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THE ROLE OF RESOLUTION ON LANDSCAPE METRICS BASED ANALYSIS

Túri Z., Szabó Sz. **Rola rozdzielczości w analizie metrycznej krajobrazu.** Parametry metryczne krajobrazu są efektywnymi elementami jego ilościowej analizy. Pomagają zrozumieć strukturę krajobrazu i procesy ekologiczne. Płaty, korytarze i macierz przez nie ułożona odgrywają istotną rolę w badaniach krajobrazu. Niniejszy artykuł analizuje wpływ rozdzielczości map na parametry metryczne krajobrazu. Głównym celem była: 1) identyfikacja parametrów, które wynikają ze skali, jak również 2) ujawnienie potencjalnych błędów we wnioskch opartych na tych parametrach. Badano następujące wskaźniki: liczba płatów (NP), obszar klasowy (CA), średnia wielkość płatu (MPS), odchylenie standardowe wielkości płatu (PSSD), średnia krawędź płatu (MPE), całkowita krawędź (TE) przy rozdzielczości 0.5–1–2.5–5–10–20–30–40–50–60–70–80–90 i 100 metrów. Można stwierdzić, że wykorzystanie jakiejś metody wektorowej jest sensowne, kiedy podstawowe parametry metryczne są studiowane w mikroskali, gdyż podobny do pikseli charakter płatów w systemie rastrowym znacznie modyfikuje parametry związane z obrzeżami (granicą) i stosunkiem obszaru do obrzeży (granicy). Wzrastająca rozdzielczość pikseli o małych rozmiarach płatów izodiametrycznych przy rozdzielczości 20–40 metrów powoduje, można wykryć więcej płatów niż wynosi ich rzeczywista liczba. Dalsza redukcja rozdzielczości skutkuje połączeniem pikseli, stają się one większe a ich liczba zmniejsza się i niewiele róży się do mapy oryginalnej. Zatem, zdaniem autorów, do analizy metrycznej płatów krajobrazu najbardziej odpowiednia jest rozdzielczość poniżej 10 m, natomiast w przypadku wskaźników typu granicznego (obrzeży) zalecane jest wykorzystanie rozwiązań opartych na wektorach.

Тури З, Сабо С. **Роль разрешения в метрическом анализе ландшафтов.** Метрические параметры ландшафтов являются эффективными элементами их количественного анализа. Они способствуют пониманию структуры ландшафтов и экологических процессов. Ячейки (участки), коридоры и образованная ими матрица играют существенную роль в изучении ландшафтов. Представленная статья раскрывает влияние разрешения карт на метрические параметры ландшафтов. Основные цели работы: 1) определение параметров, которые определяются масштабом карт, а также 2) выявление потенциальных ошибок в выводах, основанных на принятых параметрах. Исследованы следующие параметры: число ячеек (NP.), пространство классов (CA), средняя величина ячейки (MPS), стандартное отклонение величины ячейки (PSSD), средняя граница ячейки (MPE), общая граница ячейки (TE) при разрешении 0.5–1–2.5–5–10–20–30–40–6 70–80–90 и 100 м. Можно утверждать, что использование векторного анализа целесообразно тогда, когда основные метрические параметры изучаются в микромасштабе, поскольку похожий на пиксели характер ячеек в растровой системе значительно модифицирует параметры связанные с окраинами (границами) и положением территорий на окраинах (границах). Возрастающее разрешение пикселей малых размеров изодиаметрических ячеек при разрешении 20–40 м позволяет выявить больше ячеек, чем их выступает в действительности. Последующее сокращение разрешения сопровождается соединением пикселей, они становятся больше, а их число уменьшается и почти не отличается от исходной карты. Поэтому, по мнению авторов, для метрического анализа ландшафтов наиболее соответствует разрешение менее 10 м, а в случаях показателей пограничного типа (окраины) рекомендуется использовать векторные подходы.

