landscape and the lowest **patch density** in the rural landscapes is observed at Osogovo mountain rural landscape (1.06). Due to the domination of *broad-leaved forest* class Osogovo mountain rural landscape has similar patch density as the agricultural landscapes, but the difference is related to the land cover type, which in this case is "biodiversity friendly".

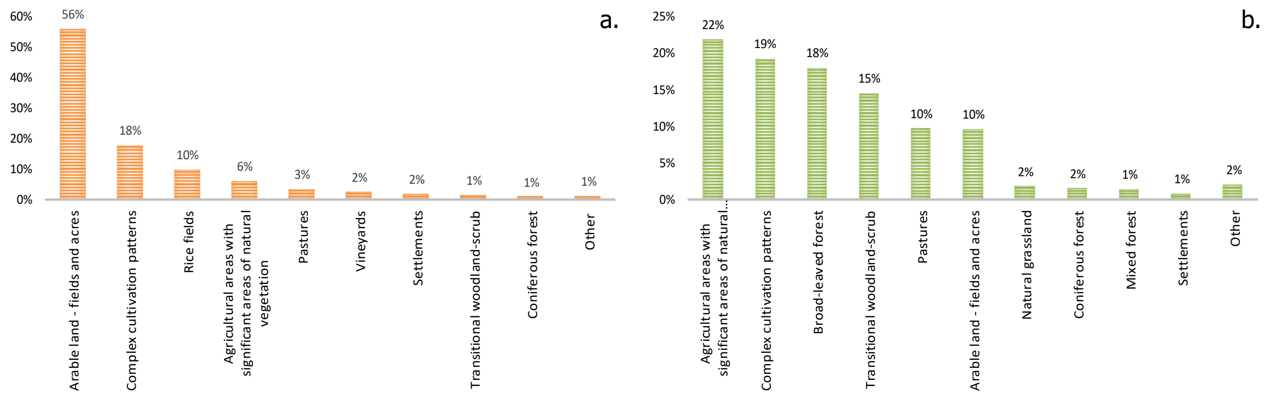

Figure 2. Types and coverage of land cover classes in a) Agricultural and b) Rural landscapes group

The **largest patch index** (Tab. 1) is significantly higher in agricultural landscapes (ranging from 22.21 in Kochani landscape to 45.23 in Ovche Pole lowland rolling landscape with wind hedges). In rural landscapes the **largest patch index** in 5 out of 7 landscape types is below 11. The highest **largest patch index** in rural landscapes is observed in Osogovo mountain rural landscape (34.15). In this regard, this landscape type once more exhibits similarities with agricultural landscapes group, but again, there is a difference in the land cover type of the largest patch, which in the case of Osogovo mountain rural landscape is represented by *broad-leaved forest*.

Total edge and **edge density** (Tab. 1) generally follow each and increase from agricultural to rural landscapes. In case of Rolling rural landscape with hedges, Mountain rural landscape and Osogovo mountain rural landscape the index of **edge density** deviates from the **total edge** index. This deviation is due to the length/area adjustment in the case of **edge density** index that is more appropriate for biodiversity analyses.

The **landscape shape index** (Tab. 1) shows that irregularity of landscape shape and the patch disaggregation is generally higher in rural landscapes group. A deviation of this trend is observed in Rolling rural landscape with hedges, mainly due to the fact that this landscape type extends on a much smaller area than other landscape types in the group. Since many of the indexes are related to landscape size, these deviations are perceptible in other results too.

Patch shapes are more irregular and more convoluted in rural landscapes and landscape complexity generally increases as **mean shape index** and **mean fractal dimension index** (Tab. 1) increases. Ovche Pole flatland landscape, Kochani landscape, Lowland rolling agricultural rural landscape and Maleshevo-Pijanec rural agricultural landscape can be singled as landscapes where patches are with more regular shape and are simpler in perimeter. Still, due to the coarse raster data (50x50 m pixel size) used for the purpose of this study, Fragstats cannot quite calculate the fractals of an edge line of a patch. Thus, the results regarding shape metrics, especially **mean fractal dimension index**, should only be used as an indicative trait in a general discussion.

Mean proximity index (Tab. 1) singles out the Ovche Pole flatland landscape and Osogovo mountain rural landscape as landscapes that are increasingly occupied by contiguous patches of the same type, though of very different land use classes. The **aggregation index** (Tab. 1) is high in agricultural landscapes where close to maximum aggregation is observed and gradually declines in rural landscapes.

