Relevance of moving window size in landform classification by TPI

Zbigniew Zwoliński
Institute Geoecology and Geoinformation
Adam Mickiewicz University in Poznań
Dzięgielowa 27, 61-680 Poznań, Poland
zbzw@amu.edu.pl

Estera Stefańska
Turek, Poland

Abstract—**The article presents the problem of the calculation window size relevance in the classification of landforms using the TPI for two diversified areas: lowland and alpine. It was found that the best results are obtained by magnifying the bigger window five times in relation to the smaller window.**

I. INTRODUCTION

Relief analysis is used in many studies of nature, as it is assumed that landform plays a leading role in the hierarchy of environmental components in any complex studies of landscape within the scope of physical geography or even human or economic geography. Relief classes can be distinguished on the basis of geomorphometric characteristics obtained from the digital elevation model. Most frequently, such maps are prepared for the purpose of geomorphological [1], [2], geological [3], or pedological studies [4], [5], [6]. It is appropriate to emphasise that the geomorphometric classification of relief constitutes the basis for typological classification. This study endeavoured to distinguish discrete relief classes of similar geomorphometric characteristics.

II. STUDY AREA

Relief classification was conducted for two areas: the lowland area of the Parsęta River drainage basin and the alpine area of the Polish Tatra Mountains. The Parsęta River drainage basin — belonging to the Baltic Sea Basin — includes the 131.57 km long Parsęta River valley and tributaries, and its surface area is 3145 km^2 [7]. The relief of the Parsęta River drainage basin is of postglacial nature. The Tatra Mountains are the highest massif in the Carpathian Mountains with distinct high-mountain relief [8]. The 53 km-long and 18.5 km-wide Tatra Massif takes up the surface area of 750 km^2, of which the Polish Tatra Mountains take up about 174 km^2. Despite their orographic tightness, The Polish Tatra Mountains divide into two mesoregions: the West Tatra Mountains and the High Tatra Mountains.

III. METHODS

Relief classification based on the topographic position index (TPI) proposed by Weiss [9] is quite commonly used. The author presents two methods allowing to distinguish a different number of classes. The first method results in the division into 6 relief classes: 1) valley bottom, 2) lower part of slope, 3) flat area, 4) middle part of slope, 5) upper part of slope, and 6) peak/culmination), whereas the second method allows to distinguish 10 classes: 1) deeply-incised valleys 2) shallow valleys/outflow network on slope 3) source areas/little valleys on hills 4) U-shape valleys 5) flat areas 6) long slopes 7) upper parts of slopes/mesas 8) little hummocks in valleys 9) hummocks on slopes/little hummocks on flatlands 10) mountain peaks/ridges.

Two DEMs were used. The first, which included the Parsęta River drainage area, is characterised with grid cells of 31×31 metres (DTED Level 2). The second model, which includes the Tatra Mountains area, is characterised with grid cells of 10×10 m. The topographic position index *(TPI)* is a quantitative relief index calculated from T. Dilts's scripts[1]. The selection of an appropriate calculation scale for the assumed goal is crucial in the calculation of the topographic position index. The scale means the size of the moving window used to calculate the index. The moving window defines the vicinity used to calculate the mean value to which values from individual cells are compared. The establishing of the calculation scale has

[1] www.arcscripts.esri.com

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fundamental influence on the TPI value for a given cell. Depending on the size of the vicinity, the topographic position index calculated for the same cell may be positive, close to zero, or negative. Generating the TPI from DEM in different scales allows to determine and analyse relief forms of various sizes. In relation to terrain morphology, TPI calculations in a small scale allow to determine local hummocks and depressions. Whereas calculation in a larger scale indicates main, large landforms. Appropriate combinations of TPI values calculated in a smaller and in a suitably larger scale allow to distinguish 10 relief classes.

IV. RESULTS

The relief classification in the Parsęta River drainage area was based on the TPI determined in a moving calculation window of 3 × 3 cells. The TPI value in this scale was compared successively with the TPI calculated in the windows of 7 × 7, 15 × 15, 31 × 31 and 63 × 63 cells. The calculations resulted in maps shown in Fig. 1 a-d. The TPI calculation window size was selected with the aim to have the first window as small as possible. For the TPI calculated in a larger scale, windows were selected in such a way that their size increased more or less in a geometric progression, while the odd-number length of window side was kept.

