Soil surface roughness quantification using DEM obtained from UAV photogrammetry

Cezary Kaźmierowski[1] Jakub Ceglarek[1],
Sławomir Królewicz [1], Jerzy Cierniewski [1]
[1] Department of Soil Science and Remote Sensing of Soils
Adam Mickiewicz Universityc
Poznań, Poland
cezark@amu.edu.pl

Jarosław Jasiewicz [2]
[2]Geoecology and Geoinformation Institute
Adam Mickiewicz University
Poznań, Poland
Michał Wyczałek[3]
[3]Institute of Civil Engineering, Division of Surveying
Poznan University of Technology
Poznań, Poland

Abstract— **The soil surface roughness is one of the most susceptible to variation in time and space characteristic, and depends on many variables like cultivation practices or soil aggregation. Various indices are used for its quantification, in microscale soil roughness is commonly expressed by HSD calculated from DEM of small sample area. The source of DEM can be close range photogramethry or laser scanning. However, for the scale of whole field that approach gives unclear separation, and new approach, based on geomorphons gives better results.**

I. Introduction

The soil surface roughness is one of the most susceptible to variation in time and space characteristic [1]..To estimate the soil surface roughness, a number of methods have been used: pin and profile meters [2], shadow analysis [3], photogrammetric processing of photographs [4], laser scanners [5]. The soil surface roughness depends on the farming practices [6], [7], and "intrinsic" soil aggregation resulting from rearrangement of particles, flocculation and cementation [8]. The shape of soil surface so far has been quantified using roughness indices, computed from their DEMs with defined horizontal and vertical spatial resolutions. The HSD expresses the height standard deviation of a soil surface area within its delineated basic DEM unit [9], whereas the T3D is the ratio of the real surface area within the DEM unit to the flat horizontal area of the unit [10]. Higher values of these indices express higher surface roughness. Those indices allowed to quantify the roughness of small sample area representing various cultivation practices. (11). Recently developed concept of geomorphons (12) used for landform classification and mapping. This technique could be applicable to quantify soil roughness. The objective of present studies is transition from quantifying surface roughness of sample area into quantifying surface roughness for whole field area.

II. Methods

Analysis were performed for surface containing two bordering field, formed by two farming tools: northern part by seeder and southern by roller At that scale, variation of other soil variables is negligible. Selected field is located in Wielkopolska province in Poland.

Digital elevation model was prepared using photogrammetric processing of 127 aerial photographs taken with hexacopter from about 10m height above the ground level (Fig. 1). Photos were made with Sony alfa 6000 camera with 24Mb pixels matrix. The location of four ground photo mark points were measured with Topcon geodetic GPS with the assumed accuracy about 1mm (horizontal and vertical) in national coordinates system 2000 zone 6 (EPSG number: 2177). Photogrammetric processing was based on Agisoft Photoscan Proffesional 1.1.6 software.

Three classical parameters were calculated directly from DEM using GrassGIS: standard deviation of DEM, standard deviation of residual and standard deviation of prominence.

Digital elevation model obtained in the Photoscan was processed in *r.geomorphon* extension for Grass GIS software (13). Using this algorithm geomorphon forms were calculated for each pixel, and based on that calculation, following parameters were also calculated: intensity, exposition, range and texture. All models were then averaged for 1x1m spatial grid.