Abstract

Landscape metric parameters are effective elements of quantitative landscape analysis. They help to understand landscape structure and ecological processes. Patches, corridors and the matrix established by them have important roles in the operation of the landscape. The present paper investigates the effect of map resolution on landscape metric parameters. The main goal was to identify parameters that are scale prone and to reveal potential faults of conclusions made on these parameters. The investigated indices were the followings: Number of Patches (NP), Class Area (CA), Mean Patch Size (MPS), Patch Size Standard Deviation (PSSD), Mean Patch Edge (MPE), Total Edge (TE) with resolutions 0.5–1–2.5–5–10–20–30–40–50–60–70–80–90 and 100 metres. It can be stated that the use of some kind of vector method is sensible when the basic landscape metric parameters are studied in the micro-scale as the pixel like character of the patches in the raster system modifies significantly parameters associated to the perimeter and the area/perimeter ratio. Increasing resolution the small sized pixels of the isodiametric patches become aggregated while elongated patches disintegrate into smaller, not continuous areas. In consequence, much more patches can be detected at

resolutions 20–40 metres than the real number of patches. Further reduction of resolution results in the joining of the pixels, they become larger and their number is decreased providing a difference to the original map that is not significant. Thus in our opinion for the area-type landscape metric analysis of patches resolution below 10 metre is most suitable while in the case of perimeter-type indices the use of vector based solutions is recommended.

INTRODUCTION, AIMS

Landscape metric parameters are effective elements of quantitative landscape analysis. They help to understand landscape structure and ecological processes. Patches, corridors and the matrix established by them have important roles in the operation of the landscape.

Landscape metric researches usually study the patches as their geometric characteristics (area, perimeter, shape, etc.) together with their relative spatial position (e.g. closeness, connectivity) can be calculated by simple mathematics. Considering patches, parameters can be classified into several groups: area/perimeter, shape, core area, isolation/proximity, contrast, contagion/interspersion, connectivity, diversity.

Perimeter, area of patches and their quotient are important landscape metric parameters that alone can give the base for regional planning. There are ecological researches that determined the minimum size of a forest that can operate as an individual ecosystem. Perimeter alone cannot give information on the vulnerability of patches but its quotient with the area can: great perimeter/area ratio reflect that the patch is connected to the neighbouring patches via a large surface that may have an effect on the composition or the behaviour of the species living in the patch (LINKEVICIENE, TAMINSKAS, SIMANAUSKIENE, 2007). Patches are composed of an inner zone, the core area and the edge zone. Different species, plants or animals endure differently the disturbing effects present potentially in the edges therefore different edges have to be calculated with in the case of different species (it is doubtless that a busy motorway produces different effect on a nesting bird than on a plant). Perimeter and area of the edges depend largely on the shape of the patch: when the shape of the patch is like a dissected continent the edge is larger, while if it resembles a nondissected coast then the edge is minimal. The size of the patch, of course is also important as virtually there are no edges in the case of small patches. Boundary between patches may serve as a filter or as a barrier. In the case of the latter landscape may become fragmented without any human interference and the rate of isolated areas increases (BARCZI, 2008). Distance between two patches may also present a barrier, especially for smaller sized animals (larger ones can cover even several hundred meters while 10 metres may prove to be too much for smaller ones). Degree of contrast is also important as it shows the difference between two connected patches (CSORBA, 2008). Ecological processes are strongly influenced by the contrast between the patch and its surroundings (and it is in close correlation to the ratio of perimeter/area mentioned above). Landscape can be assessed regarding the spatial distribution of the patches as well. At this time contagion factors (e.g. Aggregation Index, Contagion) have to be calculated that give the spatial aggregation of the patches. Mixing of patches with others is characterised by the factors of interspersion (Interspersion and Juxtaposition Index) (JAEGER, 2000). Connectivity presents information on the flow of species: large, continuous patches may become separated habitats due to habitat loss or fragmentation (MCGARIGAL, 2002). Landscape diversity factors are based on the fact that diversity increases landscape stability. There are several arguments pro and contra analysis of which is not the goal of this paper.

