Refining an Automated Model for Basic Landform Classification

An ArcGIS and Python Approach

By Josh Moss

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What are Landforms?

• Landforms are categories of structure that can be derived from observable differences in the three-dimensional geometry of the Earth’s surface.

• Landforms are familiar: plains, mountains, hills, plateaus, etc.

• Despite this familiarity, mapping landforms objectively has been an elusive goal for geomorphologists.
The Challenges of Landform Mapping

- Removing subjectivity from the process
- Identifying proper break points using geomorphological theory
- Staggering variety of the Earth’s surface
- Landforms as objects: *fiat* or *bona fide*?
- Automating complex processes for practical use by land planning and environmental professionals
- Lack of an objective standard against which to validate landform maps or classification systems
Why Classify Landforms?
The Uses for Landform Classification

• Land use planning (Zawawi 2014)
• Landslide susceptibility mapping (Dikau 1990, Pike 1998)
• Precision agriculture (Klingseisen 2007)
• Soil condition modeling (Schmidt 2004)
• Forest management (MacMillan 2004, Zawawi 2014)
• Broad framework for mapping ecological units and habitats (MacMillan 2004)
• Generalized constant spatial variable against which to perform spatially based analyses in disciplines such as anthropology, archaeology, geology, geomorphology, biology, ecology, and other natural sciences
The History of Geomorphometrical Mapping

US Forest Service 2015

Burrough 2000
“The Atlantic Coastal Plain is a well marked province, but the hilly topography of it’s landward margin is superficially more like that of the adjacent Piedmont than like the featureless flats near the coast. It is, however very much more nearly related to the latter, into which it grades without crossing any significant line of division.” (Fenneman 1914)
Lines of Division – Break Points and Mathematics

Hammond 1954

Savigear 1965
Hammond’s Moving Window

**Scheme of Classification**

**Slope** (Capital letter)
- A: More than 80% of area gently sloping
- B: 50-80% of area gently sloping
- C: 20-50% of area gently sloping
- D: Less than 20% of area gently sloping

**Local Relief** (Numerical)
- 1: 0-30 m (0-100 feet)
- 2: 30-91 m (100-300 feet)
- 3: 91-152 m (300-500 feet)
- 4: 152-305 m (500-1000 feet)
- 5: 305-915 m (1000-3000 feet)
- 6: More than 915 m (3000 feet)

**Profile Type** (Lower case letter)
- a: More than 75% of gentle slope is in lowland
- b: 50-75% of gentle slope is in lowland
- c: 50-75% of gentle slope is on upland
- d: More than 75% of gentle slope is on upland

**Legend**

- **Plains**
  - A1: Flat plains
  - A2: Smooth plains
  - B1: Irregular plains, slight relief
  - B2: Irregular plains

- **Open Hills and Mountains**
  - C2: Open low hills
  - C3: Open high hills
  - C4: Open very high hills
  - C5: Open low mountains
  - C6: Open high mountains

- **Tablelands**
  - D1: Tablelands
  - D2: Tablelands, moderate relief
  - D3: Tablelands, considerable relief
  - D4: Tablelands, high relief
  - D5: Tablelands, very high relief

- **Hills and Mountains**
  - E1: Hills
  - E2: High hills
  - E3: Low mountains
  - E4: High mountains

**Other Symbols**

- Mostly used
- Considerable standing water
- Mostly standing water
- Crests and summits
- Escarpments and valley sides

**Max and Min Elevation**

- Max elevation within the window
- Elevation point at window center
- Min elevation within the window

**Upland and Lowland**

- Upland: Max elevation - Elevation < 1/2 R
- Lowland: Max elevation - Elevation > 1/2 R

**When**

- Max elevation = Maximum elevation within the moving window
- Elevation = Elevation at moving window center
- R = Local relief within the moving window
Profile curvature is one of the most important geometrical properties of terrain derived from early digital elevation model (DEM) data used by Pike (above) and Dikau (left) to identify breakpoints for landform classification and in the case of their studies, locate areas susceptible to landslides.
Automating Landform Extraction

Schmidt 2004

Zawawi 2014

Klingseisen 2007

Schmidt 2004

Zawawi 2014
Landform Classification Modeling and ArcGIS

11 Flat or nearly flat plains
12 Smooth plains with some local relief
13 Irregular plains with low relief
14 Irregular plains with moderate relief
21 Tablelands with moderate relief
31 Plains with hills
32 Plains with high hills
41 Open very low hills
42 Open low hills
43 Open moderate hills
44 Open high hills
52 Low hills
53 Moderate Hills
54 High hills
56 High mountains

Morgan 2005
Testing the Models

Missouri Resource Assessment Partnership (MORAP) Landforms

Hammond Landforms, 50x50 pixel rectangular "moving window"
Major Errors

- Model conflates concave and convex areas of extreme relief, coding both as “Mountains”
- Model fails to correctly process DEMs containing cells with negative integer values (below sea level areas)
Peaks and Canyons

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<tbody>
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<tr>
<td>Hills</td>
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Negative Integer Cells
Model Verification
Photo Interpretation Methods

• Photographic interpretation was guided by the landform classes defined in Morgan (2005) and Dikau (1991)

• The 3D capabilities of Google Earth was be used to confirm mapping decisions, along with the following ancillary data:
  – National Agricultural Imagery Program (NAIP) aerial photography
  – USGS state geologic maps
  – USGS topographic maps
  – Soil Survey Geographic Database (SSURGO) data
  – National Hydrologic Dataset (NHD) data
## ERROR MATRIX RESULTS

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<th>Plains With Low Mountains</th>
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Total Observations: 5,000
Total Observations in Agreement: 1,977
Percentage Correct: 39%

Klingseisen et al., in their 2007 paper “Geomorphometric Landscape Analysis Using a Semi-Automated GIS Approach” in the journal *Environmental Modeling & Software*, used a similar approach to test the “accuracy” of their landform mapping software application “LANDFORM 2” against a heads-up expert classification of the landforms in their study area and achieved a percentage correct of 43%.
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<tr>
<th>STUDY AREA</th>
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<th>PERCENT AGREEMENT</th>
<th>HEADS UP POLYGON COUNT</th>
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CONCLUSIONS

• A standard, widely distributed data set of classified landforms accepted by the discipline of geomorphology would be a more ideal control group against which to verify the output of LFMapper than my heads-up classification.

• While not perfect and not as advanced as some current methods, LFMapper presents something that did not exist before: an easily distributed, mathematically rigorous, research based application for ArcGIS that classifies landforms with minimal input from the user.
Further Work

• Supervised Classification (Veronesi & Hurni 2014)
• Pattern Recognition Classification (Jasiewicz & Stepinksi 2012)
• Verify LFMapper against other current automated landform classification methods
LFMapper Access

“LFMapper” toolbox file and python source code are available at Lfmapper.blogspot.com. Please feel free to visit the site, download and use the tool, and download and improve the source code. The bibliography and write-up for this project are also hosted there.
Works Cited

- Jasiewicz, Jaroslaw, Tomasz F. Stepinski. “Geomorphons – A Pattern Recognition Approach to Classification and Mapping of Landforms” Department of Geography, University of Cincinnati, Cincinnati, OH 45221-0131, USA, Geoeconomy and Geoinformation Institute Adam Mickiewicz University, Dzielna 27, 60-680 Poznan, Poland