The reason for the deviation in the trend of several indexes (Tab. 1) in case of Osogovo mountain rural landscapes is that this landscape type, like agricultural landscapes, has uniform composition. The "apparent" uniformity of this landscape type is due to the prevalence of *broad-leaved forests* unlike the *arable land* class in case of agricultural landscapes. However, due to the abandonment of traditional agricultural practices *broad-leaved forests* are now succeeding towards more closed and compact stands and today compose the matrix. At this scale, Fragstats cannot detect the rural nature of the landscape attributed by the many patches of scattered villages, meadows and extensively managed fields and pastures which is why this landscape type separates itself from the rural landscapes' group and inclines toward forest landscapes' group.

Structural properties of agricultural and rural landscape types on a class level

In order to assess the structural characteristics and the spatial pattern of the natural habitat patches, structural properties of individual agricultural and rural landscape types by land cover class were analyzed in detail. The results are presented in Fig. 3 and 4.

The **total (class) area** metric (Fig. 3-a) indicates that agricultural landscapes have very few patches of land cover classes representing/covering natural habitats when compared to rural landscapes. These patches are small in size (no larger than 1966.5 ha) and are characterized with scattered arrangement. The highest diversity of patch types of land cover classes comprising natural habitats can be noticed in Ovche Pole lowland rolling landscape, while in Kochani landscape only *transitional woodland-scrub* (99.25 ha) and *agricultural land with natural vegetation* (89.5 ha) are recorded. On the other hand, the diversity of land cover classes comprising/representing natural habitats in rural landscapes is considerably higher. However, there is a noticeable aberration in Rolling rural landscape with hedges due to its small overall area. Thus, when analyzing landscapes that vary by size the **mean patch area** (Fig. 3-h) gives more appropriate presentation of the patch extent throughout the landscapes. In Osogovo mountain rural landscape the **patch number** of land cover classes representing/covering natural habitats is generally low (Fig. 3-b), mostly due to the prevalence of *broad-leaved forest* class. Although represented with a rather low **patch number**, *broad-leaved forests* class, covers a significant area of the landscape (**total area** of 16,064 ha). When considering the **mean patch area** (Fig. 3-h) of land cover classes separately, the cover class of *agricultural land with natural vegetation* dominates others in all rural landscapes with exception to Osogovo mountain rural landscape where *broad-leaved forest* land cover class (722.74 ha) clearly dominates all other land cover classes.

The **largest patch index** of land cover classes representing/comprising natural vegetation increases from agricultural to rural landscapes. Land cover class *agricultural land with natural vegetation, transitional woodland-scrub* and *pastures* stand out throughout rural landscapes, while the highest **largest patch index** (Fig. 3-d) is observed in *broad-leaved forests* in Osogovo mountain rural landscape (34.15%). The number of patches per ha i.e. **patch density** (Fig. 3-c) too marks a general increase from agricultural toward rural landscapes.

Table 1. Structural properties of agricultural and rural landscapes on a landscape level (Landscape metrics* are defined as in McGarigal and Marks (1994)).

		Basic Area-Edge Metrics							Shape metrics		Aggreg. metrics	Diversity metrics	
Land-scape group	Landscape type	TA	NP	PD	LPI	TE	ED	LSI	MSI	MFDI	MPI	PR	AI
Agricultural landscapes	Ovche Pole flat-land landscape	18259.00	161.00	0.88	31.54	340.85	18.67	9.90	1.62	1.07	211.94	11.00	94.73
	Ovche Pole low-land rolling land-scape	24442.75	249.00	1.02	25.32	536.55	21.95	13.89	1.66	1.08	76.41	13.00	93.51
	Ovche Pole low-land rolling land-scape with wind hedges	5083.00	30.00	0.59	45.23	59.95	11.79	4.69	1.71	1.08	8.22	4.00	96.20
	Kochani landscape	16207.75	176.00	1.09	22.21	421.00	25.98	11.04	1.64	1.07	44.66	13.00	93.31
Rural landscapes	Lowland rolling agricultural rural landscape	14173.25	281.00	1.98	5.77	431.15	30.42	15.46	1.60	1.07	30.03	12.00	90.59
	Maleshevo-Pijanec rural agricultural landscape	16694.25	316.00	1.89	25.49	539.35	32.31	15.66	1.56	1.07	78.53	12.00	90.79
	Rolling rural land-scape	34329.25	541.00	1.58	8.23	1319.85	38.45	24.52	1.86	1.09	48.78	18.00	89.28
	Rolling rural land-scape with hedges	3851.00	90.00	2.34	10.13	162.95	42.31	9.72	1.79	1.09	25.38	10.00	88.52
	Hilly rural land-scape	62736.00	935.00	1.49	4.74	2967.55	47.30	35.39	2.03	1.10	62.98	16.00	87.55
	Mountain rural landscape	13771.00	218.00	1.58	10.73	750.90	54.53	19.12	2.12	1.10	148.83	10.00	85.87
	Osogovo mountain rural landscape	24779.00	263.00	1.06	34.15	944.05	38.10	18.06	1.98	1.10	414.42	9.00	90.13

