Geoinformation Issues
Vol. 9, No 1 (9), 53–61/2017
DOI: https://doi.org/10.34867/gi.2017.5

Development of a satellite data based model for homogeneous polygons delimitation, for operational use for the agricultural sector in Poland

Martyna Gatkowska
Institute of Geodesy and Cartography, 27 Jacka Kaczmarskiego St., 02-679 Warsaw, Poland
Tel.: +48 22 3291975, Fax: +48 22 3291950, E-mail: martyna.gatkowska@igik.edu.pl
Karolina Wróbel
Institute of Geodesy and Cartography, 27 Jacka Kaczmarskiego St., 02-679 Warsaw, Poland
Tel.: +48 22 3291987, Fax: +48 22 3291950, E-mail: karolina.wrobel@igik.edu.pl
Karol Paradowski
Institute of Geodesy and Cartography, 27 Jacka Kaczmarskiego St., 02-679 Warsaw, Poland
Tel.: +48 22 3291987, Fax: +48 22 3291950, E-mail: karol.paradowski@igik.edu.pl
Michał Wyczałek
Poznan University of Technology, 5 Marii Sklodowskiej-Curie St., 60-965, Poznan, Poland
Tel.: +48 61 6653639, Fax: +48 61 665 36 35, E-mail: michal@wyczalek.pl

Abstract: The paper presents a model for homogeneous land-soil units delimitation on the basis of three main components: NDSI index (Normalized Difference Soil Index) calculated on the basis of Sentinel-2 satellite data for bare soil, NDVI (Normalized Difference Vegetation Index) calculated also on the basis of Sentinel-2 satellite data for vegetation in the end of growing phase and the DTM (Digital Terrain Model) derived from the SRTM mission. The stages of development of the designed model are presented together with the assumptions and thesis applied. The applicability of the method used and further steps to be performed are explained. The comparison of the results of land-soil units delimitation derived on the basis of the proposed model with the results of in-field electromagnetic scanning measurements (EM-38) is demonstrated. The model is proved to be applicable for the demarcation of soil managements zones in the fields and the need for its further validation is stated.

Keywords: soil parameters, NDSI index, precision agriculture, homogeneous polygons, Sentinel-2

Received: 13 November 2017 / Accepted: 23 February 2018

1. Introduction

The first applications of satellite remote sensing in agriculture date back to the 1970s, when the Landsat MSS satellite was launched (Mulla, 2013). Since then, there have been multiple studies of the utilization of remote sensing for agriculture (Singh, 2016), which, due to the increasing number of available satellite sensors, led to the first applications of satellite data for precision agriculture at the beginning of the 1990s (Mulla, 2013).

Soils play an important role in agricultural production, since they significantly affects the achieved yield and its quality. For that reason, information on soil characteristics has a prominent role in crop management practices.

Numerous researchers have been focusing on soil properties, which spatial and temporal variability is one of the pillars of precision agriculture (Sufford, 2000). Singh (2016) lists the soil characteristics which were analysed and assessed with remote sensing methods. These were mineralogy, texture, soil iron, soil moisture, soil organic carbon, soil salinity and carbonate content.

The variety of methods for the assessment of the parameters of soils is generalized by Grunwald et al.

(2015) into two broad objectives. The first one is focused on classification, in other words segmentation, of landscape into soil-landscape units, which are considered to be internally homogeneous and at the same time mutually distinct. The second approach is designed to deliver the prediction of soil properties. Moreover Grunwald (2015) demonstrates two, complementary methods of remote sensing data applications for soil parametrization: direct and indirect sensing. Within direct sensing, the soil parameters are assessed on the basis of processing of remote sensing data acquired for bare soil, whereas in indirect methods, the soil characteristics are assessed on the basis of environmental properties, such as condition of crops, yield, etc.

Mulder (2011) demonstrates that soil-landscape units (landform units) could be more accurately assessed when the spectral reflectance of soils is supported with the DTM based morphologic characteristics. At the same time, spatial and temporal variations of vegetation indices calculated from satellite data have been found to be linked to prevailing climate, ecosystem, terrain and physical soil properties (Singh et al., 2004).

The need for a more precise and repeatable method of soil surface unit delimitation was a motivation for the development of the proposed method. The demonstrated method of delimitation of homogeneous soil polygons within individual fields is based on three main components: bare soil surface reflectance explicated in the NDSI index, DTM and the NDVI value of crops at the end of the growing season.

The method was designed under the Demonstration Project ASAP “Advanced Sustainable Agricultural Production”, co-financed by the European Space Agency under the ESA Business Applications Programme. The Institute of Geodesy and Cartography, Warsaw, is the Leader of the Consortium developing the project, which is designed to run until the end of 2018. The project is expected to deliver the satellite data based operational service for the agriculture sector in Poland.

2. Input data

The presented method of homogeneous polygons delimitation is designed to develop an operational service for a significant number of individual Users within the ASAP Service, delivered by the Institute of Geodesy and Cartography, Warsaw, under the ESA Business Applications Programme.

