Automatic extraction of landslide flow direction using geometric processing and DEMs

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Abstract—**Landslides are mass wasting landforms which occur due to various triggering factors, and generate a specific morphology. This morphology is governed by the flow of the material downslope. While the majority of the landslide have the length bigger than the width (flows, slides, deep-seated landslides), in certain topographic conditions, landslides with width larger than length can exist (slides and deep-seated landslides). We target such a case, by creating a methodology to automatically determine the direction of the flow, in such a way that the oriented bounding box polygon to be aligned downslope, and the length of the landslide polygon to be determined. After the application of the first step of the algorithm, in which the direction of landslide flow is assessed using the altitude range of the midpoints of the long (length candidates) and short (width candidates) sides of the landslide oriented bounding box (for a landslide to be long the altitude range between the opposite long sides need to be greater than the range for the opposite short sides), manual check was used to assess the results. This check showed that the majority of the landslides were correctly classified, either as long or wide, but in the long landslide class there are in fact wide class landslides which are situated on valley sides with steep channels. These landslides have the altitude range between the short sides smaller than the altitude range between the long sides, although the direction of the flow is along the short side. To correctly classify the flow direction for these landslides, we have used the slope length computed on the DEM patches of the landslide polygons. Where the slope length is greater than the landslide width determined in the first phase and the landslide is classified as long, the landslide class is changed to wide, and vice versa. By this approach we manage to correctly classify the landslides as long or wide in the landslide inventory of the Moldavian Plateau, Romania (24 263 landslides).**

I. INTRODUCTION

Landslides are natural phenomena which appear when a terrain mass is moving down a slope. A typical morphology appear as an effect of this process [1], [2]. Landslide geomorphometry is very important because can be used to assess the typology of the landslides and perform various geomorphologic analyses [3], [4], [5]. While the majority of the landslides are more long than wide, there are landform situations when the landslides are wider than longer [6], [7], [8] (for example on monoclinic structure, where cuesta hills develop, or on the banks of steep channels of gullies incised in hillslopes – Fig. 1). The present study show a methodology for geometric and geomorphometric processing of landslide polygons and DEMs, for obtaining the direction of the material flow and to get the downslope oriented length and the associated width.

Figure 1. Cases of wider versus longer landslides in an area with monoclinic cuesta hillslopes and gully incision of cuesta scarp slope (Miletin village, Moldavian Plateau, Romania)

II. MATERIALS AND METHODS

A. Materials

The landslide inventory described by [9] was used to develop and test the method. The landslide inventory contains 24 263

In: Geomorphometry for Geosciences, Jasiewicz J., Zwoliński Zb., Mitasova H., Hengl T. (eds), 2015. Adam Mickiewicz University in Poznań - Institute of Geoecology and Geoinformation, International Society for Geomorphometry, Poznań

landslide polygons, extracted from high resolution aerial imagery and high resolution DEMs.

The altitude data used to determine the flow geometry was SRTM 1 DEM [10], because it covers all the inventory extent, but in the same time is easy to be manipulated using personal computers.

B. Methods

The landslide polygons were used to generate the oriented bounding box, with the ArcGIS function Minimum Bounding Geometry (RECTANGLE_BY_WIDTH geometry type). This method compute a bounding box which is oriented to the width and length of the polygon, and touch the polygon on all the four sides.

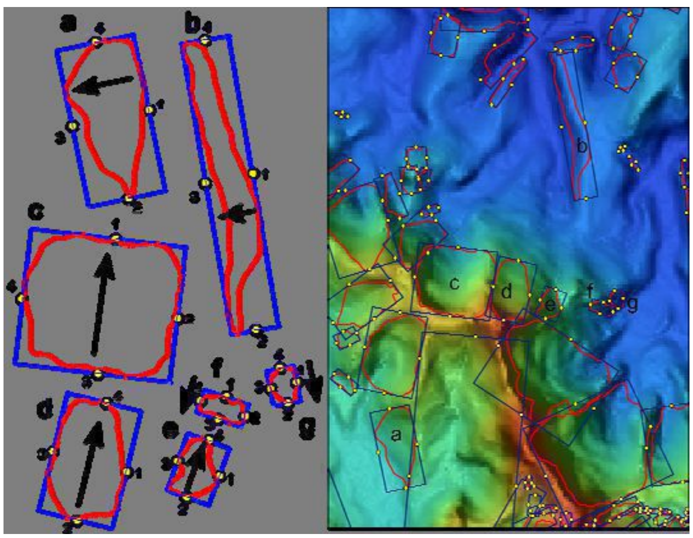

Figure 2. Geomorphometric context (shading from SRTM data - right) and geometry processing (left) of a snapshot of the landslide inventory; the position toward north is kept, but the landslide on the left were scaled, and a-g indicate the correspondence between the right and the left side; the arrows indicate the direction of landslide flow