* TA (Total area) equals the total area (ha) of the landscape; NP (Number of patches) equals the number of patches in the landscape; PD (Patch density) expresses number of patches per ha and facilitates comparisons among landscapes of varying size; LPI (Largest patch index) quantifies the percentage of total landscape area covered by the largest patch. As such, it is a simple measure of dominance (very small patch 0 < LPI ≤ 100 single dominant patch); TE (Total edge) is an absolute measure of total edge length (km) of a particular patch type TE≥0 [TE=0 no patches in the landscape]; ED (Edge density) reports edge length on a m/ha area basis and facilitates comparison among landscapes of varying size ED≥0; LSI (Landscape shape index) provides a standardized measure of edge density that adjusts for the size of the landscape. LSI can also be interpreted as a measure of patch aggregation or disaggregation - LSI = 1 when the landscape consists of a single square (or almost square) patch. As LSI increases, the patches become increasingly disaggregated; MSI (Mean shape index) measures the complexity of patch shape compared to a standard shape (square) of the same size. MSI increases as shapes are more irregular; MFDI (Mean fractal dimension index). MFDI approaches 1 when shape has a simple perimeter and approaches 2 when shapes are highly convoluted; MPI (Mean Proximity index) considers the size and proximity of all patches whose edges are within a specified search radius of the focal patch. MPI increases as the neighborhood (defined by the specified search radius) is increasingly occupied by patches of the same type and as those patches become closer and more contiguous (or less fragmented) in distribution. The index is a measure of isolation and has no units, instead it is used as a comparative index; PR (Patch richness) is perhaps the simplest measure of landscape composition, but note that it does not reflect the relative abundances of patch types; PR ≥ 1; AI (Aggregation index) shows the frequency with which different pairs of patch types (including like adjacencies between the same patch type) appear side-by-side. The maximum aggregation is achieved when the patch type consists of a single, compact patch [0 ≤ AI ≤ 100%].