For the purpose of the presented study, three components differentiating the soil-landscape units were selected: the NDSI index, NDVI index and Digital Terrain Model (DTM). The reason for the selection of these three components was the need to obtain a reliable and at the same time repeatable estimation of soil parameters. The spectral reflectance of the soil is affected by several of its parameters such as: soil colour, texture, mineralogy, organic matter and moisture (Singh, 2016). In order to segment the soil into homogeneous zones, the NDSI index was selected, which enables the image of bare soil to be classified into management zones, and at the same enables this activity to be performed in a repeatable manner. Secondly, according to Dobos et al. (2000), the digital elevation model delivers additional information to soil characteristics obtained on the basis of spectral reflectance. It was also assumed that the DTM would support the separation of soil polygons of similar NDSI values, but located in various terrains, e.g. on a slope or within a valley. Finally, Mulder (2011) indicated the possibility of the indirect analysis of soil patterns by the monitoring of changes of NDVI values of vegetation during the growing season. It was assumed that soil productivity influences the vegetation condition and final yield, thus the NDVI values, observed shortly before the harvest, were selected as the third component assessing the soil characteristics.

The NDSI index – Normalized Difference Soil Index (Deng, 2015) – is calculated on the basis of middle infrared and green spectral bands. Equation 1 below demonstrates the spectral bands of Sentinel-2 satellite data, applied for delivery of the NDSI index, where B11 stands for spectral reflectance in middle infrared (1610 nm) and B3 for green (560 nm). The spatial resolution of the NDSI index map is 20 m. For the purpose of this study, the NDSI index was calculated for the bare soil acquired by the Sentinel-2 satellite data on 3 September 2016 (Fig. 1).

$$NDSI = \frac{\mathrm{B11} - \mathrm{B3}}{\mathrm{B11} + \mathrm{B3}} \qquad (1)$$

The NDSI index is considered to reflect in the most efficient and operational way the difference in soil spectral characteristics.

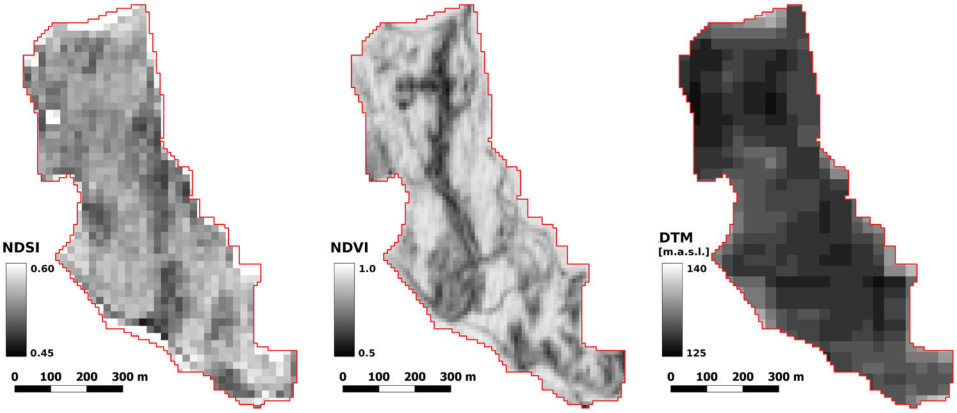

Fig. 1. Input data: NDSI index (3 September 2016), NDVI index (8 June 2016) and DTM (SRTM, 2010)

The NDVI Index – Normalized Difference Vegetation Index – is applied as an indirect sensing of soil properties. It was assumed that the NDVI index estimated for crops at their highest productive stage (before harvest) would enable the soil productivity to be assessed, in an indirect way. Moreover at the end of the growing season, the variation in NDVI index values within the field is the highest, which helps to distinguish homogeneous polygons.

Within this study, the NDVI index was calculated for winter wheat, on the basis of Sentinel-2 satellite data acquired on 8 June 2016. The NDVI index is calculated as the ratio of the difference in the spectral reflectance of crops acquired in spectral band 8 (842 nm) (near-infrared) and spectral band 4 (665 nm) (red) and the sum of these values (Eq. 2). The spatial resolution of the NDVI map is 10 m (Fig. 1)

$$NDVI = \frac{\mathrm{B8} - \mathrm{B4}}{\mathrm{B8} + \mathrm{B4}} \qquad (2)$$

In order to differentiate between the various characteristics of soils which result from various expositions of terrain, the DTM, acquired from the Shuttle Radar Topography Mission – SRTM – model with a resolution of 30 m, was implemented (Fig. 1).

3. Model development

The model of homogeneous polygons was designed in eCognition Developer 9 (version from 2014) software and demonstrated in Figure 2.

First of all, the new project, composed of inputs described above, with the boundaries of the analysed field, is created. The spatial resolution of the designed project is set as 10 m (the highest spatial resolution of the input component – NDVI index map).

