Computers & Geosciences 70 (2014) 154–163

Contents lists available at ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

The ValleyMorph Tool: An automated extraction tool for transverse topographic symmetry (T-) factor and valley width to valley height (Vf-) ratio

Heidi Daxberger, Ron Dalumpines, Darren M. Scott, Ulrich Riller*

School of Geography and Earth Sciences, McMaster University, 1280 Main Street West, Hamilton, Ontario, Canada L8S 4K1

ARTICLE INFO

Article history:
Received 23 September 2013
Received in revised form
29 May 2014
Accepted 30 May 2014
Available online 7 June 2014

Keywords:
Transverse topographic symmetry factor
Valley shape ratio
Automated data extraction
ArcGIS
GIS
Python

ABSTRACT

In tectonically active regions on Earth, shallow-crustal deformation associated with seismic hazards may pose a threat to human life and property. The study of landform development, such as analysis of the valley width to valley height ratio (Vf-ratio) and the Transverse Topographic Symmetry Factor (T-factor), delineating drainage basin symmetry, can be used as a relative measure of tectonic activity along fault-bound mountain fronts. The fast evolution of digital elevation models (DEM) provides an ideal base for remotely-sensed tectonomorphic studies of large areas using Geographical Information Systems (GIS). However, a manual extraction of the above mentioned morphologic parameters may be tedious and very time consuming. Moreover, basic GIS software suites do not provide the necessary built-in functions. Therefore, we present a newly developed, Python based, ESRI ArcGIS compatible tool and stand-alone script, the ValleyMorph Tool. This tool facilitates an automated extraction of the Vf-ratio and the T-factor data for large regions. Using a digital elevation raster and watershed polygon files as input, the tool provides output in the form of several ArcGIS data tables and shapefiles, ideal for further data manipulation and computation. This coding enables an easy application among the ArcGIS user community and code conversion to earlier ArcGIS versions. The ValleyMorph Tool is easy to use due to a simple graphical user interface. The tool is tested for the southern Central Andes using a total of 3366 watersheds.

1. Introduction

One of the major challenges in assessing potential seismic hazards is to reliably identify regions of preferred upper crustal deformation. Landform morphometrics and the respective tectonomorphic indices can be used as basic reconnaissance tools of tectonic activity which can indicate areas at risk (Bull and McFadden, 1977; Keller, 1986; Cox, 1994). The qualitative and quantitative descriptions of landform development are used to identify areas dominated by rapid tectonic deformation or erosion on a local scale. For example, the transverse topographic symmetry factor (T-factor) enables the detection of possible basin tilt caused by block rotations around horizontal axes, or differential uplift along mountain front-forming faults based on lateral meander belt migration away from its equilibrium state (Cox, 1994; Fig. 1). Besides block rotations recorded by the T-factor, tectonomorphic indices such as the valley floor width to valley height ratio (Vf-ratio; Fig. 2), in combination with the sinuosity index (Smf index) of first-order fault bound mountain fronts, allow the classification of relative tectonic activity (Bull and McFadden, 1977).

Traditionally, tectonomorphic studies including Vf-ratio and T-factor rely on manual delineations using topographic maps and aerial photographs. Manual delineation is a time consuming process and subjective due to reliance on visual estimates. As a result, tectonomorphic studies for detection of Quaternary tectonic activity were mostly limited to a smaller spatial extent (Bull and McFadden, 1977; Cox, 1994; Viveen et al., 2012). Rapid advances in geographical information systems (GIS) and availability of satellite-derived elevation data and imagery provides for a more efficient handling, manipulation and management of geomorphologic data. However, functions for Vf-ratio and T-factor data extraction are not integrated in the standard GIS software packages yet. This inspired some researchers to develop tools enabling the automatic extraction of Vf-ratio and T-factor.

