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2D and 3D landscape metrics in high mountains – a case study from the Polish Tatra Mountains

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Abstract: Traditionally, landscape metrics are computed in 2D – using projection of the spatial units on the reference plain. In recent years, the 3D approach, which uses true surface geometries, is developed. The aim of the paper is to compare values of 2D and 3D landscape metrics in high mountains, on the example of Morskie Oko catchment in the Polish Tatra Mountains. The calculations show that the metrics may differ significantly and that there is a strong correlation between size of the discrepancy and the surface slope.

Key words: landscape metrics, high mountain landscape, Tatra Mountains, 3D approach

Introduction

In recent years, the application of geographic information systems (GIS) has given the opportunity to improve methods of investigating landscape structure. The landscape is a part of a space (Zonne-veld 1989, Richling, Solon 2002) which is three dimensional – it has horizontal and vertical bound-aries (Armand 1980) and its shape depends, among others, on relief. However, the calculations of the composition and configuration of landscape units utilize plain geometries. Terrain shape can be taken into account in the 3D approach. Calculation of landscape metrics by means of the true sur-face geometries of patches, leads to more precise representation of landscape structure. The authors of the paper highlight the importance of using 3D landscape metrics in a high mountainous areas. The aim of this work is to compare 2D and 3D approaches. Study area was located in the Polish Tatra Mountains – Morskie Oko catchment. While the 3D landscape metrics are usually tested for neutral models (Hoechstetter et al. 2008), land-use units (Hoechstetter et al. 2006) or patch-corridor-matrix model (Hoechstetter 2009), the landscape consisted of geocomplexes is considered in the research.

Methods and the study area

The analysis base on TIN (Triangular Irregular Network) digital elevation model (DEM). Thanks to the irregular distribution of points and lines in the model, it allows better depiction of various terrain surface (Li et al. 2005). Grid DEM, utilized by the other authors (Jenness 2004, Hoehstetter et al. 2008), was found less accurate.
The primary parameters for landscape metrics computation are 2D and 3D perimeters and areas of particular geocomplexes. The boundary of each vector polygon is projected on the TIN. The inter-section of both datasets gives their common area. All the triangles and their parts are used to com-pute the so-called surface area.
Following landscape metrics were computed in the two-dimensional and three-dimensional versions: total area of the research polygon; area (AREA): avarage of stow (uroczysko), avarage of stow type, total of stow types;

perimeter (PERIM): avarage of stow and avarage of stow type; total edge (TE); edge density (ED); patch density (PD); largest patch index (LPI); shape index (SHAPE); fractal dimension (FRAC); perimeter-area-ratio (PARA).

$$ED = TE / AREA$$

$$PD = (number\_of\_geocomplexes) / AREA$$

$$SHAPE = 0.25 \cdot PERIM / \sqrt{AREA}$$

$$FRAC = 2\ln(0.25 \cdot PERIM) / \ln(AREA)$$

$$PARA = PERIM / AREA$$

$$LPI = (Max\_stow\_area) / (Total\_area)$$

Morskie Oko catchment is situated within the granitoid crystalline core of the High Tatra Moun-tains. The relief of this area is complicated. The surface of Morskie Oko lake is the lowest point of the study area (1393 m o.s.l.), and the highest is summit Rysy (2499 m o.s.l.). There are four land-scape altitudinal zones in this area – from upper montan zone to subnival zone.

The map of the geocomplexes (rank of stow) was prepared on the basis of the study of J. Balon (1992), which was changed as follows. The original map (constructed on the topographic map in scale 1:10 000) was verified during field works and afterwards digitized. The necessary cor-rections were done on the base of the orthophotomap, where the boundaries of all geocomplexes are clearly visible. Geocomplexes were grouped in 18 types (fig. 1).