Secondly, all the delivered values of NDVI and NDSI indices as well as DTM values were normalized to ensure equal influence of each input layer during the next processing steps.

These individual maps were then crosscut and the multiresolution segmentation within the processed field was conducted. The Multiresolution Segmentation algorithm locally minimizes the average heterogeneity of image objects for a given resolution of image objects. It is an optimization procedure which, for a given number of image objects, minimizes the average heterogeneity and maximizes their respective homogeneity (Trimble, 2014). The segmentation uses the Scale Parameter, which is an abstract term that determines the maximum allowed heterogeneity for the resulting image objects. For heterogeneous data, the resulting objects for a given scale parameter will be smaller than in more homogeneous data. By modifying the value in the Scale Parameter value one can vary the size of image objects (Trimble, 2014).

The algorithm, developed in eCognition software, automatically increases the initially set value of the Scale Parameter until the condition of defined mean object size is met.

The last procedure is the generalization of the results obtained. Within this process, too small poly-

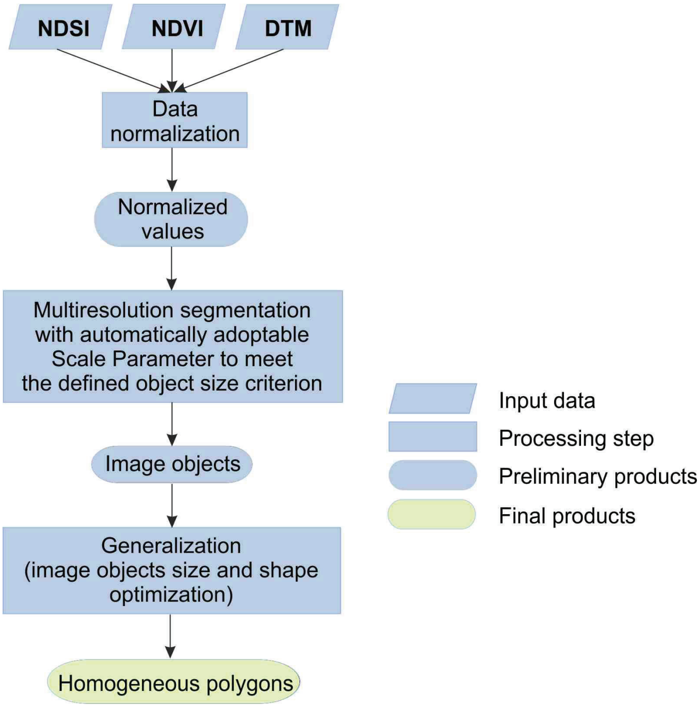

Fig. 2. The system of homogeneous polygon delimitation on the basis of Sentinel-2 satellite data

gons (in terms of shape or size) are modified or erased through their aggregation within neighbouring ones.

Finally, the map of homogeneous polygons is developed.

Figure 3 presents the map which is the result of the crosscutting described above. The numbering of polygons corresponds to the polygons characterized in Table 1, which presents the area of each polygon in [ha] as well as the max, min and mean value of each input value.

It was observed that NDSI values are not sufficient to differentiate between the characteristics of soils. In order to obtain a stronger distinction of soil variety, the NDVI index calculated for crops from the period of their strongest variance due to their condition within the field (end of the growing season) was taken under analysis. The DTM is considered essential for delimitation of soils in various morphological structures. The soil on the hillsides, on their slopes and in morphological depressions differs. That is why the use of DTM is important for the division of soil variety.

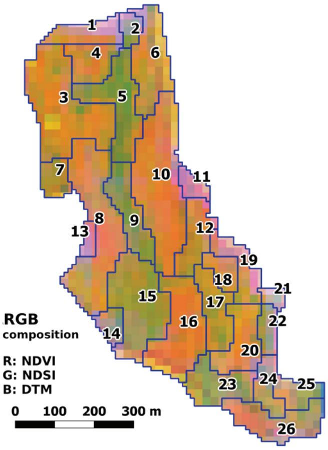

Fig. 3. Map of homogeneous polygons delivered on the basis of three data inputs: NDSI, NDVI and DTM

Figure 4 presents the result of homogeneous polygon delimitation (final result) overlapped on the each of the component maps. The visual interpretation of the correlation of final homogeneous

