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To cite this article: Nurul Muddarisna *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **412** 012027

IOP Conf. Series: Earth and Environmental Science **412** (2020) 012027 doi:10.1088/1755-1315/412/1/012027

An Automated Approach Using Topographic Position Index (TPI) for Landform Mapping (Case Study: Gede Watershed, Malang Regency, East Java, Indonesia)

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Abstract. Mostly, the researchers have been carried out landform using survey method and manual delineation. Integrating remote sensing data and GIS technique can automate identifying of landform using Topographic Position Index data as one of remote sensing data. The aim of paper is to identify and categorize landform element using Topographic Position Index in the Gede Watershed derived by DEMNAS with 30 m resolution and output scale of map is 1:25.000. The method was carried by algorithm of slope and TPI automation with Geographic Information System technique. To obtain the appropriate TPI with the real condition of landform, we used radius circle 5m, 10m, 25m, 50m and 100m neighborhood size cell for TPI. The combination of slope and TPI shows the best result which are appropriate with the real condition of landform is radius circles 5m neighborhood size cells. Based on the result shows five heterogeneous of landscape i.e peak (0,6%), upper slope (10%), middle slope (9,49%), lower slope (39,36%) and channel bad (40,49%). To achieve the better result, it needs intensive field survey and using high resolution imagery as accuracy test.

1. Introduction

Landform is the important factor that affects the physical condition. Landforms have highly correlated with the topography, process, and material. The topography is an important control for landform [2],[5],[9]. Topography in landform analysis will show related elevation and slope. Whereas for the process will explain the kind of process such as landslide, erosion, and drought which happened in each landform category. The material in each landform could be identified by field survey for detail mapping and geology maps for a small scale.

To identify a landform using delineation and classification based on the stereoscopic technique of aerial photo and field investigation. This method is very common in Indonesia. It has been applied for soil mapping, land evaluation analysis, land suitability analysis, spatial planning, etc. In Indonesia's, National Standard document of Geomorphological mapping mentioned that the technical requirement for landform mapping is an interpretation of remote sensing data combined with the field survey. The standard of mapping in Indonesia is using an ITC system. Besides, the manual method for landform classification need requires simultaneous consideration and using multiple different criteria. It also depends on the interpreter's skills. The mapping product of manual delineation sometimes will differ between each interpreter.

Over the last decade, spatial data is the basic data for several analyses related to mapping analysis such as Digital Elevation Model (DEM), aerial photograph and satellite imagery. Geographic Information System (GIS) is the tool that can be used to analysis of spatial data for production several mapping such landform mapping. GIS is a strong tool that can be used to analysis data [1],[4]. Thorough input of several variable landforms mapping in the GIS will have output landform classes. This technique also can be applied for other earth surface analysis. Using DEM and GIS for landform mapping can be used geomorphometric classification of terrains approach or particularly features such as interfluves, upper slope, middle slope, lower slope and channel bad, thereby making the heterogeneous landscapes less studied.

GIS is the tool that can be semi-automated landform classification [3],[6],[10],[12]. Topographic Position Index (TPI) can be produced by integration GIS and remote sensing data [7],[11]. Many physical such landform processes acting on the landscape are highly correlated with topographic position index. The landform process cannot be separated from the elevation aspect and general rule elevation tends to be spatially autocorrelated. Landform using TPI is based on the central point as the difference between the elevation at this point and the mean elevation within a predetermined neighborhood. Thus, we try to automated landform using Topographic Position Index (TPI) in the Gede Catchment Malang Regency East Java.

Gede catchment is the part of Bromo Volcano System. It is located in the Malang Regency, East Java Province. The wide of Gede Catchment is around 17 Km2 (Fig.1). It's located on the middle slope of Bromo Volcano Mountain. The subsurface material is dominated by the deposition of Bromo Volcano material.

