ON-SITE VERIFICATION OF SLOPE SHAPE: SPATIAL ANALYST CURVATURE FUNCTION

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ABSTRACT
Use of the ArcGIS Spatial Analyst extension for soil survey activities by NRCS is increasing. This paper presents a commonly used process to delineate the land surface into the nine slope shape categories using a digital terrain model (DTM) and the Spatial Analyst extension curvature function. This model is applied to DTMs created from a variety of elevation data sources with various cell resolutions. Points along slope shape delineation boundaries are selected in ArcMap. These points are loaded to a mobile computer using ArcPad to enable precise and accurate navigation. Results are verified by on-site visual examination.

BACKGROUND
This is the fourth paper in a series discussing the GIS related technology improvements in soil survey as accomplished by the Natural Resource Conservation Service. A similar paper delivered in 2003 discussed the use of elevation data to produce slope gradient values for comparison with existing soil map units for quantifying slope inclusions. This paper further examines the use of elevation data by application of the spatial analyst curvature function for delineation of separate slope shapes displayed in Figure 1. These delineations have been found to be useful for comparison with existing soil map units in studying map unit composition. The slope shape derivative product discussed in this paper is only one of many DEM related products that can be used for soil mapping.

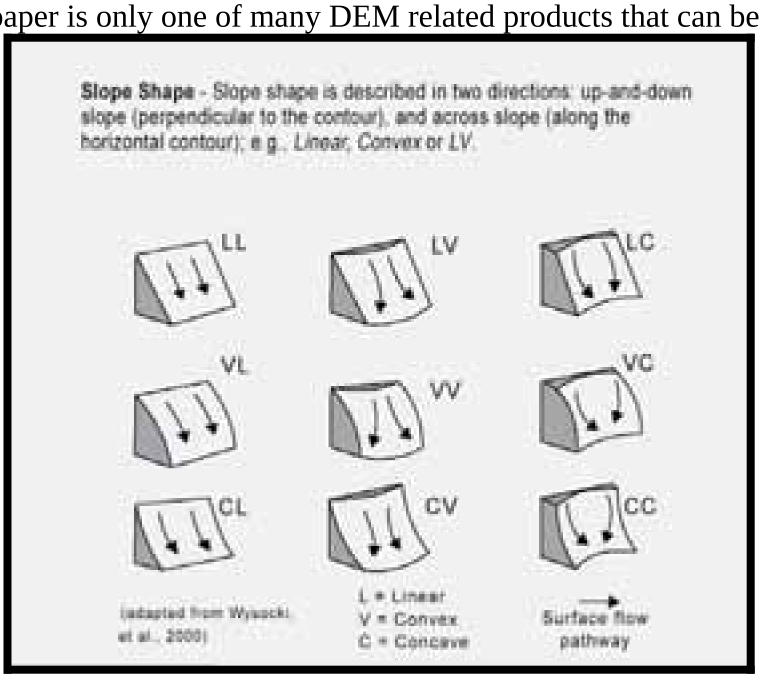

Figure 1. Nine slope shapes. Shape nomenclature is profile-plane, e.g., LV is linear profile-convex planer. The simplest form is linear in both dimensions (LL).

Soil genesis is a function of several soil formation factors: parent material, climate, vegetation, landscape position, and time. These soil forming factors that effect development of soil morphological characteristics and properties over time are strongly related to the water distribution pattern over and within the landscape. The understanding of the way soil properties vary across the landscape as a result of these factors is known as the soil-landscape model and it's comprehension by the soil scientist enables the prediction of soil occurrence from landscape position. The more thoroughly the soil-landscape model is understood the more accurate and useful a soil map is for interpretation and use. The slope shape derivative product of an accurate DEM will provide a valuable tool for a soil scientist to use in discerning a preliminary outline of the landscape configuration and in quantifying existing soil map unit delineation composition.

METHODOLOGY

In the same manner remotely sensed data has been used in the past for soil survey operations it is recommended that two principles be considered when using products of digital terrain analysis applications in soil survey:

1. Terrain Analysis digital products are considered to be useful as supplements to Field Mapping, they are not intended to replace it.
2. Procedures and models should be tested empirically against on-site evaluation of results prior to implementation.