Table 1. The statistical data calculated for each homogeneous polygon

No.	Area [ha]	DTM [m.a.s.l]			NDSI			NDVI		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1	1.0	130	138	131.9	0.530	0.630	0.576	0.774	0.965	0.894
2	0.4	129	136	133.0	0.551	0.628	0.575	0.647	0.950	0.776
3	4.0	126	129	127.3	0.516	0.611	0.546	0.622	0.949	0.870
4	1.1	128	130	128.7	0.518	0.556	0.539	0.740	0.944	0.872
5	2.2	126	130	127.6	0.532	0.562	0.549	0.545	0.870	0.689
6	2.1	127	136	128.9	0.523	0.630	0.562	0.661	0.951	0.852
7	0.7	127	129	128.2	0.523	0.611	0.548	0.651	0.940	0.791
8	3.9	127	133	129.7	0.515	0.637	0.546	0.717	0.954	0.881
9	1.5	128	132	129.6	0.532	0.563	0.552	0.586	0.836	0.697
10	4.3	127	133	128.6	0.508	0.613	0.535	0.647	0.951	0.896
11	0.4	129	135	132.2	0.514	0.627	0.553	0.784	0.943	0.898
12	1.3	127	132	128.1	0.506	0.607	0.544	0.697	0.948	0.846
13	0.3	131	135	132.0	0.513	0.626	0.553	0.788	0.939	0.885
14	0.5	128	135	131.7	0.524	0.589	0.553	0.620	0.922	0.767
15	3.0	127	137	128.7	0.527	0.624	0.558	0.637	0.962	0.765
16	2.7	127	130	128.3	0.493	0.626	0.538	0.692	0.966	0.898
17	1.4	127	128	127.8	0.540	0.573	0.557	0.678	0.925	0.814
18	0.6	128	129	128.3	0.533	0.568	0.551	0.806	0.939	0.884
19	1.1	128	134	131.2	0.520	0.619	0.566	0.730	0.946	0.883
20	1.5	126	129	127.8	0.523	0.572	0.549	0.742	0.951	0.888
21	0.3	131	137	134.2	0.576	0.624	0.600	0.708	0.944	0.871
22	0.6	127	132	129.0	0.545	0.579	0.561	0.644	0.910	0.768
23	1.5	127	131	129.3	0.538	0.614	0.563	0.604	0.924	0.760
24	0.8	128	133	129.8	0.557	0.581	0.569	0.691	0.939	0.811
25	0.8	130	136	132.5	0.530	0.640	0.571	0.614	0.930	0.802
26	1.8	129	137	130.5	0.515	0.599	0.547	0.595	0.956	0.840

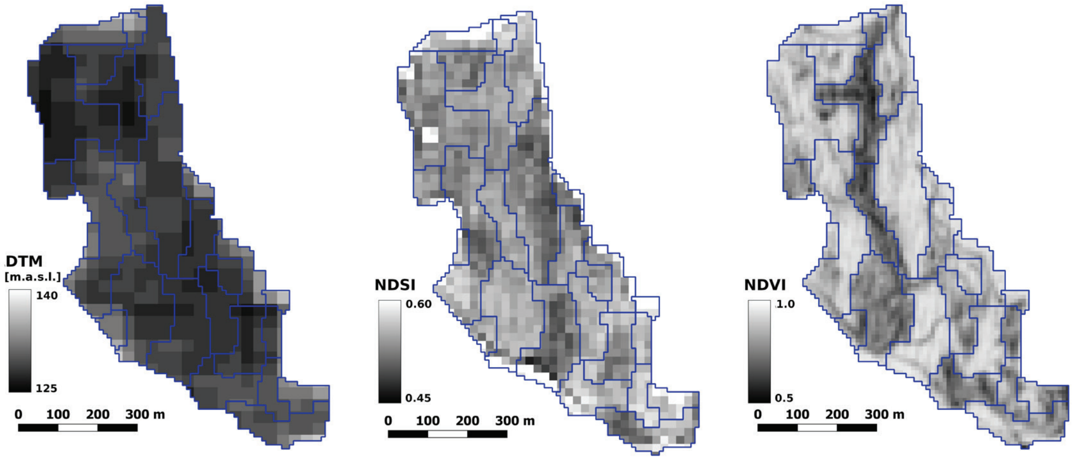

Fig. 4. Final delimitation of homogeneous polygons overlapped on DTM (on the right), NDSI index input map (in the middle) and NDVI index input map (first on the left)

polygons with each individual input map is clear and observable.

4. Validation procedure

In order to perform the validation procedure, the final results of the homogeneous polygon delimitation, were compared with the map of soil electrical conductivity.

The map of soil electrical conductivity was obtained on 1 September 2016 with the EM-38 scanner. The electromagnetic scanning performs the measurements of soil composition down to 1 m depth at the rate of 10 measurements per second. The result is presented in the digital pdf or shp file map. Since the electromagnetic scanning results are point-based, in order to compare them with satellite data based maps, they needed to be interpolated.

Interpolation was performed in eCognition software. First objects of area of 10 m^2 were created. The values of the developed polygons were estimated as the average of the point-based values delivered by the electromagnetic scanning.