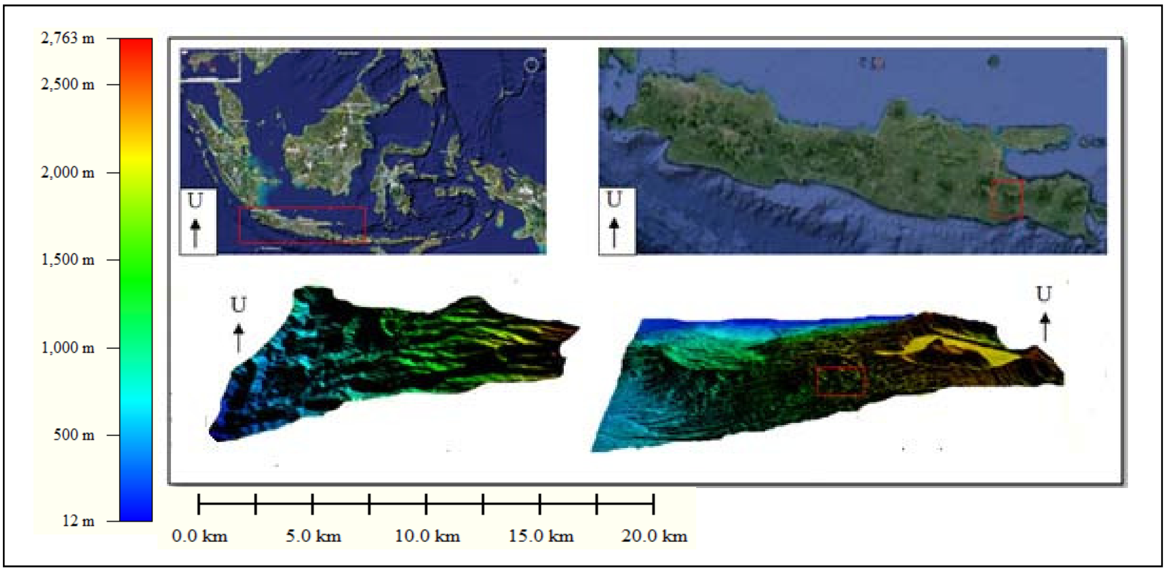

Figure 1. The Study Area

2. Methods

This research using the DEMNAS data as base data. Step to analysis the data are preprocessing data involves several steps i.e. 1) DEM download processing; 2) DEM processing; 3) Using algorithm approach to make TPI map; 4) identification of landform from TPI; 5) Field check and 5) layout landform map (Fig.2). DEM processing and algorithm analysis using Geographic Information System (GIS). To obtain the appropriate TPI with the real condition of landform, we used radius circle 5 m, 10 m, 25 m, 50 m and 100 m neighborhood size cell for TPI. All of the radius circle has been chosen by the researcher because in the research area is heterogeneous. With these radius circle, we try to find the radius which is most appropriate with the research area.

The field survey was done for accuracy of landform map and observation of each category of landform. In this research, we try to determine six classifications of landform such peak interfluves, upper slope, middle slope, lower slope, foot slope and channel bad. The result of this research is the landform map with radius circle 5 m, 10 m, 25 m, 50 m and 100 m neighborhood size cell for TPI. We found that the best radius circle of TPI which appropriate with the field condition is radius circle 5 m.