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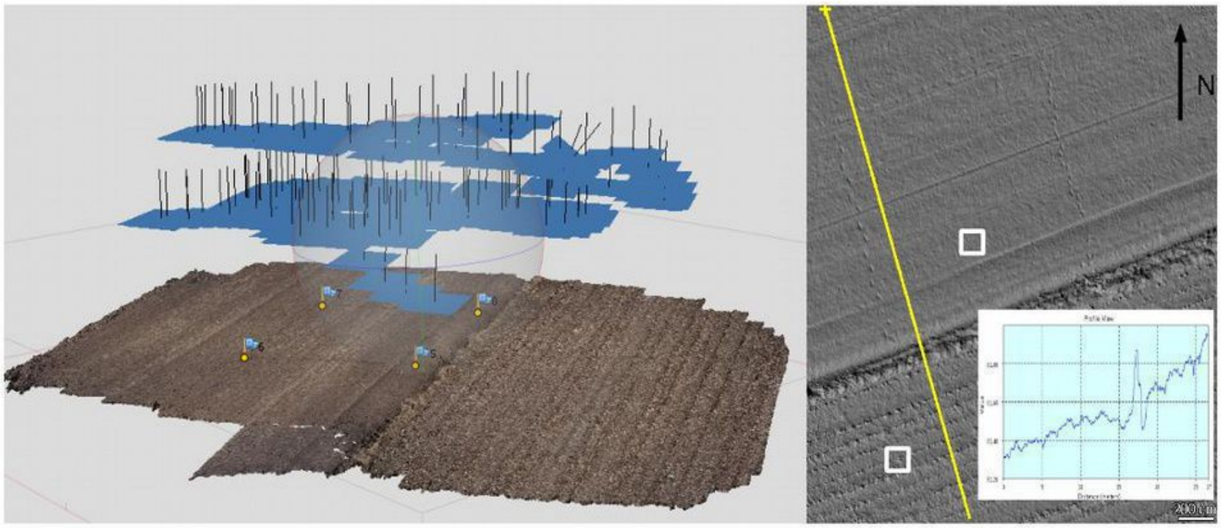

Figure 1. Aerial photos layout (blue rectangles) with generated point cloud (left) and shaded relief with transaction showing height above sea level(right) Examples of area for roughness indices calculation are highlighted in by rectangular.

III. Results

The computed mean pixel size of digital photos used in photogrammetric processing was about 0.25 cm. The computed point cloud consist of near 12 mln points, giving 19500 points per square meter. The cloud point data was processed for noise filtering. Then digital elevation model was computed using minimal curvature interpolation method with 1cm pixel spatial resolution.

So far, surface roughness was quantified based on the sample areas depicted as bounding boxes on Fig. 1. Based on those samples, HSD for northern part of field would have value of 14 mm and 33 mm for southern part and T3D values 1.02 and 1.07 respectively. For this work, HSD is calculated for whole field instead of just a sample. Parameterization of surface roughness was performed for height standard deviation of three measures of DEM and results averaged to 1x1m blocks are presented on figure 2. First model (Fig.2A) shows standard deviation of heights without detrending and while it does show differences between northern and southern part, it also contains a lot of noise. The thin border between two parts is wrongly classified as separate category. In this example, micro scale differences of roughness resulting from cultivation practices are not disconnected from field scale trend resulting from relief. Second model (Fig. 2B) shows standard deviation of prominence, which is a difference between averaged, smoothed surface and height of a pixel shows better results than previous model, but it still highlights border between northern and southern part as an independent structure, which is an error. Both of those methods point at necessity of detrending. The third model (Fig. 3C) is standard deviation of residuals, which is a way of detrending and is showing the best results among those three models. Compared to two previous models, border is relatively thinnest and separation between two areas is better. Nonetheless, it still isn't completely clear. However, generally we can observe that northern area is described by lower values of HSD compared to southern area. Obtained results suggest that precise quantification of HSD values for various farming practices calculated for small samples (11) is not clear when applied to the whole field scale.

Applying geomorphons methodology at 1cm horizontal resolution allows recognition of common classes of (micro)landform elements (Fig. 3A) in similar manner to classification of earth landforms. The northern part that is characterized by lower roughness shows dominance of gemomorphons associated with flat terrain, while southern part that has higher roughness contains more geomorphons associated with uneven terrain. The second model, showing geomorphons classified into exposition (Fig. 3B) which is difference of minimal point from the neighborhood and central cell and is most similar to prominence used in classical measurements of soil roughness.