Figure 5 presents the results of homogeneous polygon delimitation obtained on the basis of satellite data, overlapped on the raster map delivered in

Table 2. The range of the Electromagnetic scanning values (EM), NDSI index, NDVI index and DTM map values within each homogeneous polygon

No	Area [ha]	EM differences		NDSI differences		NDVI differences		DTM differences	
		Max-Min	90%-10%	Max-Min	90%-10%	Max-Min	90%-10%	Max-Min	90%-10%
1	1.0	4.179	2.089	0.101	0.082	0.190	0.113	8.0	4.0
2	0.4	2.617	1.602	0.077	0.035	0.302	0.237	7.0	2.0
3	4.0	5.703	2.345	0.095	0.028	0.327	0.125	3.0	1.0
4	1.1	10.508	2.663	0.038	0.028	0.204	0.115	2.0	1.0
5	2.2	5.507	3.255	0.030	0.018	0.326	0.152	4.0	2.0
6	2.1	4.401	1.924	0.107	0.060	0.289	0.170	9.0	3.0
7	0.7	4.023	1.823	0.087	0.031	0.289	0.122	2.0	1.0
8	3.9	7.382	3.185	0.121	0.044	0.237	0.123	6.0	3.0
9	1.5	4.961	2.096	0.030	0.017	0.250	0.127	4.0	3.0
10	4.3	7.578	3.018	0.105	0.037	0.304	0.097	6.0	2.0
11	0.4	3.672	1.716	0.113	0.100	0.158	0.098	6.0	6.0
12	1.3	5.391	2.461	0.100	0.045	0.250	0.168	5.0	2.0
13	0.3	4.492	3.244	0.113	0.058	0.151	0.103	4.0	2.5
14	0.5	3.411	2.359	0.065	0.037	0.301	0.217	7.0	2.0
15	3.0	6.680	1.805	0.096	0.020	0.325	0.146	10.0	2.5
16	2.7	5.429	2.867	0.133	0.079	0.274	0.125	3.0	2.0
17	1.4	5.430	2.435	0.033	0.020	0.247	0.158	1.0	0.0
18	0.6	4.483	2.188	0.036	0.029	0.134	0.082	1.0	1.0
19	1.1	5.781	0.080	0.098	0.066	0.216	0.119	6.0	6.0
20	1.5	4.570	2.383	0.049	0.041	0.209	0.121	3.0	2.0
21	0.3	5.199	1.799	0.048	0.038	0.236	0.022	6.0	6.0
22	0.6	2.774	1.810	0.033	0.012	0.267	0.152	5.0	5.0
23	1.5	4.063	2.665	0.076	0.036	0.320	0.209	4.0	2.0
24	0.8	3.386	2.493	0.023	0.019	0.247	0.162	5.0	0.0
25	0.8	3.828	2.607	0.110	0.034	0.316	0.240	6.0	4.0
26	1.8	6.524	3.036	0.084	0.054	0.360	0.176	8.0	2.0

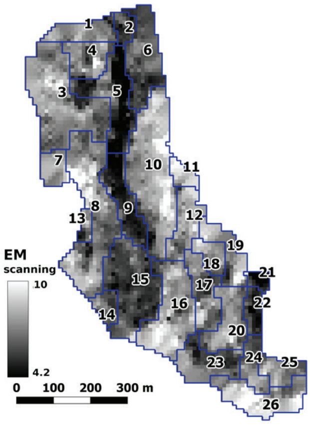

Fig. 5. The map of homogeneous polygons, delivered with the method demonstrated in the article, overlapped on the map of interpolated point-based measurements performed through electromagnetic scanning

the process of the generalization of the map performed through electromagnetic scanning.

In order to compare the homogeneity of the polygons delimited on the basis of satellite data and through electromagnetic scanning, statistical analysis was performed (Table 2).

Table 2 presents the distance between the maximum and minimum values of each parameter, for each delimited polygon. In the case of the satellite data derived model, the boundaries of the polygons obtained needed to be generalized in order to avoid the "salt and pepper" result. Due to that fact, for the purposes of analysis, the most extreme values (<10 % and >90%) were excluded.

The elimination of the Extreme values of each component data – 10 % of the lowest and highest values – is the result of the generalization of the results obtained. The eliminated polygons whose areas were too small, were included in the larger neighbouring polygons. It was observed that due to various spatial resolutions of input data, the irregular polygons of too small area are demarcated. Due to the fact that the designed model is aimed at being up-taken for operational use for farmers, the generalization was found to be essential.

In Figures 6-9, the difference between the range of EM, NDSI, NDVI and DTM values before elimi-

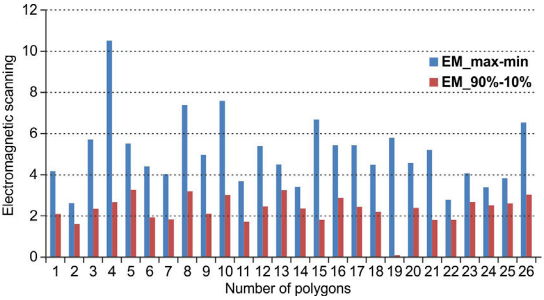

Fig. 6. Difference in the Electromagnetic scanning values before and after elimination of extreme values for individual polygons