Temme (2010) developed a stand-alone ascii-raster based tool called T-Vector Utility to enable automated T-factor extraction. Viveen et al. (2012) used this tool to generate data for a study on climate versus tectonic influences on fluvial systems. Shahzad and

* Correspondence to: Institut für Geologie, Universität Hamburg, Bundesstrasse 5, 20146 Hamburg, Germany. Tel.: +49 40 42838 6247; fax: +49 40 42838 5007.
E-mail address: ulrich.riller@uni-hamburg.de (U. Riller).

http://dx.doi.org/10.1016/j.cageo.2014.05.015
0098-3004/

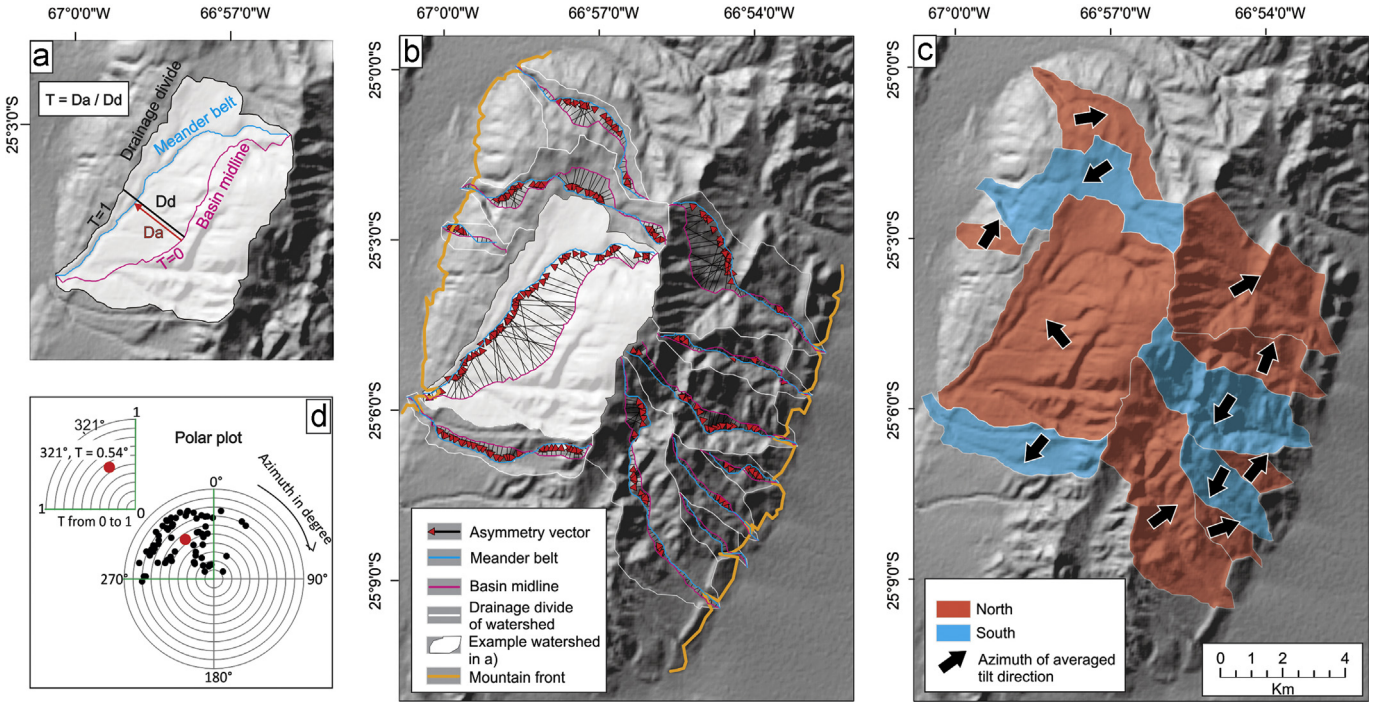

Fig. 1. Example for T-factor data delineation after Cox (1994). (a) Map view shows a sample watershed with meander belt and basin midline. Cross-sections enable measurement of the distance between basin midline to the meander belt (*Da*) and from the basin midline to the respective drainage divide (*Dd*). T-factor $T=Da/Dd$ is 0 if no lateral migration of the stream away from the midline occurs. *T* increases to 1 with progressive meander belt migration in direction of the drainage divide. (b) Asymmetry vector arrow of sample watershed. (c) Color-coded watershed polygons point to northward (red) and southward (blue) basin tilt derived from per watershed averaged T-factor data. Arrow indicates average basin asymmetry vector. (d) Polar plot shows distribution of asymmetry vectors (black dot) in (b) and the averaged asymmetry vector (red dot) of the sample watershed in (a). Asymmetry vector azimuth in degrees is indicated on the outer margin of the polar plot in clockwise direction from 0° to 360°. Asymmetry vector magnitude is displayed along the *x* and *y* axes from 0 outwards to 1. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Gloaguen (2011b) developed a MATLAB-based application for T-factor extraction integrated in the TecDEM software shell. This MATLAB toolbox provides, among other functions, a DEM-based stream flow analysis and morphometric parameter extraction necessary for drainage basin analysis (Shahzad and Gloaguen, 2011a). While the T-Vector Utility and the MATLAB-based TecDEM utility both provide an automated T-factor extraction, neither one is capable of Vf index extraction. Moreover, many earth scientists may be already ArcGIS Suite users, therefore higher costs for software incur in case of the MATLAB-based TecDEM toolbox.

