



An evaluation of digital elevation models (DEMs) for delineating land components

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ARTICLE INFO

Article history:

Received 25 January 2013

Received in revised form 29 July 2013

Accepted 19 August 2013

Available online 15 September 2013

Keywords:

Digital soil mapping

Object-based image analysis

Land components

Multi-scale digital terrain analysis

Terrain units

ABSTRACT

Land component boundaries often coincide with transitions in environmental land properties such as soil, climate and biology. Image segmentation is an effective method for delineating terrain morphological units from digital elevation models (DEMs). This paper compares the land components derived from five DEMs. The second version of the 30-m advanced spaceborne thermal emission and reflection radiometer global DEM (ASTER GDEM2), the 90-m shuttle radar topography mission DEM (SRTM DEM), two versions of the 5-m Stellenbosch University DEMs (SUDEM L1 and L2) and a 5-m DEM (GEOEYE DEM) derived from GeoEye stereo-images were considered. The SRTM DEM and the ASTER GDEM2 were upsampled to 5-m resolution for comparison purposes. Land components were delineated using the slope gradient and aspect derivatives of each DEM. The resulting land components were visually inspected and quantitatively analyzed using the slope gradient standard deviation (SGSD) measure and the mean slope gradient local variance (MSGLV) ratio. The results show that the GEOEYE DEM and SUDEM L2 yielded land components with relatively low SGSD values and that their boundaries often coincide with morphological discontinuities. The GEOEYE DEM produced land components with the highest MSGLV ratio, followed by SUDEM L2, ASTER GDEM2, SRTM DEM and SUDEM L1. Although the land components derived from SRTM DEM and SUDEM L1 were relatively homogeneous internally, their boundaries did not always trace morphological discontinuities. The ASTER GDEM2 failed to incorporate many of the morphological discontinuities in the study area. It is concluded that, although the SRTM DEM is more suitable than the ASTER GDEM2 for generating land components, higher-resolution DEMs such as the GEOEYE DEM and SUDEM L2 are required for delineating meaningful land components.

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1. Introduction

Terrain is one of the most important soil-forming factors (Behrens et al., 2010; Jenny, 1941) and is essential for soil property mapping (McBratney et al., 2003). According to Moller et al. (2008), landforms and landscape context are particularly important to understanding the processes of soil genesis and soil formation in the spatial domain. Minár and Evans (2008) describe land components as landform elements with a constant value of elevation or having a constant value of two or more readily interpretable morphometric variables, bordered by lines of discontinuities. Land component borders frequently coincide with environmental land properties such as soil, climate and biology (MacMillan et al., 2004; Speight, 1977; Van Niekerk, 2010).

Conventional approaches to delineating land components include studying topographical maps, interpreting aerial photographs and making field measurements (Drăguț and Blaschke, 2006; Graff and Usery, 1993; Speight, 1977). However, these methods are often time-

consuming, biased and costly (Adediran et al., 2004; Argialas, 1995; Drăguț and Blaschke, 2006; Speight, 1977; Van Niekerk, 2010). The increasing availability of DEMs has promoted the use of computers and image processing techniques for deriving terrain properties. The application of object-based image analysis for land component mapping has gained popularity in recent years (Drăguț and Blaschke, 2006; Drăguț and Eisank, 2011; Smith et al., 2007; Wulder et al., 2008), particularly for soil-landscape modeling purposes (Blaschke and Stobl, 2003; Deng, 2007).

Various researchers have investigated the use of DEMs for digital soil and land component mapping. Van Niekerk (2010) evaluated land component maps delineated from DEMs using three algorithms, namely the automated land component mapper (ALCoM), the iterative self-organizing data analysis technique algorithm (ISODATA) and multi-resolution image segmentation (MRS) to determine which technique yields the most homogenous and morphologically representative land components. The three algorithms generated significantly different land component maps and MRS performed better and was more sensitive to morphological discontinuities than the other algorithms. Drăguț and Blaschke (2006) investigated an automated classification system of landform elements based on object-orientated image analysis. Elevation, profile curvature, plan curvature and slope gradient was used to

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delineate relatively homogeneous objects through image segmentation. This was followed by a classification of objects into landform elements using a relative classification model based on the surface shape and on the altitudinal position of objects. They concluded that the methodology is reproducible and it is readily adaptable for diverse landscapes and data sets. A semi-automated method to recognize and spatially delineate geomorphological units in mountainous forested ecosystems using statistical information extracted from a 1-m resolution digital terrain model (DTM) derived from laser data was proposed by van Asselen and Seijmonsbergen (2006). They determined slope angle and elevation characteristics for each key geomorphological unit occurring in the study area and derived a map of slope classes from the DTM in an expert-driven multilevel object-orientated approach. They concluded that topographical data derived from high-resolution DTMs are useful for the extraction of geomorphological units in mountainous areas.

It has been demonstrated that delineating land components from DEMs is more cost-effective and objective than traditional field-based and visual interpretation methods and that land component mapping is invaluable for landscape characterization and soil mapping (Minár and Evans, 2008; Moller et al., 2008). However, although research has been done on the various algorithms available for segmenting DEMs to produce land components (Van Niekerk, 2010), very little has been done to determine how the use of different input DEMs influences the delineation of land components. This paper compares the land components derived from five DEMs, namely the 90-m shuttle radar topography mission DEM (SRTM DEM), the second version of the 30-m advanced spaceborne thermal emission and reflection radiometer global digital elevation model (ASTER GDEM2), two versions of the 5-m Stellenbosch University DEM (SUDEM L1 and L2), and a 5-m DEM (GEOEYE DEM) derived from GeoEye stereo-images. The results are interpreted and evaluated in the context of using land component delineation for mapping and studying soil properties.