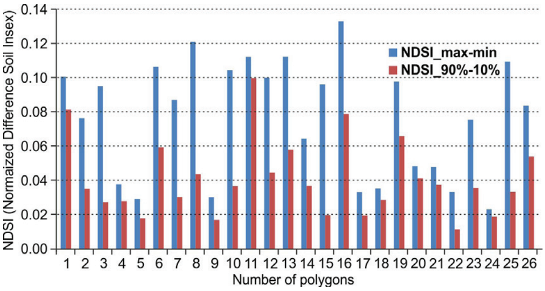

Fig. 7. Difference in the NDSI index values before and after elimination of extreme values for individual polygons

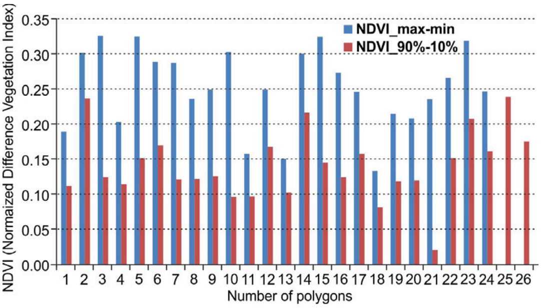

Fig. 8. Difference in the NDVI index values before and after elimination of extreme values for individual polygons

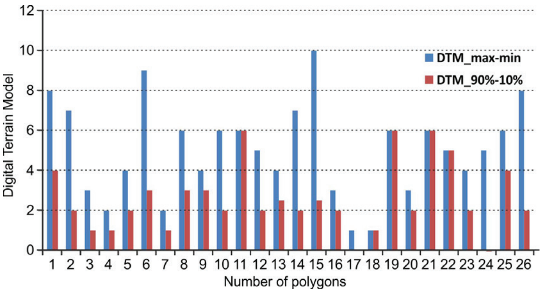

Fig. 9. Difference in the DTM values before and after elimination of edge values for individual polygons

nation and after elimination of the Extreme values is presented for each individual polygon.

As is observed, the difference between the maximum and minimum values, after elimination of the extreme 10%, was in most cases, decreased by 50%.

In Table 3 the average difference between Minimum and Maximum values of electromagnetic scanning, NDSI and NDVI indices as well as DTM values within the whole field, are demonstrated as well as the average values before and after elimination of extreme values are indicated.

Table 3. Average difference between Minimum and Maximum values of electromagnetic scanning, NDSI and NDVI indices as well as DTM values, before and after elimination of the extreme values

Component:	Average difference Max - Min	Average difference Max - Min after elimination of the extreme values
Electromagnetic scanning	5.076	2.306
NDSI index	0.077	0.041
NDVI index	0.259	0.142
DTM	5.038	2.558

In Table 4, the Mean, Maximum and Minimum values of all components of the model for homogeneous polygon delimitation: NDSI index, NDVI index as well as DTM and the interpolated values of Electromagnetic scanning, within the whole field are demonstrated.

The values of the components within individual homogeneous polygons are much more condensed than within the whole field. Moreover the Max and Min values of the components differ between polygons. These two observations are considered to prove delimitated polygons internal homogeneity with mutual distinction.

5. Summary and conclusions

The results have crucial scientific and application importance. Taking into account two indices calculated from the new European satellite Sentinel-2 (NDVI and NDSI) and DTM it is possible to advise to the farmer how to manage the farm in an optimum way in order to obtain the potential for his farm yield. It was also proved that applying only one index based on satellite data and to indicate the crop yield and crop prognosis on the basis of it is not sufficient. There is no need to consider the type of the soil, which is difficult to obtain, but to consider it through the indirect method using spatial and temporal information. It is also proved that the satellite data have very strong potential for precision agriculture and that there is no need to obtain numerous time-consuming and expensive ground data. The new index gave very good results due to Mid Infrared (MIR) information and should be introduced to the research on agriculture.

The work on precision farming with the implementation of Sentinel-2 from the new European Copernicus Programme will be continued by the authors of this paper.

Acknowledgements

The presented work was performed within the project entitled: Advanced Sustainable Agricultural Production (ASAP), co-financed by the European Space Agency under the ESA Business Applications Programme.

Table 4. Mean, Maximum and Minimum values of components of homogeneous polygons, measured for the field as a whole

Component:	Mean values for the whole field	Maximum values for the whole field	Minimum values for the whole field	Difference Max - Min
Electromagnetic scanning	7.060	14.805	2.617	12.188
NDSI index	0.551	0.637	0.493	0.144
NDVI index	0.837	0.966	0.545	0.421
DTM	129	137	126	11

References

Deng Y., Changshan W., Miao L., Renrong C., (2015): *RNDSI: A ratio normalized difference soil index for remote sensing of urban/suburban environments*, International Journal of Applied Earth Observation and Geoinformation, 39 (2015), pp. 40–48.

Dobos E., Micheli E., Baumgardner M.F., Biehl L., Helt T., (2000):*Use of combined digital elevation model and satellite radiometric data for regional soil mapping*, Geoderma 97, pp. 367–391.