Description of the spatial analyst extension curvature function

The output of the Curvature tool can consist of 5 different layers consisting of values calculated from an elevation model dataset using a 3 by 3 neighborhood function displayed in Figure 2. The two layers of interest for obtaining the coded slope shape layer are the planer and profile layers.

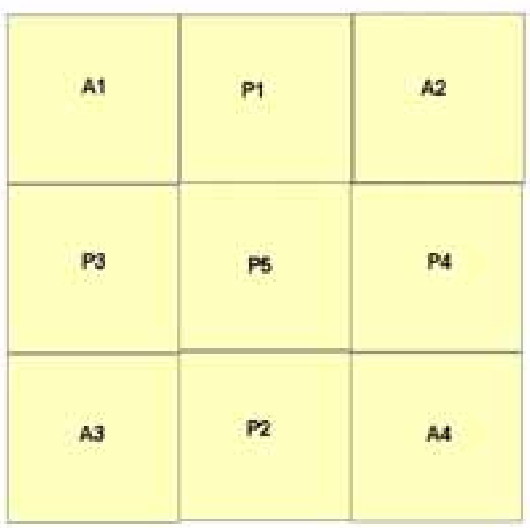

Figure 2. Diagram of 3 x 3 cell window that is used to calculate the curvature surface.

Where the calculated surface has elevation values greater at A1 to A2 than A3 to A4, then the planer and profile layers are calculated such that:

> Planer curvature value = [(P3 + P4) / 2 – P5] / (Cell size) * 2] * 100
> Profile curvature value = [(P1+ P2) / 2 - P5] / (Cell size) * 2] * 100.

Units for the profile curve raster and output plan curve raster are 1/100 (z units). It is recommended the z units match the x, y coordinate units for this function. A negative profile indicates that the surface is upwardly convex at that cell. A positive profile indicates that the surface is upwardly concave at that cell. A positive planer value indicates that the surface is convex relative to the contour at that cell. A negative planer value indicates that the surface is concave relative to the contour at that cell.

Curvature and Reclass Model

The profile and planer output files produced by the curvature function can be reclassified to produce a numeric value depicting one of the 9 slope shapes that are defined in the NRCS soil survey guidelines for site description. A simple model to perform the curvature calculation and the reclassification process is displayed in Figure 3.