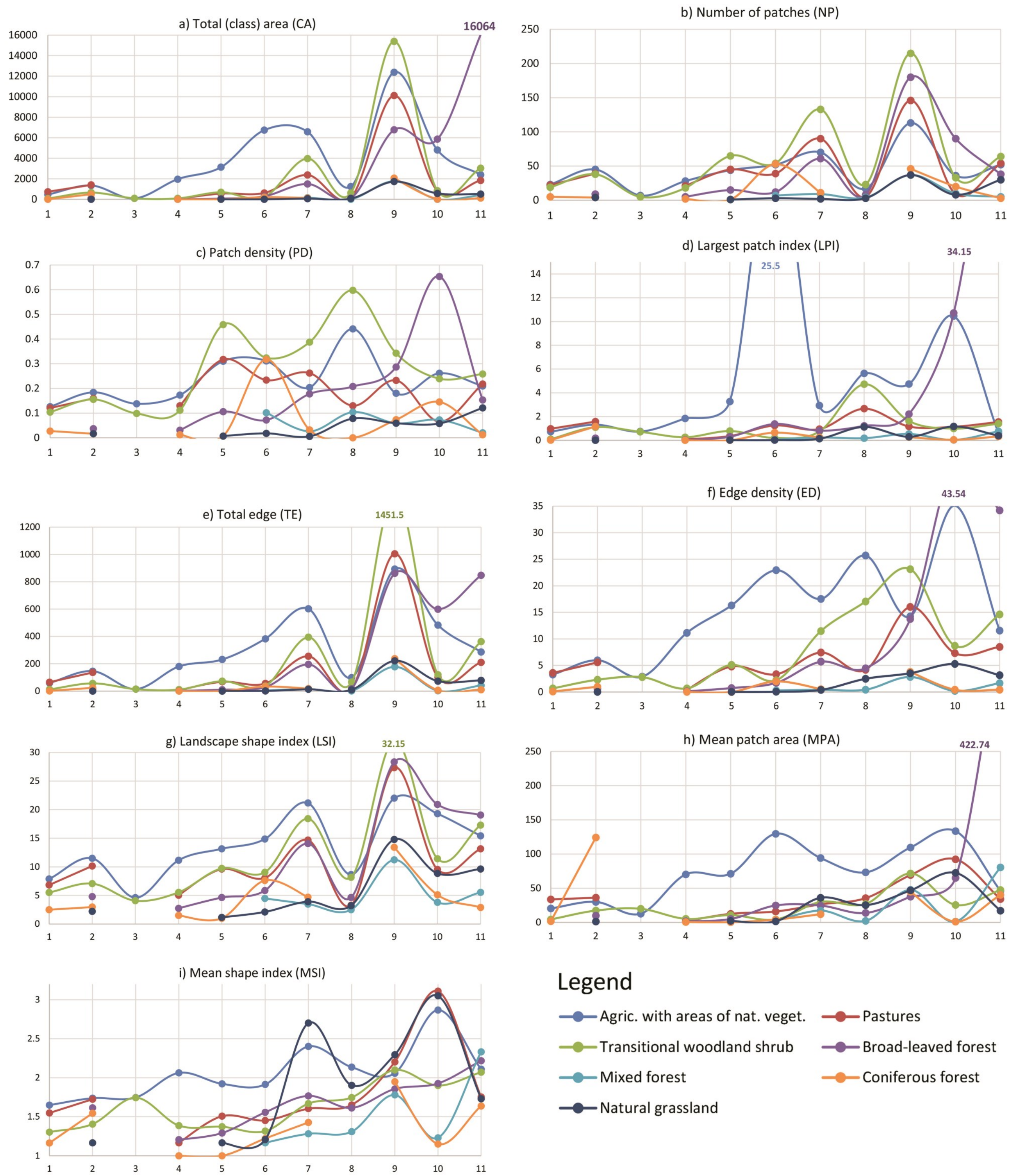

Figure 3. Agricultural and rural landscapes area-edge and shape metrics on a class level. Codes of landscape types presented on the axis are: Agricultural landscapes: 1-4 i.e. 1 (Ovche Pole flatland landscape); 2 (Ovche Pole lowland rolling landscape); 3 (Ovche Pole lowland rolling landscape with wind hedges) and 4 (Kochani landscape); Rural landscapes: 5-11 i.e. 5 (Lowland rolling agricultural rural landscape); 6 (Maleshevo -Pijanec rural agricultural landscape); 7 (Rolling rural landscape); 8 (Rolling rural landscape with hedges); 9 (Hilly rural landscape); 10 (Mountain rural landscape) and 11 (Osogovo mountain rural landscape)

The **total edge** (Fig. 3-e) of patches also increases from agricultural to rural landscapes (except the Rolling rural landscape with hedges) followed by an increase in **edge density** (Fig. 3-f). The largest increase in **edge density** over the landscape types is marked by the land cover classes of *agricultural land with natural vegetation* and *transitional woodland-scrub* followed by the abrupt increase in **edge density** in *broad-leaved forest* in Mountain rural landscape (43.54 m/ha) and Osogovo mountain rural landscape (34.21 m/ha).

The **landscape shape index** (Fig. 3-g) shows that the patches of *transitional woodland-scrub* class disaggregate and their irregularity increases when grading from agricultural to rural landscapes. When the landscape shape is considered in regard to the overall extent of the corresponding patch type throughout the landscape, this trend is more regular if the **mean shape index** (Fig. 3-i) is analyzed.

