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Applying Terrain analysis to human population?

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Abstract—**Terrain analysis methods are suitable to analysis datasets from a wide variety of statistical domains – not only digital elevation models. We applied a range of these to the total population dataset for Europe for the year 2011 to see the feasibility of identifying outliers, artefacts in the dataset as well as compare against more traditionally generated population derived datasets. The methods applied proved feasible and viable to identify corresponding regions for statistical purposes.**

I. INTRODUCTION

The Geomorphometry community applies their methods mainly on surfaces derived from elevation measurements [1]. However the author argues that the quantitative and qualitative methods can be applied to any surface derived from any measurement. In the traditional Geomorphometry sense it would be an elevation surface, however it could be any sparse or complete matrix covering a given area.

Outside the Geomorphometry domain examples observed are human brain images recorded in 3D using Magnetic Resonance Tomography (MRT) [2], shell morphometry [3], charcoal morphometry [4] or dairy cow lameness [5] to name a few. The author observes on a non statistical sound sample from the research literature (n=20) that simple methods (e.g. like length/width) are often used to describe and analyse the respective aspect under consideration. We postulate that it seems the more advanced methods developed in the Geomorphometry community have not reached the main stream research as a tool of choice for specific research areas outside the direct Geomorphometry / environmental domain.

We argue that the primary (e.g. based on elevation like focal mean), secondary (based on first derivative like slope) or tertiary (landform classification based on slope and curvature) methods applied can be used for a variety of purposes. Examples could be simply a hill shade for error detection, a landform classifications applied for generating feature objects in the feature space for future statistical aggregation or analysis. The objective of this abstract is to showcase the application of terrain analysis methods to a population distribution surface and to encourage the Geomorphometry community to reach out to other domains so the more "advanced" methods become part of the standard toolset for scientist.

II. DATA & METHODS

A. Dataset

Every 10 years the Census is executed in the statistical world. A census is the periodic enumeration of a population containing quite often a variety of demographic information. In 2011 the European Statistical System (ESS) headed by Eurostat together with the European Forum for Geography and Statistics (EFGS) compiled a 1km total population (e.g. count of people) grid.

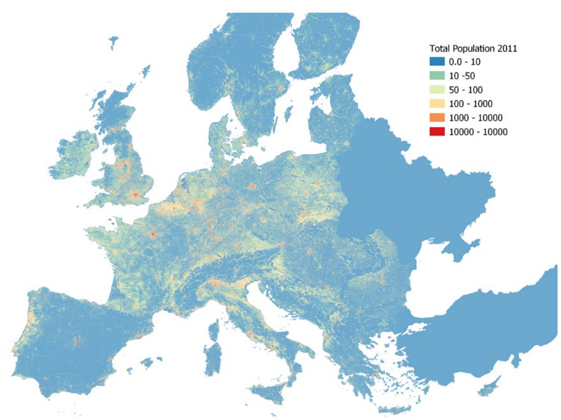

Figure 1 Total Population distribution for 2011

The data were aggregated from point observations or using a hybrid approach for 16 countries, while the rest of the submission from the Countries used a downscaling approach. Reporting data on a grid allows studying causes and effects of many socioeconomic and environmental phenomena.

Additional advantages on reporting on a grid compared to a traditional reporting on statistical/administrative areas are:

- grid cells all have the same size allowing for easy comparison;
- grids are stable over time;
- grids integrate easily with other scientific data (e.g. meteorological information);
- grid systems can be constructed hierarchically in terms of cell size thus matching the study area; and
- grid cells can be assembled to form areas reflecting a specific purpose and study area (mountain regions, water catchments).

The full dataset of total population for the year 2011 is shown in Figure 1. The dataset is available for the years 2011 and 2021 at https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/population-distribution-demography/geostat.

A new dataset has been created for the reference year 2021 containing preliminary and final data.

B. Software

The WhiteboxTools Software Suite, an open-source geospatial data analysis platform was used to perform a variety of analytical tests on the above mentioned dataset.

I. RESULTS

We deployed various terrain measures which are known to highlight inconsistencies in classical terrain analysis. No significant errors could be identified visually using hill shades as seen in Figure 2 and Figure 3. Similar results could be observed for Circular Variance of Aspects which highlighted clearly the stream network type distribution where people are living in Figure 4.