Individual factors are usually interpreted on patch, class and landscape levels. Patch level parameters are regarded on an individual patch, while class level parameters are given as simple or as weighted according to a certain aspect (usually area) average of the characteristics of the patch by landuse categories. Landscape level parameters summarise class level parameters by different aspects. Naturally there are no variations at all three levels for all of the parameters: there are parameters that can be interpreted only at patch level and others interpretable only at landscape level (MCGARIGAL, 1995).

It is clear that the scale applied in the studies determine the value of the individual indexes as well. Due to generalisation of the maps, boundaries of the patch are simplified in meso-scale and small-scale. Sometimes smaller patches cannot be depicted by the maps, however, they are important ecologically. Ideal scale for landscape ecological planning would be large scale but unfortunately conditions are not given for such investigations as there are no maps available with the required scale. The present paper investigates the effect of map resolution on landscape metric parameters. The main goal was to identify parameters that are scale prone and to reveal potential faults of conclusions made on these parameters.

METHODS

Landscape metric investigations were performed in a 63 km^2 lowland landscape (Tiszazug, eastern Hungary; fig 1). The area is located in low and high flood-

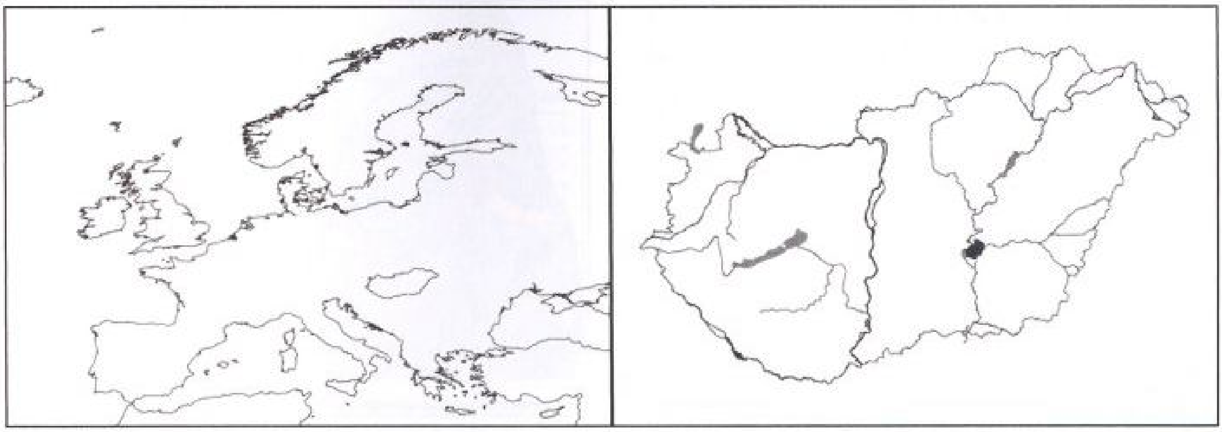

Fig. 1. Location of the model area
Rys. Lokalizacja obszaru modelowego

plains dissected by abandoned channels, point bars and sickle flats. It is part of a Neo-Holocene terracette series consisting of fluvial sand, silt and infusion loess (ALDOBOLYI, 1954). Its deeper parts were frequently flooded by the Tisza prior to the water regulation and flood prevention works while its western edge still serves as the wave area of the Tisza.

Landscape mosaics were digitized in a scale of 1 : 5000 by the geoinformatics software ArcGIS 9.0 from digital orthophotos created from aerial photos taken in the summer of 2005. Land cover categories were given based on the simplification of categories of the CORINE Land Cover database with the scale of 1 : 50 000 (CLC50) adapted onto Hungary (87 categories). Landscape structure was studied based on 14 combined categories (CSORBA, 2007): 1. settlement; 2. area of industrial, trade and agricultural establishments, traffic network elements; 3. quarries, depositories, construction areas; 4. artificial, non agricultural green areas; 5. arable lands; 6. vine and fruit production lands; 7. pastoral lands; 8. mixed agricultural lands; 9. deciduous forest; 10. pine forest; 11. mixed forest; 12. close-to-natural bush and/or plants; 13. water; 14. wetlands. 290 landscape mosaics were identified in the patch distribution of land-use.