In the landform classification made for the Parsęta River drainage area on the basis of the TPI calculated in the windows of 3 × 3 and 7 × 7 cells, over 76% of the surface area belongs to class 5 (Fig. 1a) corresponding to flat areas (with average local height of 1.83 m, average slope of 1.3°, and mean values for planar and vertical curvature equal to zero). Almost 10% of the surface area belongs to class 4 — river valleys (with average local height of 4 m, average slope of 2.8°, planar curvature mean value of -0.05, and vertical curvature mean value of 0.09; thus the curvatures indicate a valley area with a profile characteristic for a concave slope) and almost 10% of surface area belong to class 7 – upper convex parts of slopes (with average local height of 4.3 m, average slope of 2.98°, planar curvature mean value of 0.07, and vertical curvature mean value of -0.08). The remaining 7 classes take up less than 4% of the surface area, of which class 6 takes up about 2%, and classes 1 and 10 — less than 1% each. With this calculation scale, class 8 was not distinguished, whereas classes: 2, 3, 9 take up trace surface area.

In the classification based on TPI calculated in the windows of: 3 × 3 and 15 × 15 cells, three classes: 5 (50%), 4 (24%) and 7 (24%), prevail in terms of the surface area taken (Fig. 1b). On the other hand, in the classification based on TPI calculated in the windows of 3 × 3 and 31 × 31 cells (Fig. 1c) class 4 (34.81%) takes up the biggest surface area, followed successively by class 7 (32.67%) and class 5 (30.24%). Classification results based on TPI calculated in the window of 3 × 3 and 63 × 63 cells show further increase in the surface area of classes 4 and 7 (Fig. 1d). In this classification, the percentages of these classes are 41% and 38%, and the percentage of class 5 is only 19%. Such a proportion of classes for the Parsęta River drainage area has to be considered incorrect.

Classifications were also made for the Parsęta River area with the initial window increased approximately two times. The initial small scale TPI was determined in a moving calculation window of 7 × 7 cells. In this classification, the TPI values in a larger scale were determined in the windows of 15 × 15, 35 × 35, 71 × 71 and 141 × 141 cells. Analogically, the larger scale TPI calculation windows were intended to increase, approximately, in a geometric progression in relation to the initial window. Results of this classification are presented in maps (Fig. 2).

For the TPI in the windows of 7 × 7 and 15 × 15 cells (Fig. 2a), the biggest surface area in this classification is taken up by: class 5 (with average local height of 1.62 m, average slope of 1.16°, and mean values of curvatures equal to zero) – 49%, 4 (with average local height of 2.43 m and average slope of 1.73°) – 15%, 7 (with average local height of 2.62 m and average slope of 1.86°) – 14%, and classes 1 and 10 (10% each). An increase in the percentage of class 1 (deeply-incised valleys) and class 10 (ridges) can be observed in comparison with the previous classifications (Fig. 1); previously, the classes took up less than 1% of the surface area. In the window pair of 7 × 7 and 35 × 35 cells (Fig. 2b), there are the following classes: 5 (26%), 4 (27%) and 7 (25%). In the next window pair of 7 × 7 and 71 × 71 cells (Fig. 2c), the biggest surface area is taken up by classes: 4 (33%), 7 (30%), 5 (15%) and classes 1 and 10 (almost 8% each). In the last window pair of 7 × 7 and 141 × 141 cells (Fig. 2d), the biggest surface area is taken by classes: 4 – 36%, 7 – 33%, 5 – 10%, and classes 1 and 10 – 7% each.