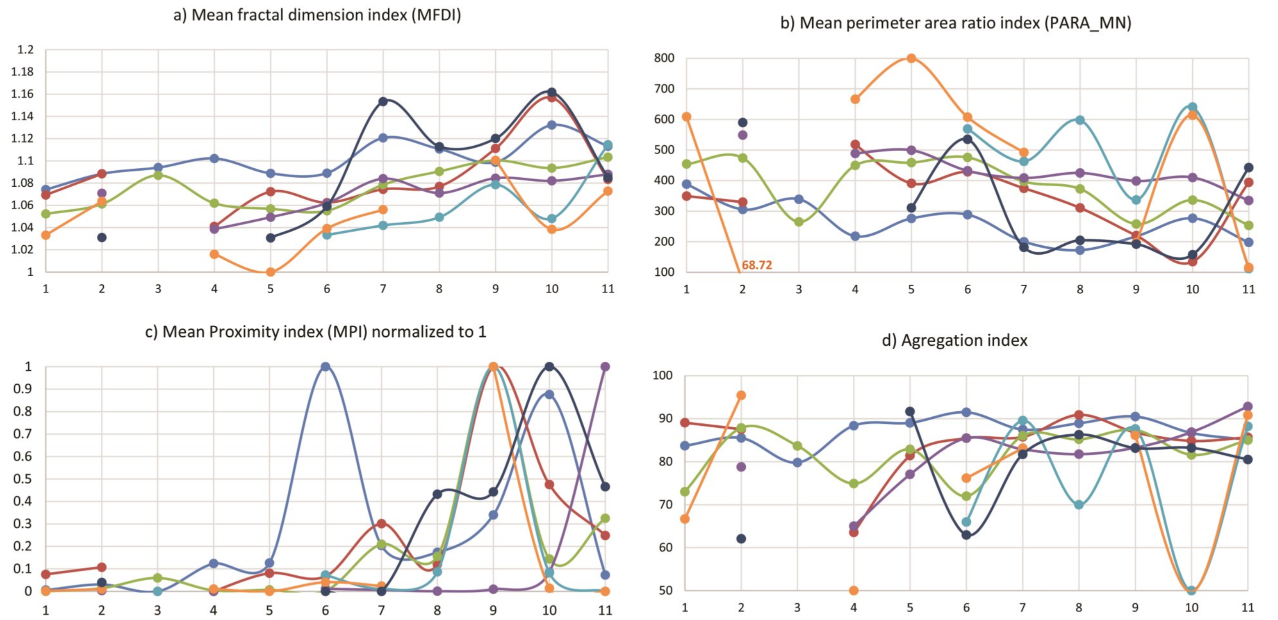

Figure 4. Agricultural and rural landscapes shape metrics (fractal dimension and perimeter-area ratio) and aggregation metrics (proximity index and subdivision and aggregation metrics) on a class level. For land cover class legend and codes of landscape types presented on the axis see Figure 3.

The **mean fractal dimension index** (Fig. 4-a) shows that patch shape complexity generally increases from agricultural toward rural landscapes. The alterations in this trend mainly depend on the level of natural occurrence of the specific land cover type in the landscape. For example, patches of coniferous plantations have the lowest **mean fractal dimension index**, which is much lower in the agricultural landscapes group and low in rural landscapes that are more agricultural in character compared to other rural landscapes. The shape complexity varies throughout the landscape types and even marks a decrease ranging from agricultural to rural landscapes (due to increase of patch size of corresponding patch types) that leads to a decrease of **perimeter/area ratio** (Fig. 4-b).

The **mean proximity index** (Fig. 4-c) indicates that contiguity of patches of land cover classes representing/ comprising natural habitats increases in rural landscapes (as compared to agricultural landscapes) and is notably high in Hilly rural landscape, Mountain rural landscape and Osogovo mountain rural landscape. The opposite trend is observable in the **aggregation index** (Fig. 4-d).

Specifically, *agricultural land with natural vegetation* is represented mostly in extensively managed agricultural land and it typically contains large portion of hedges of natural vegetation (shrubs, forest patches, riparian belts and tall forbs' stands). This land cover class exhibits the largest **patch density** (Fig. 3-c) in Rolling rural landscape with hedges (0.44) than Lowland rolling agricultural rural landscape and Maleshevo-Pijanec rural agricultural landscape (both have a **patch density** of 0.31). The **largest patch index** (Fig. 3-d) of *agricultural land with natural vegetation* is observed in Maleshevo-Pijanec rural agricultural landscape (25.5% of the overall landscape area). The **total edge** (Fig. 3-e) of *agricultural land with natural vegetation* generally increases from Kochani landscape (with exception to Rolling rural landscape with hedges (only 99 km) toward Hilly rural landscape (**total edge** of 893 km). However, it marks decline in both mountain rural landscapes because, as explained above, this land cover class is less represented here (i.e. as the "naturalness" of the landscape types increases, land cover classes that not only comprise but represent natural habitats prevail). The lowest **edge density** (Fig. 3-f) in rural landscapes group is observed in Rolling rural landscape (17.5 m/ha), Hilly rural landscape (14.2 m/ha) and Osogovo mountain rural landscape (11.6 m/ha). The **mean shape index** (Fig. 3-i) does not demonstrate a clearly noticeable trend in regard to the land cover class of *agricultural land with natural vegetation* though there is an increase in patches' disaggregation and irregularity starting from Lowland rolling agricultural rural landscape to Mountain rural landscape (MSI larger than 2). Osogovo mountain rural landscape is an exception since this land cover class covers small area.

The land cover class of *pastures* represents hill pastures that are still managed with extensive grazing practices. The largest surface under pastures (Fig. 3-a) is recorded in Rolling rural landscape (2378.25 ha) and Hilly rural landscape (10108.25 ha). When the **number of patches** (Fig. 3-b) of this land cover class is considered, *pastures* exhibit gradual increase in surface starting from Lowland rolling agricultural rural landscape (12.49 ha) to Mountain rural landscape (92.36 ha) and then decline in Osogovo mountain rural landscape (34.11 ha). In agricultural landscapes pastures are not representative and occupy very small area. The largest **patch density** (Fig. 3-c) of the cover class *pastures* is observed in Lowland rolling agricultural rural landscape (0.3175) and the **largest patch index** (Fig. 3-d) sets the largest patch of *pastures* in Rolling rural landscape with hedges (2.66). Hilly rural landscape holds the highest scores for both **total edge** (1005.25 km) and **edge density** (43.54 m/ha) metrics (Fig. 3-e and f). The **landscape shape index** (Fig. 3-g) indicates that patches of *pastures* in Hilly rural landscape disaggregate and are of irregular shape (27.34). The **mean shape index** (Fig. 3-i) demonstrates that the highest level of disaggregation and irregularity of patches of *pastures* is observed in Mountain rural landscape (3.11). The **mean fractal dimension index** (Fig. 4-a) shows that complexity of *pasture* patches increases in rural landscapes as the patches become more convoluted and more aggregated (Fig. 4-d) and patch contiguity increases (Fig. 4-c).