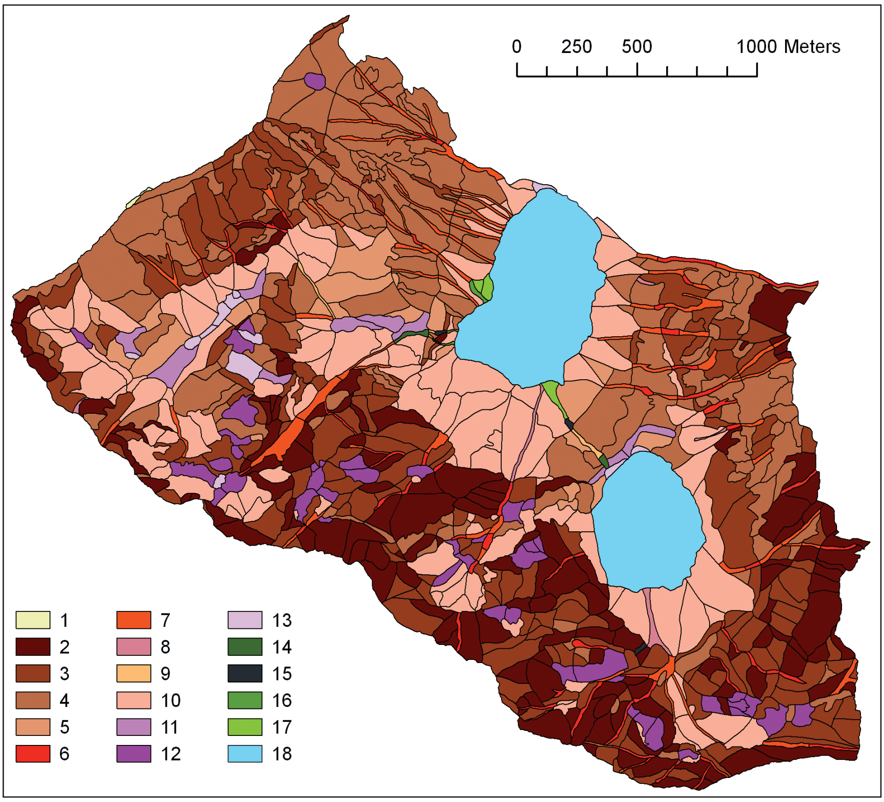

Fig. 1. Stow types in Morskie Oko catchment. Elaborated on the basis of the map of J. Balon (1992)
1 – surfaces of mountain culminations, 2 – rockwalls, 3 – rocky slopes, 4 – steep waste-covered slopes, 5 – gentle waste-covered slopes, 6 – rock-cut gullies, 7 – gullies with debris, 8 – fresh gravitational forms, 9 – V-shaped valleys, 10 – talus cones and heaps, 11 – valley floors filled with morainic mantle, morainic ridges, 12 – beds of glacial and nival cirques, 13 – morainic plains and depressions with lakes, 14 – rocky stream beds, 15 – waterfalls (rockwalls), 16 – alluvial stream beds, 17 – alluvial cones, 18 – lakes

Results

The calculations show a large diversity of the total area of the research polygon. In the two dimen-sional approach, the result is 6 156 617 m2, while the calculation of the true surface area gives the result – 9 278 248 m2 (151%). It has a significant impact on the other landscape metrics computed for the whole area. The patch density, edge density and the largest patch index calculated as the 3D metrics have lower values, while the total edge value is higher (table 1). The average stow area in the 3D approach is higher then in traditional analysis in the same proportion as the total area (151%). The average stow perimeter differs to a lesser degree (125%), which makes the average perimeter-area-ratio also changes – from 0.097 in 2D-version to 0.081 in its 3D-equivalent. The values of shape index are similar and the values of fractal dimension are identical (table 2).

Tab. 1. Landscape metrics for the entire study area (elaborated by authors)

Nazwa	2D	3D
Total area	6 156 617 m^2	9 278 248 m^2
Patch density (PD)	0.00015	0.0001
Total edge (TE)	183 074 m	228 625 m
Edge dencity (ED)	0.03	0.025
Largest patch index (LPI)	0.0531	0.0353

Tab. 2. Mean values calculated for the individual geocomplexes(elaborated by authors)

Nazwa	2D	3D
Patch area (AREA)	6743 m^2	10 162 m^2
Patch perimeter (PERIM)	384 m	479 m
Shape index (SHAPE)	1.368	1.393
Fractal dimension (FRAC)	1.071	1.071
Perimeter-area-ratio (PARA)	0.097	0.081

The landscape metrics computed using both methods lead to contradictory conclusions about fea-tures of the investigated landscape structure. On the reference plain, the largest area is covered by steep waste-covered slopes, then rocky slopes and talus cones and heaps. In contrast, as far as the 3D approach is concerned, the rock walls are dominant, before the rocky slopes and steep waste-covered slopes (fig. 2). It is worth mentioning that the area occupied by the rock walls calculated using true surface geometries is more than two times larger (230%). The situation is similar when it comes to the average area of the stow types (fig. 3).

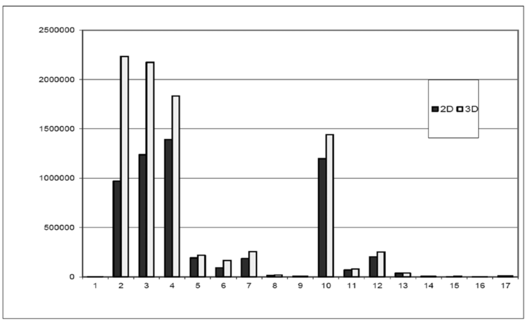

Fig. 2. Area of stow types in m^2 (elaborated by authors)

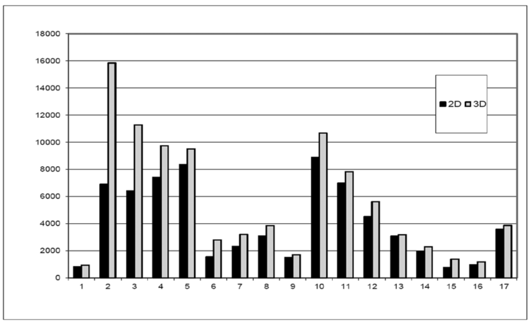

Fig. 3. Average stow area in m^2 (elaborated by authors)

On the map, the geocomplexes of talus cones and heaps and of gentle waste-covered slopes are the largest, while 3D computations show that geo-complexes of rock walls are significantly larger than others (apart from two lakes, which for clarity are not placed on the chart, as their areas are not differentiated).

Conclusions

1. Landscape is a part of three-dimensional space and it is important to develop methodology of investigating it in the way which would allow to take this feature fully into account.
2. Most of the analyzed landscape metrics vary significantly depending on the method – 2D or 3D.
3. The values of patch density, edge density and the largest patch index are lower when calculated as the 3D

metrics, while the total area and total edge are larger.
4. The landscape metrics calculated using 2D and 3D approsches leads to contradictory conclusions about features of the landscape structure.
5. The steep waste-covered slopes prevail in the structure of the landscape of Morskie Oko catch-ment in 2D approach, while the computations made using true surface geometries indicate that the largest areas are occupied by rock walls. Similarly, the largest 2D patches are talus cones and heaps, whereas the largest 3D geocomplexes are rock walls.
6. The shape index and fractal dimension have similar values in 2D and 3D approaches.
7. There is a strong correlation between the size of the discrepancy between values of 2D and 3D metrics and the surface slope.
8. It is very important to distinguish between 2D and 3D metrics and to use them consciously, ac-cording to the particular problem.

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