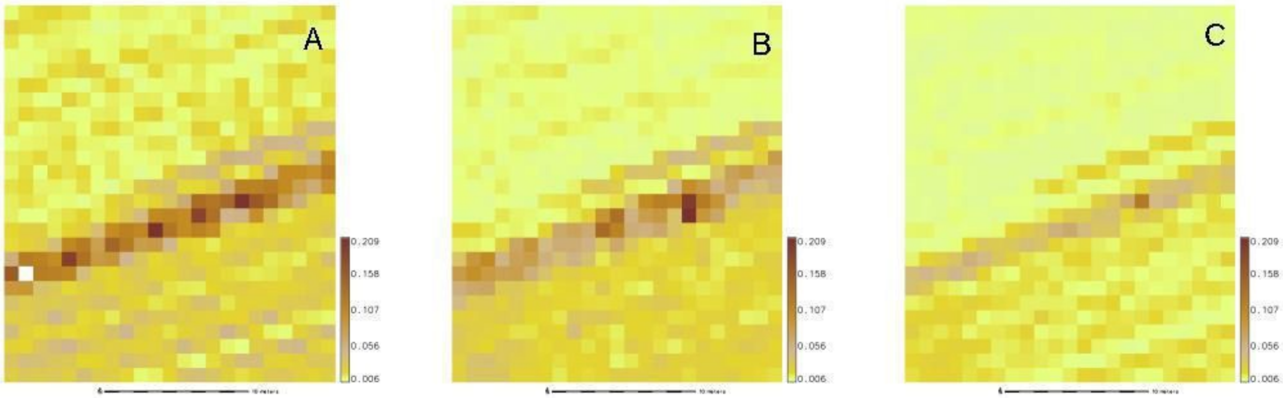

Figure 2. Three different roughness indicators: A standard deviation of DEM, B standard deviation of prominence and C standard deviation of residuals.

As can be observed, both of those indicators differentiate between northern and southern parts of the field, showing that the northern part is generally more flat, while southern is characterized by higher roughness. It's worth noting that exposition model shows even the footprints of a person left while setting local reference grid. Presented results show that this approach is sufficient for microstate modeling of surface state. Other indices (texture, intensity and range) were also calculated and they show similar ability to distinguish between northern and southern surfaces.

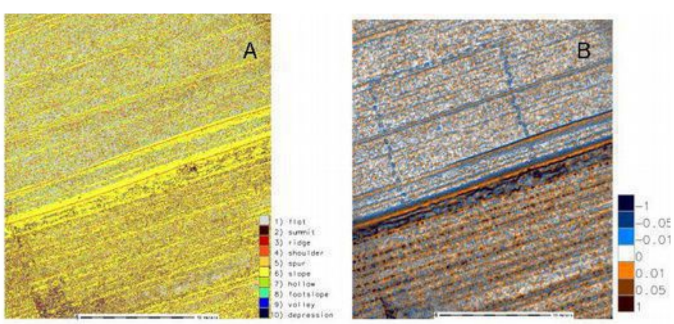

Figure 3. Models obtained using geomorphons methodology: landform classes (A) and exposition (B).

Two models (Fig. 4), obtained by averaging texture and exposition values for 1x1 m resolution grid show very clearly the distinction between smooth and rough surfaces. Texture shows percentage of geomorphons that are not flat or sloped (peak, pit, valley and ridge), whereby higher value of texture means more rough surface. Exposition shows difference between minimal point from the neighborhood and central cell and values close to zero reflect flat surface. Big advantage of both of those indicators is clear separation of flat and rough surface, while border between them is not highlighted as another feature itself.

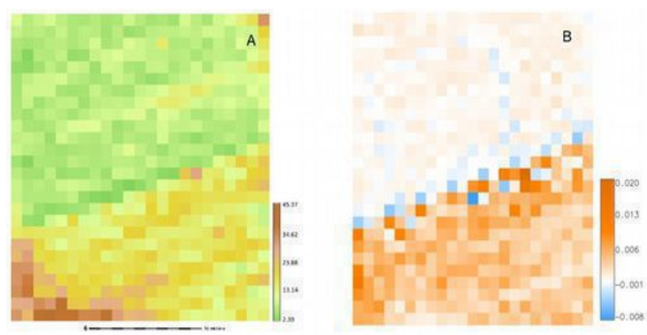

Figure 4. Models averaged for 1x1m spatial resolution showing texture (A) and exposition (B).

IV. Conclusions

Parametrization soil surface roughness at field scale is more difficult than similar task at scale of laboratory samples or for small samples of the field because for bigger scales calculations global trend can influence results. Using classical indicators like HSD, even after conducting detrending the clear separation is not achived. Adopting methodology used previously in geomorphology, based on premise of local neighborhood seems to work well independently of scale of analyst, and without being affected by global trend. Approach based on geomorphons manages to quantify surface roughness even at field scale really well, and without falsely highlighting borders between classes as another object.

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