The land cover class of *transitional woodland-scrub* in the Bregalnica basin generally comprises abandoned arable land or hill pastures that due to abandonment of traditional grazing practices are now successioning into pastures with shrubs or sparse low stem oak forests. The largest **patch density** (Fig. 3-c) of *transitional woodland-scrub* is observed in Lowland rolling agricultural rural landscape (0.46), Rolling rural landscape (0.38), Rolling rural landscape with hedges (0.59) and Hilly rural landscape (0.34). The **largest patch** (Fig. 3-d) of *transitional woodland-scrub* is registered in Rolling rural landscape with hedges, though its **total edge** (Fig. 3-e) reaches its highest in Hilly rural landscape (1490.5 km) and it is also perceptibly high in Rolling rural landscape (394.15 km) and in Osogovo mountain rural landscape (361.75 km). **Edge density** (Fig. 3-f) of *transitional woodland-scrub* continuously increases from Rolling rural landscape (11.5 m/ha) and reaches its maximum in Hilly rural landscapes (23.14 m/ha). The **landscape shape index** (Fig. 3-g) shows that the patches of *transitional woodland-scrub* class disaggregate and their irregularity increases when going from agricultural toward rural landscapes. This trend is better visible in case of the **mean shape index** (Fig. 3-i). In the rural landscapes group the irregularity and disaggregation (Fig. 4 a,b and d) of patches is most visible in Hilly rural landscape (2.1), Mountain rural landscape (1.9) and Osogovo mountain rural landscape (2.1). Patches of this land cover type are most contiguous (Fig. 4-c) in distribution in Hilly rural landscape.

Broad-leaved forest class in the region is represented by oak forests (up to 900 m a.s.l.) and beech forests higher up (beech forests also occur in ravines and occupy the northern slopes at lower elevations). In agricultural landscapes *broad-leaved forests* are not representative and occupy very small area. The area under *broad-leaved forests* class increases as "naturalness" of the landscapes increases. The largest surface (Fig. 3-a) under *broad-leaved forests* is noted in Osogovo mountain rural landscape where this land cover type occupies even 64.8% of the total landscape area, thus representing the matrix of the landscape. The **number of patches** (Fig. 3-b) of *broad -leaved forest* in this landscape type is rather low (38) and consequently this landscape type holds the **largest patch index** (Fig. 3-d) for broad-leaved forests (34.15). The high **mean shape index** (2.2) in this landscape (Fig. 3 -i) indicates rather high disaggregation and irregularity of *broad-leaved forest* patches. Other landscape types that contain significant number of *broad-leaved forest* patches are Rolling rural landscape (61), then Hilly rural landscape (180) and Mountain rural landscape (90). The **mean patch area** (Fig. 3-h) of this land cover type gradually increases from Lowland rolling agricultural rural landscape and riches its maximum in Osogovo mountain rural landscape (422.7 ha). The **patch density** (Fig. 3-c) too demonstrates a gradual increase throughout rural landscapes. The largest **patch density** is observed in Mountain rural landscape (0.65). **Edge density** (Fig. 3-f) of *broad-leaved forests* also increases continuously throughout rural landscapes and reaches its maximum in Mountain rural landscape (43.54). *Broad-leaved forests* patches contiguity (Fig. 4-c and d) is highest in Osogovo mountain rural landscape indicating low fragmentation and high corridor value for species inhabiting the neighboring forest landscapes.

Mixed forests land cover class represents broad-leaved forests (mostly oak) with coniferous tree stands. Patches of *mixed forest* are registered only in rural landscapes. The largest **total (patch) area** (Fig. 3-a) of *mixed forest* is observed in Hilly rural landscape (1758.5 ha) where a noticeable portion of the area under pastures has been afforested in the past and are now covered with scattered coniferous tree plantations recently encroached with the naturally successioning broad-leaved forest. Still, when the **number of patches** (Fig. 3-b) is considered, Osogovo mountain rural landscape holds the highest **mean patch area** (80.3) (Fig. 3-h). *Mixed forests* **patch density** (Fig. 3-c) is rather low in all landscape types (not higher than 0.1) and the highest **largest patch index** (Fig. 3-d) is observed in Osogovo mountain rural landscape (only 0.76). These large patches actually contributes toward the significant increase of the **mean patch area** (Fig. 3-h) in this landscape type. The highest **total edge** (Fig. 3-e) is again represented in Hilly rural landscape (177.9 km) as is the **edge density** (Fig. 3-f) (3.78). The shape indexes show that patches of *mixed forests* demonstrate highest level of disaggregation (Fig. 4-c and d) and irregularity (Fig. 4-a, b) in Hilly rural landscape and Osogovo mountain rural landscape.