Grunwald S., Vasque G.M., Rivero R.G., (2015): *Fusion of Soil and Remote Sensing Data to Model Soil Properties Advances in Agronomy*, Vol. 131, pp. 1–109.

Mulder V.L., de Bruin S., Schaepman M.E., Mayr T.R., (2011): *The use of remote sensing in soil and terrain mapping – A review*, Geoderma 162, pp. 1–19.

Mulla D.J., (2011): *Twenty five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps*, Biosystem Engineering, 114, pp. 358-371.

Singh D., Herlin I., Berroir J.P., Silva E.F., Meirelles S.M., (2004): *An approach to correlate NDVI with soil colour for erosion process using NOAA/AVHRR data*, Adv. Space Res. 33 (3), pp. 328–332.

Singh S., (2016): *Remote sensing applications in soil survey and mapping: A Review,* International Journal of Geomatics and Geosciences, Vol. 7, No 2, pp. 192–203.

Trimble, (2014): *Cognition Developer 9.0 Reference Book*, Version 9.0, User Guide, Munich, Germany.

Opracowanie modelu do wyznaczania obszarów homogenicznych gleby, na podstawie danych satelitarnych, celem operacyjnego zastosowania dla sektora rolniczego w Polsce

Martyna Gatkowska
Instytut Geodezji i Kartografii, ul. Jacka Kaczmarskiego 27, 02-679, Warszawa
Tel.: +48 22 3291975, Fax: +48 22 3291950, E-mail: martyna.gatkowska@igik.edu.pl

Karolina Wróbel
Instytut Geodezji i Kartografii, ul. Jacka Kaczmarskiego 27, 02-679, Warszawa
Tel.: +48 22 3291987, Fax: +48 22 3291950, E-mail: karolina.wrobel@igik.edu.pl

Karol Paradowski
Instytut Geodezji i Kartografii, ul. Jacka Kaczmarskiego 27, 02-679, Warszawa
Tel.: +48 22 3291987, Fax: +48 22 3291950, E-mail: karol.paradowski@igik.edu.pl

Michał Wyczałek
Politechnika Poznańska Wydział Budownictwa Instytut Inżynierii Lądowej, Zakład Geodezji, pl. Marii Skłodowskiej-Curie 5, 60-965 Poznań
Tel.: +48 61 6653639, Fax: +48 61 665 36 35, E-mail: michal@wyczalek.pl

Streszczenie: W artykule zademonstrowany jest model wyznaczania obszarów jednorodnych, pod kątem właściwości gleby, w obrębie pola z jednorodną uprawą. Zaproponowany model jest opracowany na podstawie trzech komponentów wejściowych: wskaźnika NDSI obliczonego na podstawie obrazu satelitarnego gołej gleby zarejestrowanego przez satelitę Sentinel-2, wskaźnika NDVI obliczonego na podstawie obrazu satelitarnego Sentinel-2 dla uprawy pod koniec okresu wegetacji oraz Numerycznego Modelu Terenu DTM, pozyskanego z misji SRTM.

W artykule przedstawiono krótki przegląd literatury dotyczący zastosowania teledetekcji satelitarnej dla szacowania parametrów gleby. Ponadto w artykule zaprezentowano etapy opracowania modelu, przyjęte tezy i założenia, jak również dalsze kroki rozwoju modelu i jego zastosowania w operacyjnym serwisie ASAP.

Słowa kluczowe: parametry gleby, wskaźnik NDSI, rolnictwo precyzyjne, obszary homogeniczne, Sentinel-2

INSTRUCTIONS TO AUTHORS

GEOINFORMATION ISSUES (Problemy Geoinformacji) is a journal issued 1-2 times a year, publishing peer-reviewed articles covering theoretical, experimental or applicable problems of geodesy, surveying engineering, photogrammetry, cartography, GIS and remote sensing.

Legal requirements

The author(s) guarantee(s) that the manuscript will not be published elsewhere in any language without the consent of the copyright owners, that the rights of the third parties will not be violated, and that the publisher will not held legally responsible should there be any claims for compensation.

Authors wishing to include figures or text passages that have already been published elsewhere are required to obtain permission from the copyright owner(s) and to include evidence that such permission has been granted when submitting their papers. Any material received without such evidence will be assumed to originate from the authors.

Manuscript submission

Submission of the manuscript implies that the work has not been published before (except in form of an abstract or as a part of a published lecture, review or thesis); that it is not under consideration for publication elsewhere; that its publication has been approved by all co-authors, if any, as well as by the responsible authorities at the institution where the work was carried out.

Manuscripts should be submitted in English in electronic form to the Editor-in-Chief of GEOINFORMATION ISSUES, 27 Modzelewskiego St., 02-679 Warsaw, Poland, tel:+48 22 3291904, fax:+48 22 3291950, e-mail: geoinfo@igik.edu.pl. Please be sure to include your e-mail address and your fax as well as phone number. The manuscripts and figures will not be returned, unless specifically requested by the authors.