In the analysis of the topographic position index for the area of the Polish Tatra Mountains, efforts were made to select the size of the initial TPI calculation window in such a way, as to make possible the comparison of results obtained with the analysis for the Parsęta River drainage area. The comparability of results was achieved by calculating the TPI in windows covering similar surface area of terrain. Because the DEM for the Parsęta River drainage area is characterised by a grid cell of 31 × 31 m, and the DEM cell size for the Polish Tatra Mountains is 10 × 10 m, the decision was made to calculate the topographic

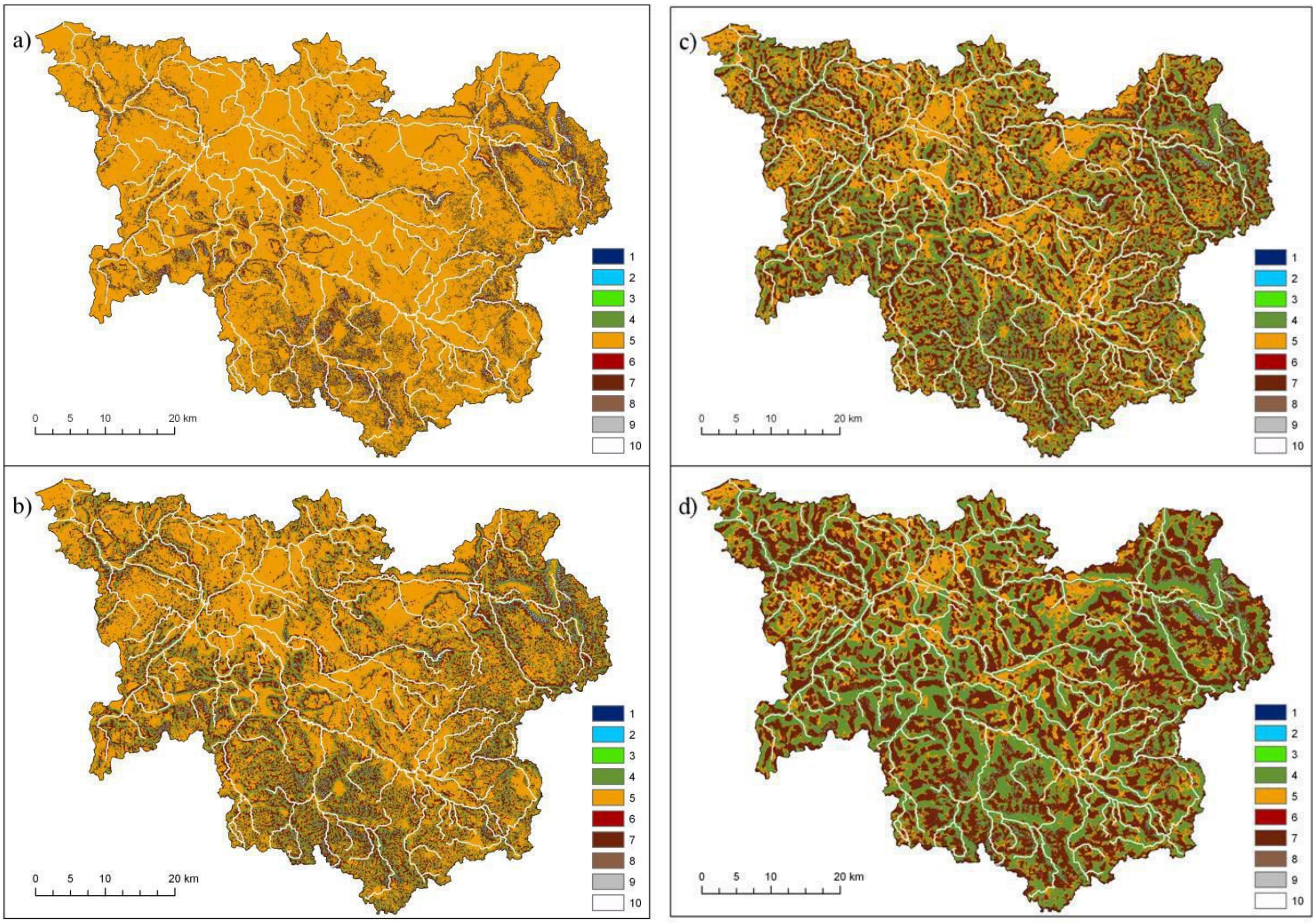

Figure 1. Landform classification for the Parsęta River drainage basin on the basis of TPI in different moving windows
a) 3 × 3 and 7 × 7 cells, b) 3 × 3 and 15 × 15 cells, c) 3 × 3 and 31 × 31 cells, d) 3 × 3 and 63 × 63 cells; 1-10 – explanation in section Methods