Landscape metric parameters were calculated by the module vLATE of the software ArcGIS 9.0. Several parameters can be determined by the software FRAGSTATS 3.3, however, the high resolution (0.5–1–2.5 m) map versions exceeded the calculation capacity of the computers. Landscape indexes were calculated more reliably on vector base by vLATE. Vector maps were transformed into raster ones with the help of ArcGIS Spatial Analyst module with resolutions 0.5–1–2.5–5–10–20–30–40–50–60–70–80–90 and 100 metres and then they were vectorized again.

As the shape of the land-use categories is different (there are elongated and isodiametric types), investigations were performed regarding land-use as well. 14 categories were not always possible to handle during statistic analyses therefore combinations were required:

- isodiametric (categories 1., 2., 3., 4., 7.) and elongated (categories 6., 8., 9., 12., 13., and 14) and
- on the basis of similar character of land-use.

Land-use variables were classified into three groups in the latter: artificial surfaces (categories 1., 2., 3., 4.); agricultural, forest and close-to-natural areas (categories 6., 7., 8., 9., 12.); water, wetlands (categories 13. and 14.). In the study area composed primarily of agricultural cultivation landscape metric parameters of the arable lands enclosing the patches and thus giving the matrix were not investigated.

The parameters were depicted in diagrams with resolution and it was determined at which resolution occurs any change in the parameters. Correctness of the results was controlled by statistic methods. One-way and multiple ANOVA (with Tukey HSD post-hoc test) was applied to test the significance of differences of landscape metrics by land use categories.

In the course of the investigations testing all of the potential landscape metric parameters according to resolution sensitivity was not possible, however, the most fundamental parameters are presented that form the basis of landscape ecological investigations or other parameters. Investigated indices were the followings: Number of Patches (NP), Class Area (CA), Mean Patch Size (MPS), Patch Size Standard Deviation (PSSD), Mean Patch Edge (MPE), Total Edge (TE).

RESULTS

Effects of resolution

Analysis of different resolutions produced interesting results. If only statistic analyses are considered it can be stated that resolution has no significant influence on results, however, going into details this proves not completely true. It has to be emphasized that the results cannot be interpolated into meso-scale and large-scale investigations due to their resolution as in this work partches were digitized in the scale of 1 : 5000, i.e. a smaller area was analysed in detail.