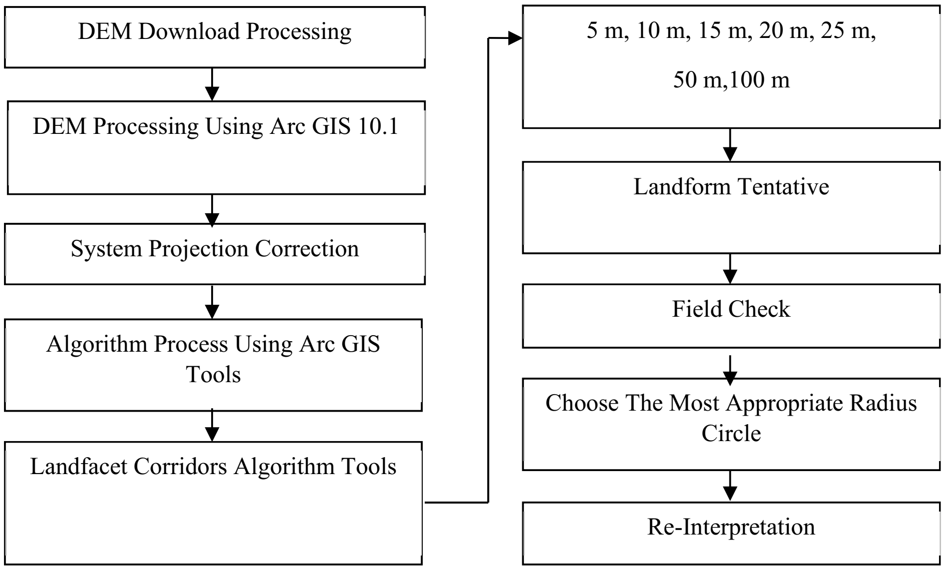

Figure 2. Research Process Flowchart

3. Results and Discussion

3.1 Basic Algorithm of Topographic Position Index and Analysis

TPI is produced by algorithm analysis using Geographic Information System (GIS). The formula of algorithm compares the elevation of each cell of DEM with continuous circle [13]. The algorithm of TPI is consist local neighborhood (C) and it is as defined by window size. TPI algorithm also consist central point (Z_0) which express the vertical position in length above or below some comparative elevation such mean elevation of the neighborhood. The elevations distribution variability increases with the spatial scale such relief generally increase from smaller to larger neighborhood size and algorithm of TPI also consist radius (R) [10],[11].

$$TPI = Z_0 - Z \quad (1)$$

Topographic Position Index (TPI) has to support with the DEV algorithm to landform identification. DEV measures the topographic position of the central point (Z_0)

$$DEV = \frac{Z0 - Z}{SD} \quad (2)$$

$$SD = \sqrt{\frac{1}{n_R - 1} \sum_{i=1} (z_i - \bar{z})^2} \quad (3)$$

DEV measures the topographic position of local relief normalized to local surface roughness. TPI and DEV were automated calculated using Arc GIS 10.2 tools and using Arc GIS script (Reuter and Nelson, 2009). TPI and DEV is the most data algorithm for created landform identification.

TPI has positive (+) and negative (-) values. A positive value is representing the higher area than the average of their surroundings. It can be identified by radius circles of neighborhood cells (ridges). The negative value is representing the area that has lower than their surroundings area (valleys). TPI also has the flat area that represented by zero value. This area is constant slope the position of TPI will have affect to soil movement, site water balance and other physical condition of environment. TPI algorithm is also considering slope position and it also has affected to determine the TPI. Slope position in this research show many individual ridge line and valleys are delineated at fine scale including lateral drainages in the major valleys, and the bottom of the major canyons are classified as flat areas. Slope of this research also define the major of classification landform such mountains, valleys and canyons. The detail of classification landform is depending of scale of mapping. TPI and slope position has related each other because each TPI position has characteristic of slope value (Fig. 3)

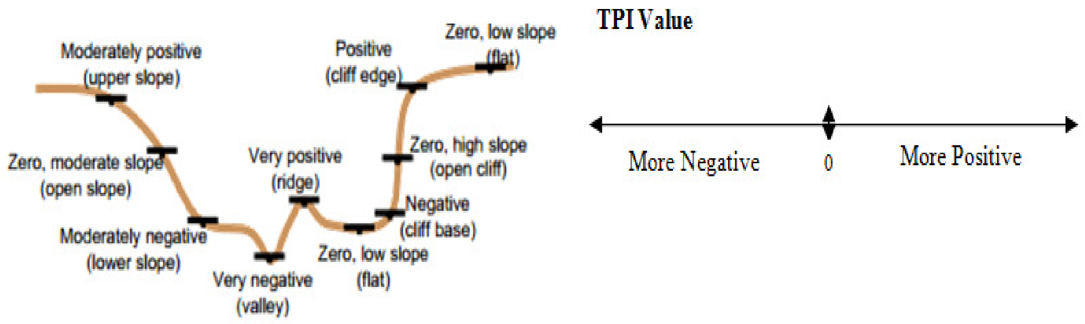

Figure 3. Illustration TPI, Slope and Value of TPI [10]