The bounding box rectangle was then split in 4 lines, for every side in SAGA GIS, and a unique id of the polygon was given to the side lines. The construction of the bounding box polygons allowed also the numbering of the sides from 1 to 4, starting from the northernmost in a clockwise direction in such a way that the length sides of the rectangle are coded as 1 and 3, while the widths as 2 and 4 (Fig.). For every landslide bounding box rectangle, the midpoint of the bounding box rectangle side line was generated using ST_Line_Interpolate_Point(b.geom, 0.5) PostGIS function. The bounding box side lines midpoints were numbered also according to the line numbering, 1 and 3 being coded for the midpoints of the rectangle length sides, and 2 and 4 for the midpoints of the rectangle width sides.

For every landslide bounding box rectangle side midpoints the SRTM3 altitude was assigned. Then for every 1-3 (dzL) and 2-4 (dzW) pairs the difference in altitude (dz) was computed in R [11]. Root mean squared (RMS) values of the above differences were used to obtain the difference in altitude between the length and width side.

Using the altitude difference between the length and width sides, the landslides can be assessed as more wide (MW) or more long (ML) this way:

- If for a certain landslide the length side difference of altitude is smaller than the width side, then the landslide is considered to be more wide than long;
- If for a certain landslide the length side difference of altitude is greater than the width side, then the landslide is considered to be more long than wide.

This pass of the classification classify well only 2/3 of the more wide than long landslides, because some of these landslides are situated on hillslopes of steep first order valleys (Fig. 2). For correctly classifying these cases, the slope length (SL), computed in SAGA GIS using a D8 flow algorithm is used. The maximum slope length (maxSL) for the more long than wide landslides is compared with the length (L) of these landslides, and the wrong classified landslides are reclassified this way:

- If for a certain more long than wide classified landslide the maximum slope length is bigger than the landslide length, than the landslide is considered to be more long than wide;
- If for a certain more long than wide classified landslide the maximum slope length is smaller than the landslide length, than the landslide is considered to be more wide than long.

III. CONCLUSION

Using the specified data and methodology, the flow direction of landslides, along the width or the length of the geometric bounding box, and from here the “real” width and length were successfully determined. This approach can be useful when dealing with inventories where the morphometric variables of the landslide polygons are not computed (like in a semi-automatic derived landslide inventory [7]), if the wider landslides are a reality. The “correct” length and width of a landslides can be used for the separation of flows, slides and deep seated landslides and in susceptibility modelling.

A further step in this work would be to increase the validation dataset, and to validate the method on other datasets, from other areas, where the wider than longer landslides appear. Also, the general aspect (as north azimuth) of the landslide can be estimated after the direction of flow was determined.

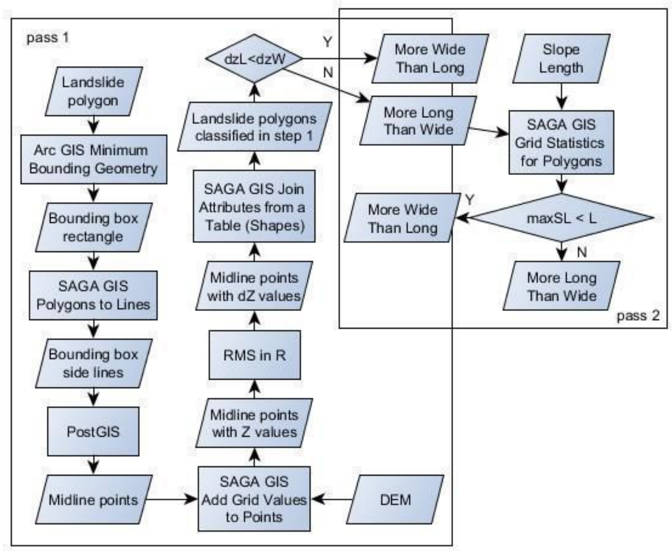

Figure 3. The workflow for landslide geometry classification

Acknowledgment

The authors gratefully acknowledge partial support by the European Social Fund in Romania, under the responsibility of the Managing Authority for the Sectoral Operational Program for Human Resources Development 2007-2013 [grant POSDRU/159/1.5/S/133391].

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