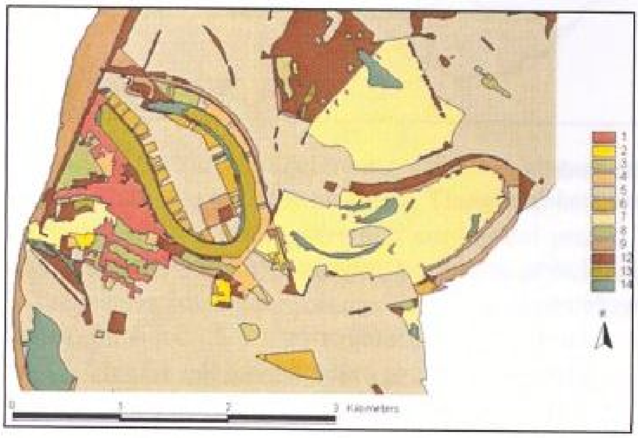

Fig. 2. Patch map of one part of the study area at the original resolution:
1 – settlements, 2 – areas of industrial, trade and agricultural establishmnets, traffic network elements, 3 – quarries, depositories, construction areas, 4 – artificial, not agricultural green areas, 5 – arable lands, 6 – vine and fruit production areas, 7 – pastoral lands, 8 – mixed agricultural lands, 9 – deciduous forest, 12 – close-to-natural bush and/or plants, 13 – water, 14 – wetlands
Rys. 2. Mapa obszaru badań przy oryginalnej rozdzielczości:
1 – zabudowania, 2 – obszary przemysłowe, handlowe i rolnicze, 3 – elementy sieci komunikacyjnej, 3 – kamieniołomy, zwałowiska, obszary konstrukcyjne, 4 – zielone obszary antropogeniczne, 5 – grunty orne, 6 – obszary produkcji winnej latorośli i owoców, 7 –pastwiska, 8 – mieszane obszary rolnicze, 9 – las liściasty, 12 – zarośla krzewiaste podobne do naturalnych, 13 – woda, 14 – obszary podmokłe

Fig. 3. Patch map of one part of the study area at 5 metres resolution (for legend see fig. 2)
Rys. 3. Mapa obszaru badań przy rozdzielczości 5 m (legenda – por.rys. 2)

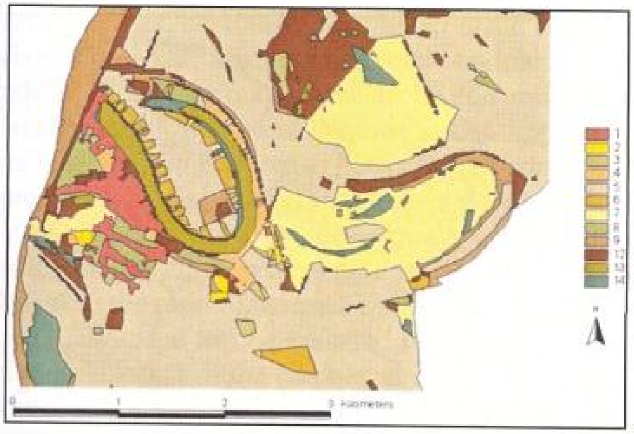

Fig. 4. Patch map of one part of the study area at 20 metres resolution (for legend see fig. 2)
Rys. 4. Mapa obszaru badań przy rozdzielczości 20 m (legenda – por.rys. 2)

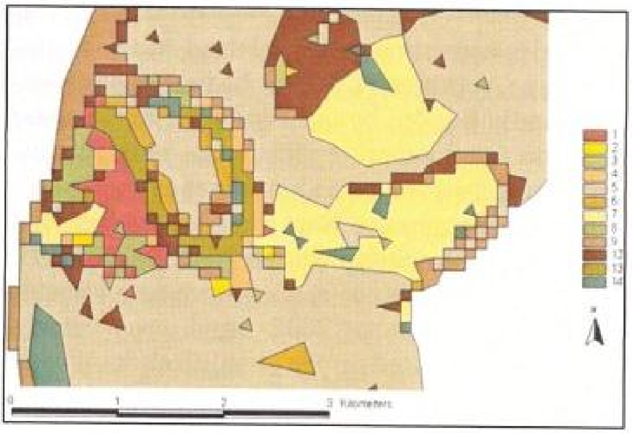

Fig. 5. Patch map of one part of the study area at 100 metres resolution (for legend see fig. 2)
Rys. 5. Mapa obszaru badań przy rozdzielczości 100 m (legenda – por.rys. 2)

Results were always compared to the initial map (fig. 2) and the change of the above mentioned landscape metric parameters with resolution was investigated. Differences are usually not significant (at $p<0.05$ level) but it is worth noting that the change occurs at the 20 metre resolution in the case of every parameter (fig. 3). Figure 6 shows the effect of resolution on the number of patches by land-use categories. As it can be seen the change occurs at 10 metre resolution, however, significant change ($p<0.05$) can only be observed between the 20 and 40 metres resolutions (fig. 4)

Explanation is found in that as resolution decreases patches become more pixel like and – especially elongated patches – disintegrate into smaller, not continuous areas. Therefore at these 20–40 metres resolutions significantly more patches can be detected than their real number. As resolution decreases more pixels become larger and thus their number decreases (fig. 5) reducing the difference ($p<0.05$) compared to the original map.