2. Materials and methods

2.1. Study area

The Sandspruit catchment, a subcatchment in the Berg River basin, was chosen as the study area. The catchment has an extent of 152 km² and is situated in the vicinity of Riebeeck-Wes, north of Cape Town in the Western Cape Province of South Africa (Fig. 1). The geology of the Sandspruit catchment is dominated by Malmesbury shales, although there are smaller occurrences of fine sediment, silcrete-fericrete, greenstone, quartzite and granite. Most of the catchment is used for dryland cultivation, particularly winter wheat. Land is also used for canola cultivation and pasturage. Natural vegetation covers only a small proportion of the catchment.

The Sandspruit catchment has a semi-arid (Mediterranean) climate and is located in a winter rainfall region with a mean annual rainfall of about 400 mm (Flügel, 1995). The catchment generally has undulating topography with gentle to moderate slopes. According to Flügel (1995), the valleys have a molded shape and the groundwater table is shallow in the lower-lying areas during the winter rainfall season. Salt crystallizes in patches during the hot summers from November to March. The Sandspruit catchment was considered a suitable site for this study as its landforms are representative of large parts of the Berg River catchment.

2.2. Data

2.2.1. Digital aerial photographs

High resolution (0.5 m) orthorectified digital aerial images covering the Sandspruit catchment were obtained from the Chief Directorate National Geo-spatial Information (CDNGI) (<http://www.ngi.gov.za>). The orthorectified digital aerial images were used to delineate test morphological discontinuities and as backdrops when assessing the accuracy of the DEM-delineated land components.

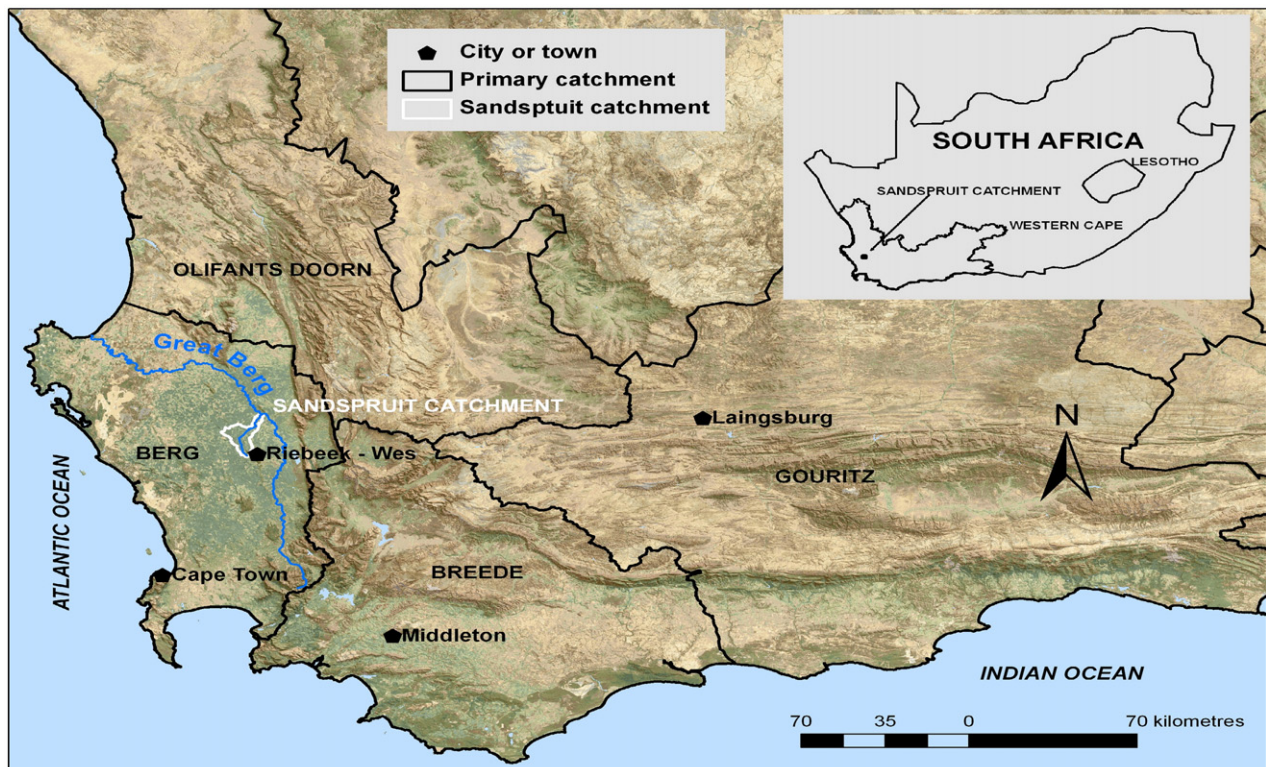


Fig. 1. Location of the Sandspruit catchment.

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