Coniferous forests land cover class in the survey area is mostly represented with coniferous plantations (natural coniferous forests are present in Malesh region). This land cover type demonstrates similar trends of the landscape metrics with mixed forests. The difference is that coniferous plantations are also registered in agricultural landscapes and are especially noticeable in Ovche Pole lowland rolling landscape where the **mean patch area** (Fig. 3-h) reaches even 124.5. Coniferous plantations also have a significant **mean patch area** in Rolling rural landscape (11.98), Hilly rural landscape (44.74) and Osogovo mountain rural landscape (40.08), though the largest **number of patches** (Fig. 3-b) of this land cover type (53) is found in Maleshevo-Pijanec rural agricultural landscape. Still, the **mean patch area** of *coniferous forests* in this landscape is low (4) due to the generally low **total (patch) area** (212 ha) (Fig. 3-a). This landscape type also has the largest **patch density** (Fig. 3-c) of *coniferous forests* (0.32) and holds the highest **largest patch index** (0.65) (Fig. 3-d). The highest **total edge** (Fig. 3-e) of coniferous plantations patches is registered in Hilly rural landscape (237.65 km) with **edge density** of 3.79 (Fig. 3-f), followed by Maleshevo-Pijanec rural agricultural landscape with a **total edge** of 33.35 km and **edge density** of 1.99. Patches of coniferous plantations are generally disaggregated throughout landscape types. The highest disaggregation (Fig. 3-g and i) is registered in Hilly rural landscapes (**landscape shape index** is 13.95 and **mean shape index** is 1.95). In Kochani landscape and Lowland rolling agricultural rural landscape this land cover type is represented with a single patch.

Natural grasslands in the survey area includes dry grasslands with tall grasses, small patches of mesic grasslands and montane pastures of a secondary origin at high altitude. Patches of *natural grasslands* in the survey area are typically present in the rural landscapes group. The largest **number of patches** (Fig. 3-b) of *natural grassland* is recorded in Hilly rural landscapes (37) where *natural grasslands* have also high **total (patch) area** (1731 ha) (Fig. 3-a) as is the case with Mountain rural landscapes (579.25 ha). A significant area under *natural grasslands* is also found in Osogovo mountain rural landscape (515 ha) but here that patch area is distributed among a large number of patches (30). **Total edge** (Fig. 3-e) of *natural grasslands* is highest in Hilly rural landscape (221.8 km) where the **edge density** (Fig. 3-f) is also high (3.53). However, when **total edge** is taken into account, the highest **edge density** is observed in Mountain rural landscape (5.35). The disaggregation and irregularity of *natural grasslands* patches in accordance with **landscape shape index** (Fig. 3-g) marks an abrupt increase in Hilly rural landscapes, Mountain rural landscapes and Osogovo mountain rural landscapes. When the number of patches is considered, the largest **mean shape index** (Fig. 3-i) is observed in Maleshevo-Pijanec rural agricultural landscape (2.7) and Mountain rural landscape (3.05).

When considering both landscape groups the diversity in terms of composition and the spatial arrangement of land cover classes is greater in rural landscapes. Patches of natural vegetation in agricultural landscapes are presented by land cover categories that comprise but do not exactly represent natural habitats (*agricultural land with natural vegetation, pastures and transitional woodland-scrub*) meaning that these landscape types could only sustain species that are closely related to secondary anthropogenic habitats (Pimentel et al. 1992). Conversely, the higher presence of diverse patches of natural habitat in the rural landscapes supports the higher diversity of species (Harvey et al. 2008; Dorresteijn et al. 2013; Cevasco and Moreno 2013; Hristovski and Brajanoska 2015). In rural landscapes, all calculated landscape metrics demonstrate an increase in diversity and dominance of land cover classes representing natural habitats, clearly distinguishing Hilly rural landscape, Mountain rural landscape and Osogovo mountain rural landscape by their capacity to "conduct" and sustain biodiversity. Namely, when all landscape metrics are considered, Osogovo mountain rural landscape is more likely to be included in the forest landscapes group. Still, the domination of *broad-leaved forests* class only gives a specific feature, but does not define the forest character of the landscape. That is, forests in Osogovo mountain rural landscape bare more anthropogenic characteristics than those in forest landscapes (they mostly lack fully closed canopy structure and are rather sparse at some areas with clearly visible tracks of recent human intensive management). The rural nature of the landscape is attributed by the share of land cover classes - *agricultural land with natural vegetation, pastures* and *transitional woodland-scrub*. Another significant attribute that contributes to the rural character of this landscape type is the large number (though small in size) of extensively managed fields and meadows surrounding the numerous clumps of houses belonging to the villages of a scattered type (Melovski et al. 2015). Specific physical attributes (as are the structural metrics) normally should serve as a basis for characterization of different landscape types (Wu et al. 2000) but they should not be absolute. The long-lasting human-nature relationship that have shaped the landscape character through time (Nassauer 1995) should also be considered when determining the landscape type.