position indexes for this area in windows three times bigger than for the Parsęta River drainage area. Thus, the TPI analysis was made for the Tatra Mountains area in the windows of: 9 × 9, 21 × 21, 45 × 45, 93 × 93, and 189 × 189 cells. The second series of classifications was made based on the initial TPI calculated in windows which were three times bigger: 21 × 21, 45 × 45, 105 × 105, 213 × 213, and 423 × 423 cells. Results obtained according to this classification proved to be too general, therefore, their presentation was abandoned.

Landform classification made on the basis of the TPI calculated in the windows of: 9 × 9 and 21 × 21 cells (Fig. 3a) includes classes: 1 – deeply-incised valleys (19%: average local height of 12.5 m and slope of 24°, mean planar curvature of (-1.01) and mean vertical curvature of (1.07)), 4 – U-shaped valleys (17%: average local height of 7 m, average slope of 14°, mean values of planar and vertical curvature of: 0.11 and -0.06), 6 – long slopes (15%: average local height of 5.5 m, average slope of 12°, mean values of planar and vertical curvature: 0.01 and 0), 7 – upper parts of slopes (18%: average local height of 6 m, average slope of 13°), and 10 – mountain peaks/ridges (18%). As can be observed in Figure 3a, classes 1 and 10 prevail in the Tatra Mountains area with a contribution of classes 4 and 7. Class 5 – flat area – takes up the biggest surface area within the Podtatrzański Trench. In the area of Gubałowskie Foothills,

