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Landscape diversity indexes application for agricultural land use optimization

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Abstract

The paper is focused on land use optimization using landscape metrics (landscape diversity indexes) in order to solve the urgent problem of biological and landscape diversity loss due to intensive agricultural activities. Besides the ecological and social values, more diverse ecosystems appear to be more productive and stable, than are less diverse landscapes, affecting the economic component. Landscape metrics applications allow objectively and expeditiously assess landscape diversity and present an appropriate model for optimized allocation of lands in agro-landscapes.

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Keywords: Landscape Diversity Index; Optimization

1. Introduction

Sustainable agriculture and land management aim to make use of nature's goods and services while producing good yields in an economically, environmentally, and socially rewarding way, preserving resources for future years

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and future generations. One of the key goal of sustainable agricultural land management is achieving the ecologically optimal agroecosystem structure considering landscape perspective, ecosystem carrying capacity and habitat connectivity. So far as ecosystem functions depend on the spatial context and composition of the ecosystem (landscape context), landscape diversity conservation (including areas with natural vegetation) reduce negative impacts on the environment and enhance natural capital and the flow of ecosystem services [9]. The landscape structural heterogeneity is critical for agroecosystem stability [5] and profitability, as has been shown in the studies on the relations between crop productivity and landscape diversity [1,4].

One of the important aspect of landscape design is the rule of required diversity, which essentially repeats the common system rule, whereby the existence and function of any system are only possible when the system includes interacting and heterogeneous but complementary elements. The landscape is subjected to the general rule of a causal relationship. A change in any component of ecosystems leads to alteration in all other components and ecosystem as a whole. Therefore, for sustainable agriculture there is a need to assess the structure of agroecosystems, to find out whether agrolandscape structure is efficiently transformed to meet the ecological, economical, and social functions.

The application of landscape metrics can be an easy-to-use and effective tool for assessing the ecological framework and development of recommendations to improve the territorial structure of agricultural landscapes to ensure the conservation, optimum use of land resources and increase crop productivity without increasing the area of arable land.

2. Method explanation

A number of landscape metrics has been developed for investigation, monitoring and evaluation of landscape structure. Landscape metrics describe the landscape structure quantitatively on the basis of area, shape, edge lines, isolated areas and insufficient density of erosion control facilities and protection network, the dominance of monoculture, the high proportion of arable land, and plowing of grasslands and steppe areas to the boundary of the forests or river in the landscape are observed, causing the reduction of environmental sustainability of agroecosystems [4]. Two test sites with area of 25 км^2 was selected within the study area as test polygon with different level of agricultural intensification (12 % and 64 % of arable lands in test site) to test landscape metrics application for different land use structure on local level.

On the first stage of the research the mapping of biotope types of the study area, based on the remote sensing images classification, was conducted. Land cover maps of test sites were created according to CLC2000 classification (Fig.1). Then the biotope types was assessed on the criteria of naturalness, substitutability, and similarity. Since the shrubs class is mainly represented by forested gullies within a test sites, a class of shrubs and forest class valuated with high similarity of habitat type. One the third stage of the research the landscape metrics was calculated using Fragstat and AcrGIS Desktop software.

For this analysis, the following indexes were selected [11]:

- Habitat heterogeneity (HH): a number of habitat patches
- Habitat diversity (PD): a number of habitat types per unit area
- Landscape shape index (LSI): a standardized measure of total edge or edge density that adjusts for the size of the landscape; equals 1 when the landscape consists of a single square patch; increases without limit as landscape shape becomes more irregular and/or as the length of edge within the landscape increases
- Contiguity Index: a spatial connectedness, or contiguity, of cells within a grid-cell patch to provide an index on patch shape; equals 0 for a one-pixel patch and increases to a limit of 1 as patch contiguity, or connectedness, increases (CONTG).
- Euclidean Nearest-Neighbor Distance (ENND): distance (m) from patch to nearest neighboring patch of the same type
- Modified Simpson's Diversity Index (MSIDI): proportion of the landscape occupied by patch type (class); equals 0 when the landscape contains only 1 patch (i.e., no diversity); increases as the number of different patch types increases and the proportional distribution of area among patch types becomes more equitable

Shannon's Evenness Index: a proportional abundances; equals 0 when the landscape contains only 1 patch (no diversity) and approaches 0 as the distribution of area among the different patch types becomes increasingly uneven (dominated by 1 type); equals 1 when distribution of area among patch types is perfectly even (SHDI).