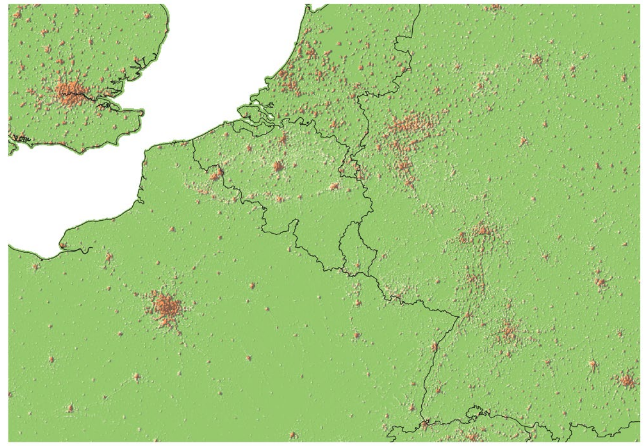

Figure 2 Hypsometric tinted hill shade encompassing some of the BeneLux states.

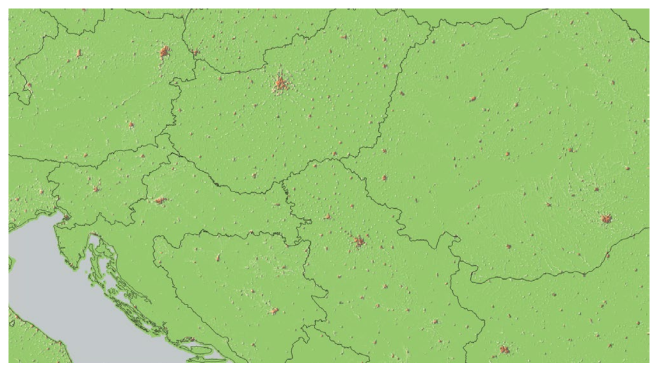

Figure 3 Hypsometric tinted hill shade encompassing some Eastern Europe countries

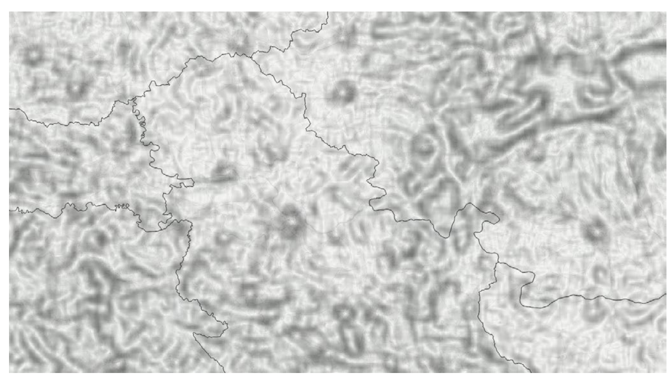

Figure 4 Circular Variance of Aspect for some Eastern European Countries.

Profile curvature however showed single cells consistently distributed across the city centres plus around the city boundaries of unclear origin as seen in Figure 5 below. Negative profile curvatures could be attributed to unpopulated areas (e.g. graveyards, railway infrastructures) while positive curvatures are of unknown origin. The authors postulates from the metadata that these could be due to allocation of populations of specific nature e.g. foreign duty personal, homeless people. Edges of cities could also be observed with city centres as well. The identified cells can be used as input for further quality control as these could be indications of possible errors in the dataset compared to their surroundings. Further research need to be performed to see if any valuable information can be extracted – e.g. possible together with land use datasets.

Figure 5 Profile Curvature across Berlin and Potsdam (top) and Madrid (bottom) draped over an OSM background map. Note the location of the dark pixels in the city centers and the white areas surrounding the city boundaries.

The dataset is generated for each Member states separately, than merged into a pan-European dataset. One could expect to see edge artefacts across country boundaries due to different methodologies. However no effects were observed for the 2011 dataset.

Landform classification based on Geomorphons and k-means clustering delivered similar results for populated areas/non populated areas as well for urban/regional classifications.

II. Conclusions

The application of terrain analysis methods usually applied to Digital elevation models allowed a quantitative and qualitative assessment of the population grid from 2011 and the upcoming grid from the 2021 exercise. The same methods can be applied elsewhere in the world for the validation of the population grids. While execution times were exceptionally fast, some difficulties were encountered as the sparse data matrices (e.g. large areas set to Zero due to unpopulated areas) need to reasonably treated as edge effects were sometimes polluting the results.

References

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