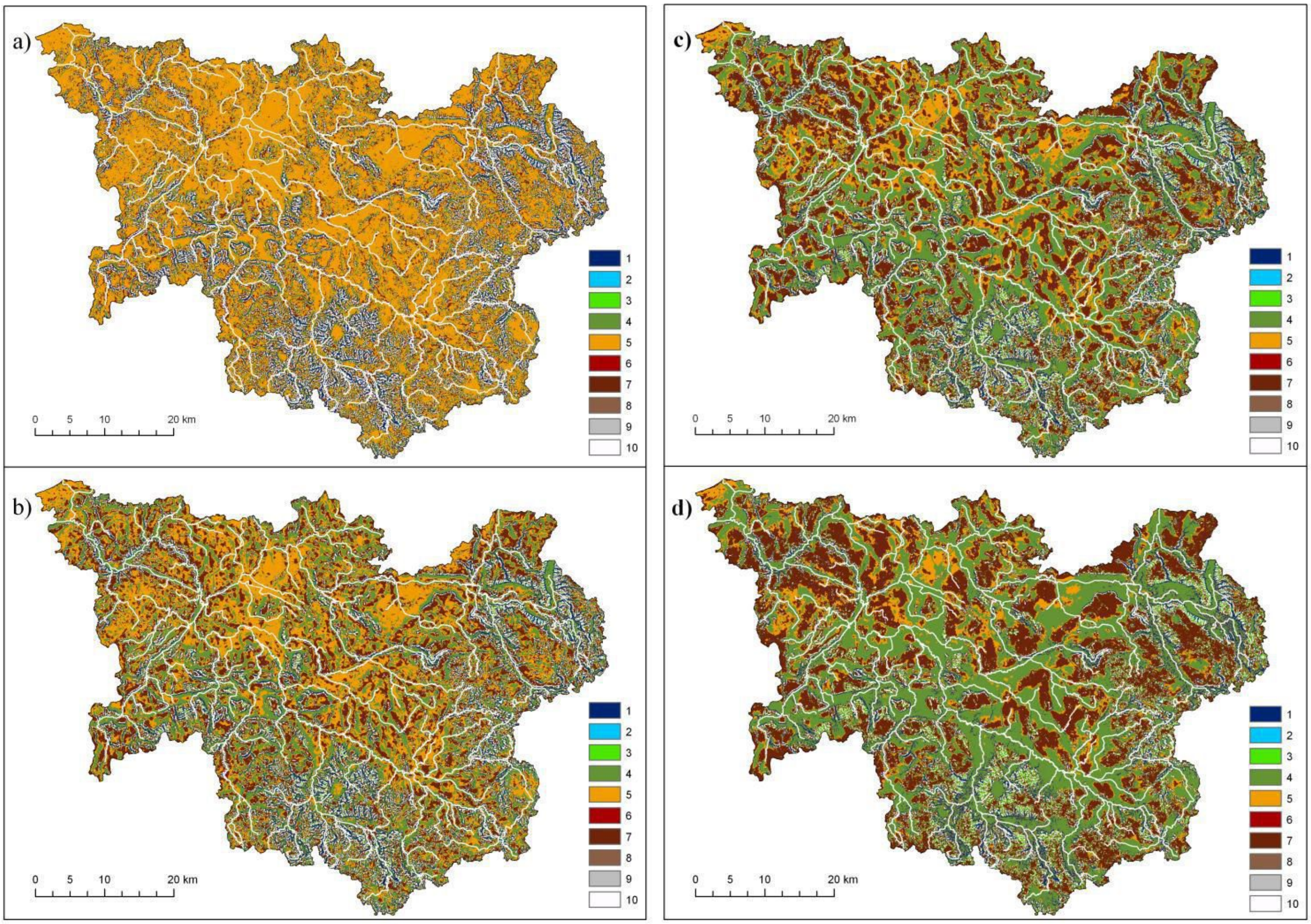

Figure 2. Landform classification for the Parsęta River drainage basin on the basis of TPI in different moving windows
a) 7 × 7 and 15 × 15 cells, b) 7 × 7 and 35 × 35 cells, c) 7 × 7 and 71 × 71 cells, d) 7 × 7 and 141 × 141 cells; 1-10 – explanation in section Methods

the dominant percentage of classes 6 – long slopes and 7 – upper parts of slopes with a contribution of class 4 – U-shaped valleys can be observed. In the Bukowińskie Foothills, when compared with the Gubałowskie Highland, an increase in the percentage of classes 1 and 10 can be noticed.

In the window pair of 9 × 9 and 45 × 45 cells (Fig. 3b), the percentage of classes 4 (25%) and 7 (25%) increased, and the percentage of class 6 (5%) decreased. In turn, change in the window pair to the size of 9 × 9 and 93 × 93 cells (Fig. 3c) caused a change in the surface area taken up by individual classes. In the last classification of landform for the windows of 9 × 9 and 189 × 189 cells (Fig. 3d), the biggest surface area is taken up by classes: 4 (31%), 7 (25%), 1 (15%), 10 (13%), 8 (8%), and 3 (7%).

V. CONCLUSIONS

The best results in the TPI calculations were obtained when a relatively small calculation window was determined. For the Parsęta River drainage basin, a window of 7 × 7 cells (217 × 217 m) proved the most suitable. Whereas for the Tatra Mountains area, a window of 9 × 9 cells (90 × 90 m) was the best. It can be judged that the more diverse the relief of the area under study, the smaller calculation window should be used. Unfortunately, the window size must be determined using the trial-and-error method, but focus must be maintained on testing small windows.

The analysis of a classification of up to 10 relief forms allows to judge that for the Parsęta River drainage area the best results were obtained by calculating the topographic position indexes (used in the analysis) in the windows of 7 × 7 and 35 × 35 cells (Fig. 2b). In the case of the Tatra Mountains the best results were obtained for the windows of 9 × 9 and 45 × 45 cells (Fig. 3b). Thus, it can be judged that this method gives the best results with the second calculation window being approximately five times bigger than the first one. At the same time, the size of the first window should be adjusted to relief changeability in a given area and correspond approximately to the smallest landform to be distinguished.