3. Results discussion

As illustrated on the land cover maps (Fig. 1), two test sites differ significantly in the spatial structure. First polygon consists mainly of natural vegetation areas with a small portion of arable lands (around 12%). Second test polygon is dominated by arable lands (64%), therefore a patches are mostly rectangular is shape.

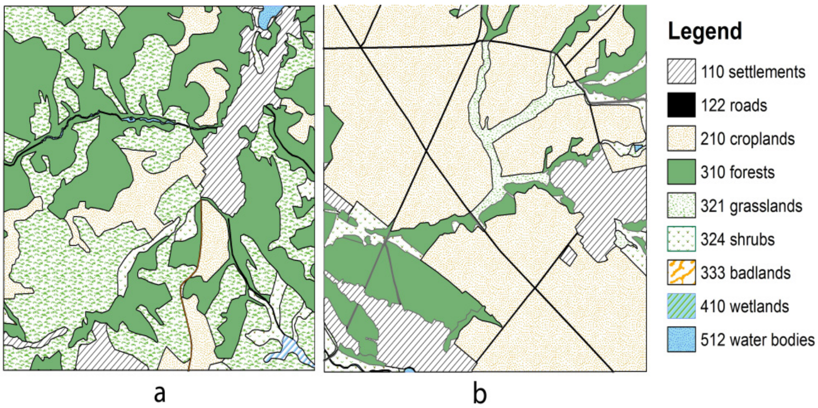

Fig.1. Land cover map: (a) test site 1; (b) test site 2.

Landscape metrics were calculated to compare a different land optimization scenarios. According to the particular landscape structure of test sites the following scenarios were developed:

- Scenario 1: create forest hedgerows as 15-m buffer zones along roads and create forest buffer strips across fields with area of more than 100 ha.
- Scenario 2: create grassland shelter-belts as 15-m buffer zones along roads and create grassland buffer strips across fields with area of more than 100 ha (this scenario is much easier to implement than the first one as the farmer only need to leave a boundary areas without cultivation).
- Scenario 3: enlarge areas with natural vegetation by expanding the boundaries of the nearby agricultural and other lands needing rehabilitation (the additional 10-m grassland buffer zone around arable land patches was modulated for test site 1; two fields eroded areas was changed to grasslands for test site 2).

The results of landscape diversity metrics calculation for current and modulates situation is presented in the tables 1-2.

Table 1. Landscape diversity metrics for test site 1

Situation	HH	PD	LSI	CONTG	END	MSIDI	SHEI
Test site 1 – current situation	74	2.9708	8.9060	0.8850	169.87	1.1161	0.6499
Test site 1 – scenario 1	75	3.0110	9.1157	0.8720	168.33	1.1131	0.6488
Test site 1 – scenario 2	73	2.9307	9.1145	0.8817	173.00	1.1133	0.6489
Test site 1 – scenario 3	76	3.0511	10.2750	0.8815	167.57	1.1009	0.6442

Table 2. Landscape diversity metrics for test site 2

Situation	HH	PD	LSI	CONTG	END	MSIDI	SHEI
Test site 2 – current situation	92	3.6392	8.4677	0.7942	119.94	0.7595	0.5703

Test site 2 – scenario 1	132	5.2210	11.6894	0.6883	74.98	0.7995	0.5867
Test site 2 – scenario 2	131	5.1814	11.6967	0.7100	79.01	0.8162	0.6050
Test site 2 – scenario 3	130	5.1419	11.6056	0.7084	76.11	0.9235	0.6517

According to the results, the spatial model with forest hedgerows demonstrated slightly better values of landscape diversity metrics then a scenario with grassland shelter-belts, since the values a very close to each other. But the current situation of test site 1 was better then modeling situations, as well as in general landscape indexes of test site 1 were better then in second test site. Its can be explained by the high rate of natural areas in the landscape of test site 1 and indicated landscape structure optimization activities are not proved to be effective. The same time modeling situations of test site 2 demonstrated efficiency with respect to landscape metrics.

4. Conclusion

The landscape structure assessment tools for selecting the most appropriate models of rational spatial organization of the agroecosystem, conserving biodiversity and ecological stability, is required at both the regional administrative land management level, and at the level of individual farm planning. Assessment tool must be simple, efficient and quantitative objective, so that it could easily be used as by experts and local authorities so as by farmers. Landscape metrics could be a powerful tool for spatial planning of agrolanscape structure and selection the optimal model of agrolandscape arrangement and land use model by quantifying the composition, configuration, density and aggregation of landscape structure element.

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