Today, landscape structure is clearly presented by landscape metrics which are easily computed, that is, once one goes through the "pile of numbers" served by different spatial pattern analysis programs (Kupfer 2012). The ultimate strive lies in linking the landscape structure properties to the ecological processes and the functional properties of the landscape (Turner 1989; Kupfer 2012; Lausch et al. 2015). However, published results in this field show different conclusions on whether and how landscape structure is connected to the functional properties of the landscape (Moilanen and Hanski 1998). The difficulty arises from various input factors used in the models (e.g. image resolution, habitat classification scheme, scale ranges and lack of extensive species data) (Wu et al. 2000; Brown et al. 2004; Kupfer 2012). Furthermore, when interpreting landscape metrics on different levels (patch, class, landscape), landscape size and number of patches must be taken into account (McGarigal and Marks 1994) since these have a significant role in the final outcome. For example, in the case of Rolling rural landscapes with hedges in Bregalnica basin there is a diverse representation (composition and spatial arrangement) of the focus land cover classes that is not detected in many of the landscape metrics since this landscape type covers smaller area when compared to other landscapes in the rural landscapes group. The interdependence of various structure metrics and their applicability in different levels of analyses (McGarigal and Marks 1994; Haines-Young and Chopping 1996) should also be considered and their use should be tailored in accordance of the general objective of the study, e.g. shape metrics (fractal dimension and perimeter-area ratio) and aggregation metrics (proximity index and subdivision and aggregation metrics) allow comparison among different landscapes but, on a coarse scale, are not clearly indicative on a land cover class level.

In this paper we only assess landscape structure and discuss it as an attribute that distinguishes landscapes without questioning the functional outcome of the individual landscape structural properties of each landscape type. In the absence of systematic and targeted data on spatial distribution of species throughout the survey area, this study does not intend to provide discussion for the pattern-process relationships. Instead, the results are interpreted within the scope and limitation to our study and are primary meant to interpret and assess the current spatial pattern of the targeted landscape groups to guide the land managers and stakeholders in their landscape management endeavors. An overall detailed assessment of landscape structure provides a platform for assessing and monitoring changes in landscape pattern over time (Gökyer 2013) and by extension serves as a prerequisite in defining pattern-process relationships (Turner 1989; Kupfer 2012).

Conclusions

Agricultural landscapes in the area of the Bregalnica watershed are characterized by small number of patches dispersed in a rather compact matrix. These landscapes have low patch density and high largest patch index followed by low value of total edge length resulting with a low edge density and low landscape shape index. The complexity of patch shape is low (aggregated patches of regular shape) and the fractal dimension index indicates that patches are with simple perimeter. The agricultural landscapes are increasingly occupied by patches of the same type leading to uniform composition of compact patches.

The rural landscapes on the other side are characterized with large number of patches dispersed in a ragged matrix. In the rural landscapes it is more difficult to single out the dominant patch, the total edge length is high resulting with a high edge density and raising landscape shape index (irregular landscape shape and disaggregated patches). The complexity of patch shape is high and patch shapes are more convoluted. The rural landscapes are variably occupied by patches that differ by type leading to uneven composition of rambling patches.

When considering the structural properties of agricultural and rural landscapes in terms of patch composition and spatial arrangement of land cover classes representing/comprising natural habitat, agricultural and rural landscapes are clearly separated in regard to their "nature friendliness". The structural analysis shows that capacity to sustain biodiversity levels up in rural landscapes and is most perceptible in Hilly rural landscape, Mountain rural landscape and Osogovo mountain rural landscape.

The results in this study should serve as a basis for future research on the change in the spatial pattern of the targeted landscape groups and the structural properties specific for each landscape type. In a region where there are ongoing conservational efforts, such as Bregalnica basin, providing a thorough database on spatial distribution of species is urgent as a prerequisite for definition of the pattern-process relationships for species that are important for conservation. Moreover, more precise definition of the shape and potential of natural habitat resource patches that connect key core areas is required for accurate identification of the broader conservation significance of separate units of agricultural and rural landscapes. In general, a detailed assessment of landscape properties will provide a broad scale perception of the conservation requirements in the river Bregalnica basin and will allow re-arrangement of the nature conservation policy and management by giving the future conservation endeavors a landscape approach.

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