This research is using modeling of several circle radius of TPI map such 5 m, 10 m, 20 m, 25 m, 50 m and 100 m. The TPI circle radius that had been chosen because in the study area is really heterogeneous landform (Fig. 4). The smaller circle radius of Topographic Position Index (TPI) shows the topographic which produced is more detail (Fig. 4). The topographic map shows different map based on the circle radius. For the 5 m x 5 m circle radius, the landform shows more heterogeneous and it is closely with the real condition. For the circle radius 5 m, 10 m, 20 m, 25 m, 50 m and 100 m is rather not appropriate because mostly the categories of automated landform are different with the real condition such the peak interfluves are too narrow or too wide, nor each landform such as the upper slope, middle slope, foot slope.

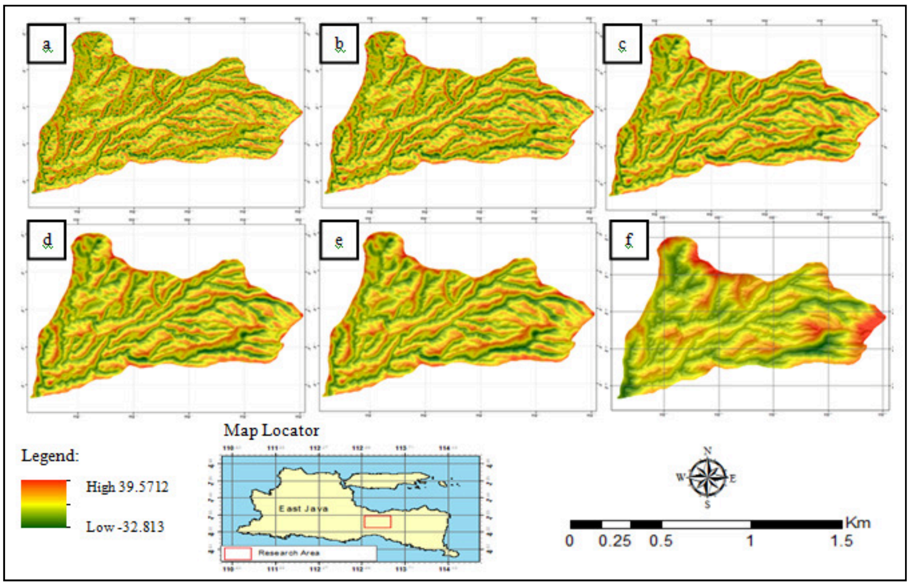

Figure 4. The circle radius of TPI a) 5m; b)10m; c)20m; d)25m; e)50m; f)100m

3.2 Landform Classification

As general, TPI maps show that the circle radius of TPI influences heterogeneous of landform. The TPI circle radius is as small as the landform display (Fig.4). Each landform in the TPI map has each percentage. The widest of landform is foot slope (40.49%), peak (0.6%), upper slope (10%), middle slope (9.49%), and lower slope (39.36%) (Fig.5). Each landform has each characteristic including characteristics for potential soil movement. Peak interfluves are the landform that has flat morphology, so in this landform, there is no potential for soil movement. Mostly, the land management of peak interfluves landform in the Gede Catchment is used to road and settlement. Between peak interfluves and upper slope mostly there is crack. Sometimes, it is the start of soil movement. The upper slope landform is the most potential of soil movement because in this landform has the highest of force than the middle, lower and foot slope. In this landform, we could find erosion and landslide processes. The land management in the upper slope is used to woody plants with the plantation such as Sengon, Mahoni, and Pine trees. Middle slope until the lower slope is the landform that has potential soil movement. A middle slope in the research area mostly uses to the mixed garden plantation with the plant such as carrot, apple, and cabbage. This area also has a landslide process is intensive. It is caused by the terrace soil technique. Terrace technique is appropriate to use for landslide and erosion management, but it is not appropriate for an area that has thick soil conditions. Lower and foot slope is the landform that lower landslide potential than upper and middle slope.