Here, we present the first version of a new ArcGIS-compatible, specifically the ArcGIS version 10.1 herein referenced as ArcGIS, ValleyMorph Tool for automated extraction of the Vf-ratio and T-factor parameters. We chose ESRI ArcGIS, as a foundation due to its comprehensive data management, manipulation, and visualization capabilities which allows us to create an efficient workflow within a single software suite. The new data extraction utility is based on methodology suggested by Bull and McFadden (1977, Fig. 1) and Cox (1994, Fig. 2). Our computation model partly follows the procedure used by Temme (2010) in the T-Vector Utility. However, we refined some work flow components and further added automated Vf-parameter extraction (Fig. 3). Furthermore, we provide a standalone script version (Auxiliary material AM1) of the tool for use outside of ArcGIS. The Python coded utility which uses arcgisscripting for geoprocessing, enables a simple conversion to earlier ArcGIS versions. As data input for the ValleyMorph Tool a watershed polygon shapefile of the drainage basins of interest as well as a digital elevation model raster of the respective study area is required. The Graphical User Interface (GUI) allows a user-friendly selection of input, extraction parameter and output location (Fig. 4). During computation several ArcGIS point, polyline, polygon feature classes with respective attribute tables, as well as ArcGIS data tables are created. Automated Vf-ratio and T-factor calculation was excluded from the tool to enable a more specific selection of extracted data used for a manual index calculation and thorough accuracy checks. The error as well as the resolution of the resulting data, necessary for an index calculation, depends highly on the quality of the input data set (DEM and watershed delineation).

The main objective of this study is to create an application that minimizes the time and strenuous manual data selection during Vf-ratio and T-factor parameter extraction by using ArcGIS. Furthermore, an adequate scripting language has to be chosen not only to allow the development for an ArcGIS tool box but also to facilitate a better compatibility with earlier ArcGIS versions. Furthermore, the complexity and syntax of programming languages hinders users without the respective programming skills from using applications solely available in script form. This necessitates a user-friendly graphical user interface of the ValleyMorph Tool in ArcGIS. This first version of the fully functional ValleyMorph Tool offers a large potential for satellite-based studies of Quaternary deformation of large and remote areas and hence to advance the efficiency of tectonomorphic surveys.

2. Description of the tectonomorphic methodology

In this study, we developed a tool that extracts (1) the Transverse Topographic Symmetry Factor (T-factor; Cox, 1994) and (2) the Valley width to valley height ratio (Vf-ratio; Bull and McFadden, 1977). These two indices are briefly explained in the following sections, which also highlights data required for their computation.