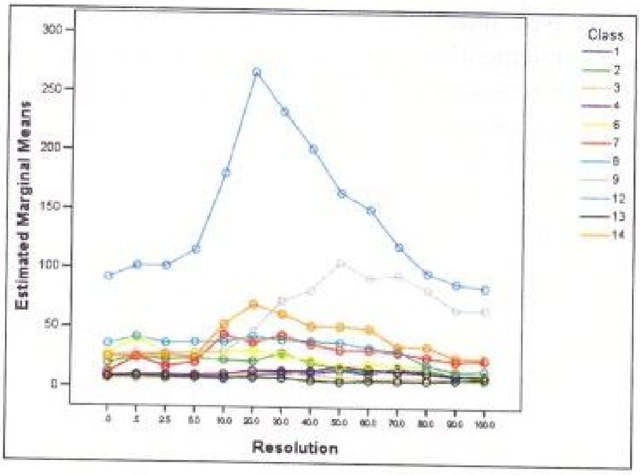

Fig. 6. Estimated marginal means of Number of Patches (NP, pieces) by resolution land-use types (legend is the same as for fig. 2)
Rys. 6. Szacunkowe średnie marginalne liczby płatów (NP, sztuki) przy różnych rozdzielczościach mapy (legenda – por. rys. 2)

Area type parameters showed similar result as Number of Patches in the case of MPS and PSSD, however, CA showed no sensitivity for resolution. Parameters relevant to perimeter behaved completely different from the earlier ones: increasing pixel character influences perimeter significantly. Resolution dependence is presented on the example of Total Edge (fig. 7).

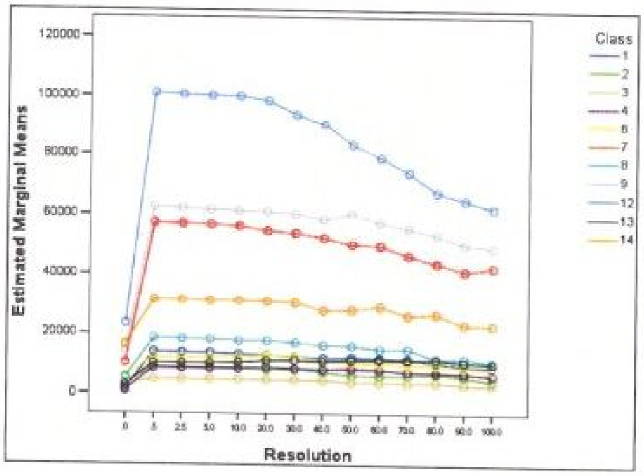

Fig. 7. Estimated marginal means of Total Edge (TE, meter) by resolution and land-use types (legend is the same as for fig. 2)
Rys. 7. Szacunkowe średnie całkowitej krawędzi (TE, metry) przy różnych rozdzielczościach mapy (legenda – por. rys. 2).

Figure 8 gives help to understand the result: shortest distance between two points is a straight (this is reality that is reflected best by vector systems), however, this is not possible in the present case due to the raster character as the distance – depending on resolution – can be covered only by two perpendicular sections of equalled length. Assuming a square with side length of 1 unit, shortest distance is √2 (1.414), this is 2 in a raster system. Similar results were obtained by Szabó (2006) as well.

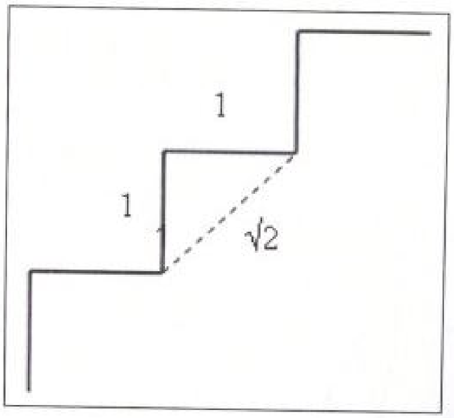

Fig. 8. Changing of distance between 2 points depending on vector or raster based approach
Rys. 8. Zmiana odległości pomiędzy 2 punktami zależna od podejścia wektorowego bądź rastrowego

This effect influences every parameter associated to the perimeter. Therefore applying it, two ways are possible: investigations associated to perimeters shall be analysed in a vector form or the above statement is accepted and results are treated accordingly. In the latter case it is worth noting that comparison between landscapes and to former analyses is only possible if every condition is the same (data recording, resolution), otherwise results may become misleading.