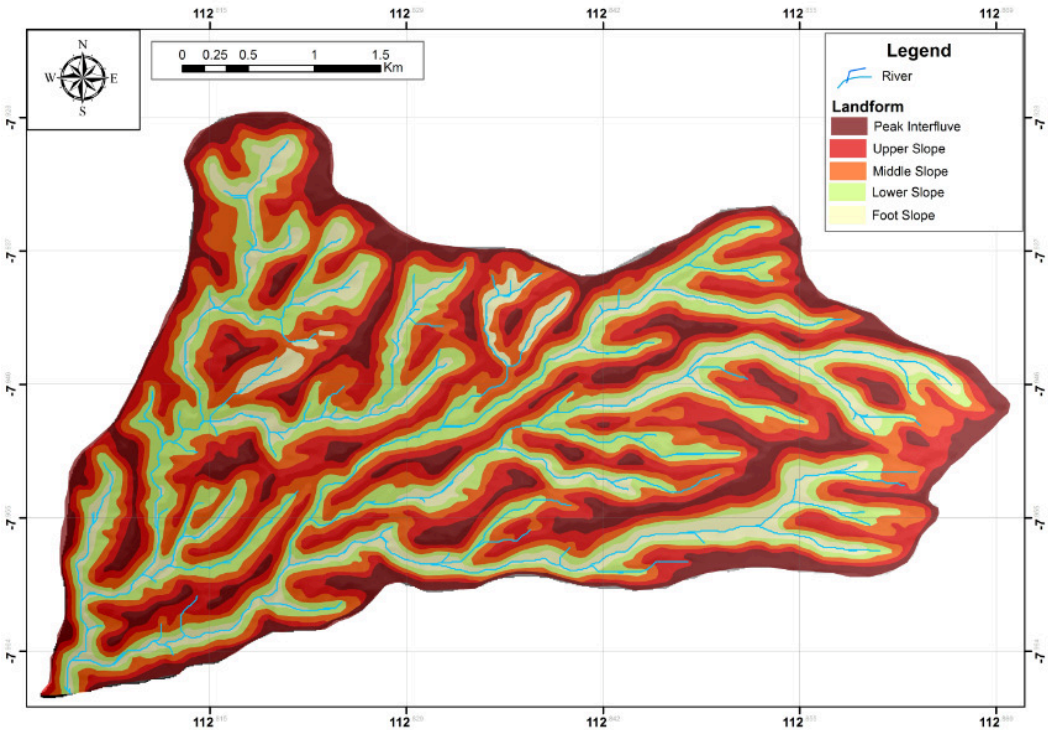

Figure 5. Landform based on TPI Analysis

3.3 Accuracy Test

The field survey is needed for accuracy tests because of the landform map produced by automated landform identification. An accuracy test is important to check how accurate the map which had been produced. The sample of accuracy is stratified random sampling in each landform. The result of accuracy is used to guide for the re-interpretation of the landform map. The technique of obtained sample use grid system 100 m x 100 m. The size of the grid system is considering a minimum legible area for a 1:25,000 scale [8]. The whole of the accuracy test has been arranged by an error matrix table. For determining a spot in each landform based on the sport that obtained by crossing the vertical and horizontal line.

The accuracy test is producing product accuracy and user accuracy. Product accuracy is an accuracy test produced by omission error. Whereas, for the user, accuracy is produced by commission error. All the accuracy is based on the amount of all classification divided by all the omission and commission error. The accuracy test shows that the value of accuracy is 85% and its accuracy value is acceptable. The error of accuracy is caused by inappropriate landform classification of a map with the real landform classification in the field.

4. Conclusion

Integration remote sensing data and Geographic Information System (GIS) is necessary for the identified physical conditions in the research area. TPI is the automated landform map produced by an integration of DEMNAS data and Geographic Information System. For taking the high accuracy we have made the modeling of TPI. The most TPI model that has appropriate with the existing condition is with the circle cells 5 m x 5 m. Based on the accuracy-test with intensively field check shows 85% accuracy value and its acceptable.

Acknowledgment

Thanks for the Ristekdikti (Directorat Research and Strengthening and Development) who has funded this research and also LPPM Universitas Wisnuwardhana Malang that support during proposal submission until doing the research.

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