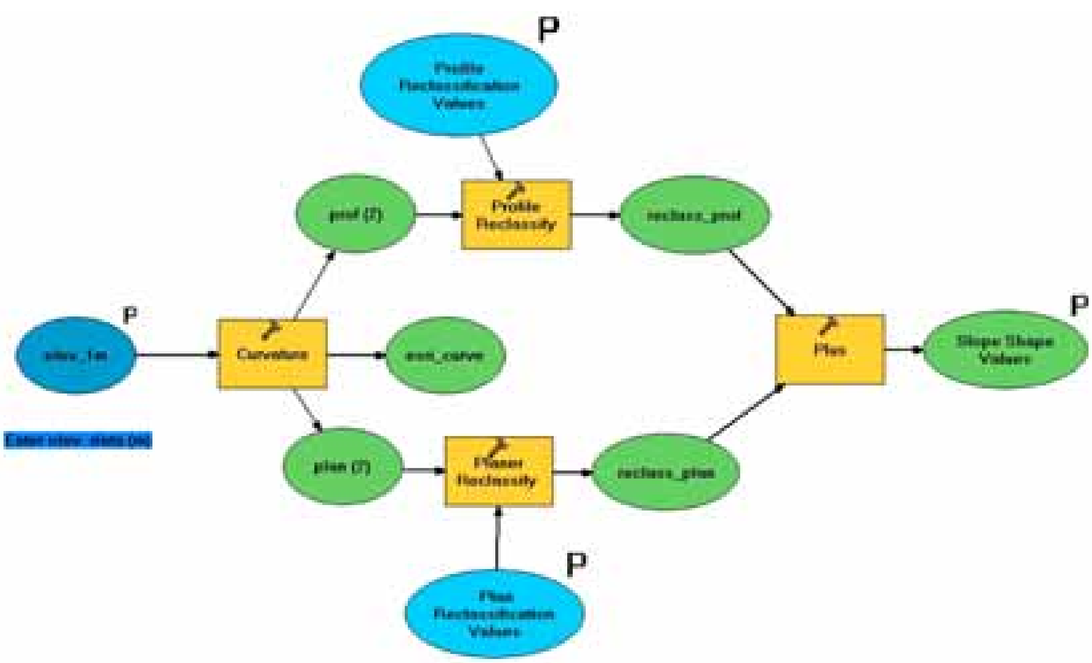

Figure 3. Slope shape model. This model will produce a reclassified combination of the profile and planer curvature derivatives of an elevation dataset.

The result of this model will be a coded integer grid with profile values being represented by 10 = convex, 30 = linear, and 50 = concave. The planer values will be 1 = concave, 3 = linear, and 5 = convex. Addition of these 2 grids creates a grid where cell values can be 1 of 9 combinations representing the 9 different slope shapes, for example cells that have a linear profile and linear planer will have a value of 33. *What is critical are the* *values above and below 0 that are used in the reclassification process to differentiate between the linear and the concave/convex shapes to most accurately depict the features "on the ground" .* True linear is 0, however the range for depicting the linear shape in the positive and negative will vary based on a number of variables including resolution of the elevation data.

On – site validation.
The results in two of the areas that were selected for documentation of the curvature derived functions are described.
Area 1. Elevation mass points were collected with TopCon HyperLite+ GPS survey equipment. The model was used to create a reclassified slope shape layer for 1 and 2 meter resolution elevation datasets. Values used to separate the curved areas from the linear shaped slope were validated by on-site observation. Figure 4 displays the concave toeslope position delineated by flags set to profile values of 2.

Figure 4. Concave toeslope position with flags at profile value 2 locations.

Is the shape derived from an interpolated surface created with high resolution elevation data more accurate than the shape configuration determined by on-site examination? Placement of a flag on where the observer has decided the slope shape changes from linear to concave has been found to generally underestimate by one or two cells the location selected by values selected based on remote sensing with the contour and surface evaluation. For this 1 m resolution data, profile and planer curvature values of 2 were very close to the on-site position of slope break between different slope shapes in the areas examined. The curvature values were calculated using the ESRI method without any modifications or generalization of the original surface values.   Figure 5 displays the area displayed in Figure 4 in ArcMap with the concave area shaded green and convex area shaded yellowish brown. The red points are the locations where 2 observers identified the linear to convex/concave break.

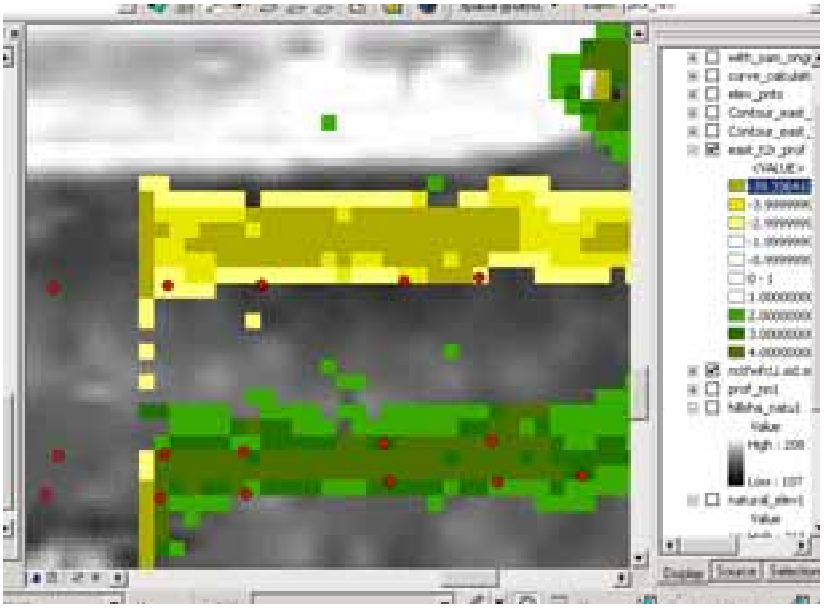

Figure 5. Concave toeslope and Convex shoulder areas with on-site locations.