Effects of resolution and land use

Furthermore, the common effect of land-use and resolution is investigated in the multiple ANOVA model (naturally land-use can produce differences alone, thus its effect has not been investigated individually). In the analysis categories combined according to naturality were applied for better interpretation. Significant differences were not gained in the case of either studied parameter suggesting that land-use, land cover have no influence on the result. As it was expected significant ($p<0.05$) differences were found among the three categories but these are not discussed here as analysing landscape ecological specifics is not amongst the goals of this study.

Effects of resolution and patch shape

Analyses were performed according to the shape of the patches (with the help of multiple ANOVA), however, significant differences were not found regarding the joint effect of resolution and patch shape. An important result is that the isodiametric and elongated character of the patches influences NE and TE parameters significantly ($p<0.05$). There are no significant differences in the results in the rest of the cases. Figure 9 shows – on the example of MPS – that although there are smaller-or-greater changes in patch shape depending on resolution but the two types do not cross each other, i.e. there is no interaction thus the 2 dimensional space created by the 2 factors gives no addition for the explanation.

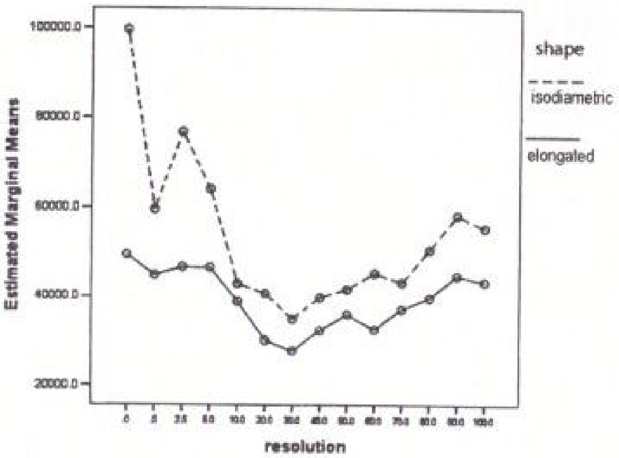

Fig. 9. Estimated marginal means of MPS (m^2) by resolution and land-use types

Rys. 9. Szacunkowe średnie marginalne MPS (m^2) przy różnej rozdzielczości i typach użytkowania ziemi

CONCLUSIONS

In conclusion it can be stated that the use of some kind of vector method is sensible when the basic landscape metric parameters are studied in the micro-scale as the pixel like character of the patches in the raster system modifies significantly parameters associated to the perimeter and the area/perimeter ratio. Increasing resolution the small sized pixels of the isodiametric patches become aggregated while elongated patches disintegrate into smaller, not continuous areas. In consequence, much more patches can be detected at resolutions 20–40 metres than the real number of patches. Further reduction of resolution results in the joining of the pixels, they become larger and their number is decreased providing a difference to the original map that is not significant. Thus in our opinion for the area-type landscape metric analysis of patches resolution below 10 metre is most suitable while in the case of perimeter-type indices the use of vector based solutions is recommended. It is clear that landscape metric based analysis can give us differing results than reality when not proper resolution is applied. This study dealt with only the area- and perimeter-type indexes, but there are several parameters implementing them. A simple example can be the perimeter-area ratio: see the sensitivity of edge to resolution (fig. 7) and the consequences on the calculations (patch shapes shows smaller compactness than they are – especially in the case of elongated ones).

As a summary it is advisable that recommendations for the landscape preservation practice based on the misleaded analysis should be handled carefully.

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