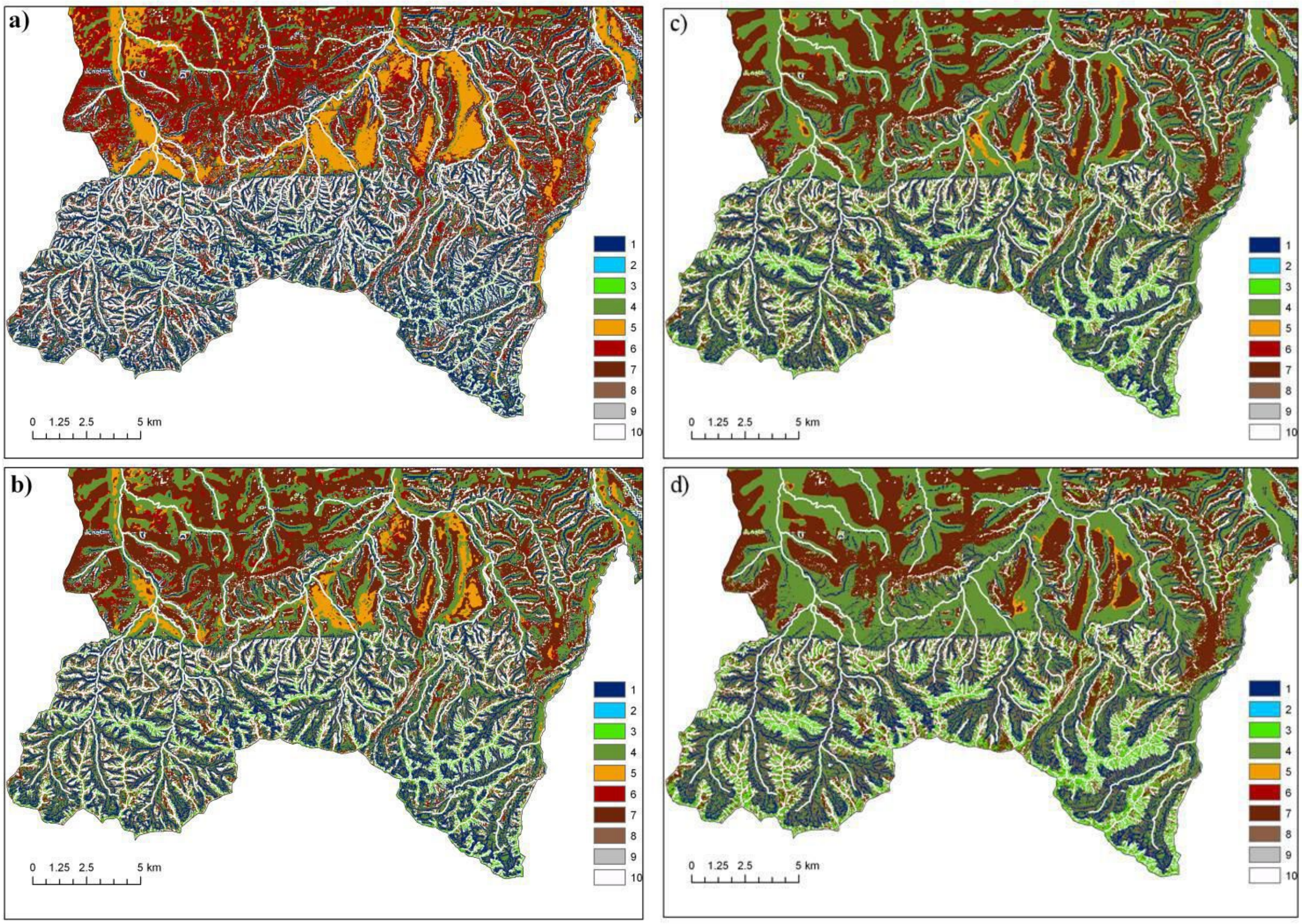

Figure 3. Landform classification for the Tatra Mountains on the basis of TPI in different moving windows
a) 9 × 9 and 21 × 21 cells, b) 9 × 9 and 45 × 45 cells, c) 9 × 9 and 93 × 93 cells, d) 9 × 9 and 189 × 189 cells; 1-10 – explanation in section Methods