Area 2. A similar examination of the curvature product derived from 5m elevation data was performed at a location in Presidio County, Texas. For this 5 m resolution elevation data, profile and planer curvature values of 0.1 were very close to the break between different slope shapes in the areas examined. Elevation points were captured in two traverses up and down a short slope. The profile curvature was calculated using the ESRI method for calculation for 12 selected locations along these traverses. Figure 6 displays the location in ArcMap with the concave area shaded green and convex area shaded yellowish brown.

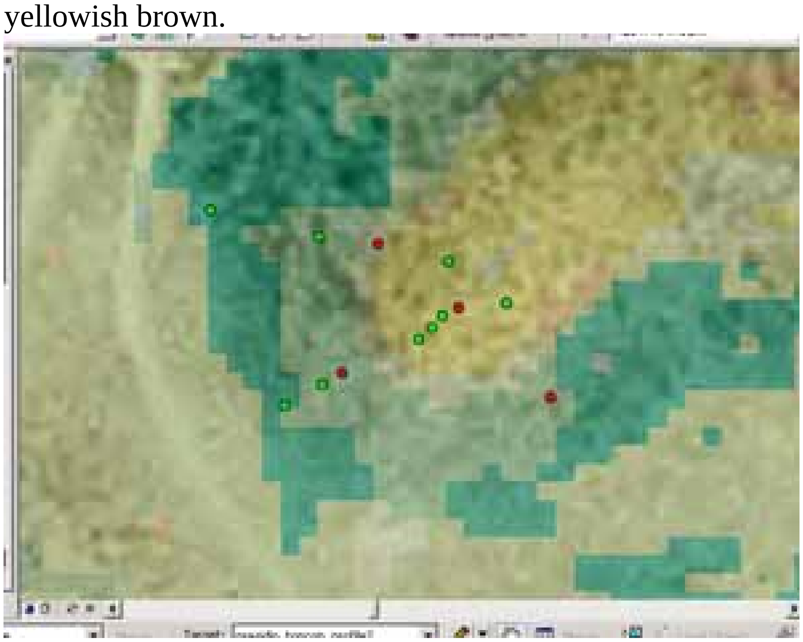

Figure 6. Location of on-site measurements with concave and convex slope shape grid.

The red points are the locations where the profile curvature calculated from survey observations did not agree with the value in the curvature layer. These results were that are given in Table 1.

Table 1. Comparison of profile curve values and slope shape reclass against on-site data.

Point of traverse	GPS Survey profile calculated	IFSAR 5m DEM profile	Shape classification with +/-0.1 break	Profile concurrence at 0.1 break.
X section				
2	0.1	0.17	53	Y
30	1.45	0.23	53	Y
5	-0.6	0.016	35	N
10	-0.2	-0.59	15	Y
16	-0.65	-0.397	15	Y
21	-0.7	0.22	55	N
Nose slope				
2	0.2	0.2	53	Y
4	1.1	0.34	55	Y
5	-0.2	0.2	55	N
10	-0.85	-0.27	15	Y
11	-0.5	-0.34	15	Y
12	-1.15	-0.35	15	Y
13	-0.05	-0.28	15	N

Out of 12 points calculated from on-site elevation data 66% concurred with the shape classification. In 2 of the 4 points that did not agree a larger or smaller value selected for separating the linear break would not have mattered because the on-site calculation was convex and the DEM was concave.

CONCLUSIONS

These findings support the premise that DEM derived products should be tested empirically against on-site evaluation to determine the correct parameters for slope shape classification.

More evaluations need to be performed to further validate these results using the ESRI function with unmodified elevation data. According to these areas examined, for 1 meter resolution elevation data a profile curvature value of 2 cm may be used as a break between linear and curved shapes. For 5 meter data the break may be around 0.1 cm for linear to curved shapes.

Evaluations also need to be conducted on the benefits to interpretation of results by generalization of the elevation data.

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