In case the manuscript has more than one author its submission should include the list specifying contribution of each author to the manuscript with indicating who is the author of the concept, assumptions, research methodology, data processing. Major responsibility is of the author submitting the manuscript.

The Editor will counteract in GEOINFORMATION ISSUES against *Ghostwriting*, i.e. when someone substantially contributed to the preparation of the manuscript but has neither been included to the list of authors nor his role is mentioned in the acknowledgements as well as *Ghost authorship*, i.e. when the author/co-author did not contribute to the manuscript or his contribution is negligible. Any detected case of *Ghostwriting* and *Ghost authorship* will be exposed and the appropriate subjects, i.e. employers, scientific organisations, associations of editors etc, will be informed.

Electronic submission of a manuscript

Layout guidelines:

- use a normal, plain Times Roman font for text, italics for textual emphasis, bold for mathematical vectors,
- use the table functions of your word processing program, not spreadsheets, to make tables,
- use the equation editor of your word processing program for equations,
- place all figures with figure legends and tables with table legends in the manuscript,
- submit also all figures as separate files.

Data format:

Save your manuscript in RTF or DOC Microsoft Word for Windows format.

Illustrations:

Figures should be provided in the vector graphics. The preferred figure format is CDR (Corel Draw), XLS (Microsoft Excel), EPS. Exceptionally JPG or TIF (specifically for halftone illustrations) formats will be accepted. The filename should include the figure number. Figure legends should be included in the text and not in the figure file. Scanned line drawings should be digitised with a minimum resolution of 800 dpi relative to the final figure size. For digital halftones, 300 dpi is usually sufficient. Non-standard fonts used in the vector graphics must be included. Please do not draw with hairlines. The minimum line width is 0.2 mm (0.567 pt) relative to the final size.

Delivery of a manuscript:

Please send your manuscript, preferably a zip file (text and illustrations in separate files, unencoded) either by e-mail or on a CD ROM. Please always supply the following information with your data: operating system, word processing program, drawing program, image processing program, compression program. The file name should be memorable (e.g. author name), have no more than 8 characters, and include no accents or special symbols.

Manuscript preparation

Manuscripts should be typed in single-line spacing throughout on the A4 sheet with 2.5 cm margins.

1. **Title page:**
- a concise and informative title,
- the name(s) of the author(s),
- the name(s) and address(es) of the affiliation(s) of the author(s),
- the e-mail address, telephone and fax numbers of the communicating author.

2. **Abstract:** the paper must be preceded by a sufficiently informative abstract presenting the most important results and conclusions.

3. **Keywords:** three to five keywords should be supplied.

4. **Introduction:** should state the purpose of the investigation and give a short review of the pertinent literature.

5. **Acknowledgements:** should be brief and consist of grant or individuals that require acknowledgement.
The names of funding organizations or institutions providing data should be given in full.

6. **References:** the list of references should be in alphabetical order and should only include works that are cited in the text and that have been published or accepted for publication. Personal communications could only be mentioned in the text. References should consist of the complete list of authors and should be given in the following form:
- journal articles:

Blais J.A.R., Lodwick G.D., Ferland R., (1983): *Gravimetric terrain corrections in western Canada*, Canadian Journal of Earth Science, Vol. 20, No 2, pp. 259–265.
- books:

Heiskanen W.A., Moritz H., (1967): *Physical geodesy*, W.H. Freeman and Company, San Francisco.
- multi-author books (proceedings):

Rummel R., (2000): *Global unification of height system and GOCE*, in: M.G. Sideris (ed), Gravity, Geoid and Geodynamics 2000, IAG Symposia, Vol. 123, Springer, pp. 13–20.

In the text, references should be cited by author(s) last name and year: e.g. (Beutler, 2003a), (Müller and Rapp, 1993), (Schwarz et al., 1990), (Sjöberg et al., 2000; Sideris, 2001b; 2002).

7. **Formulae and symbols:** must be written legibly and will be typeset in italics. One-layer indexing is preferable. Numbering of formulae, if necessary should be given in brackets fitted to the right margin.

8. **Footnotes:** to the text should be numbered consecutively and placed on the bottom of the page to which they refer. Footnotes to the tables should be indicated by superscript lowercase letters.

9. **Illustrations and tables:** all figures (photographs, graphs or diagrams) and tables should be cited in the text and each numbered consecutively throughout. Lowercase roman letters should identify figure parts. Figure legends must be brief and must contain self-sufficient explanations of the illustrations. Each table should have a title and a legend explaining any abbreviation used in that table.

10. **Units:** SI units must be used.

11. **Running head:** consisting of at most 60 characters a concise banner representing the title of the article must be submitted by the author(s).

Proofreading

Proofreading is the responsibility of the author. Corrections should be clear; standard correction marks should be used. Corrections that lead to a change in the page layout should be avoided. The author is entitled to formal corrections only. Substantial changes in content, e.g. new results, corrected values, title and authorship are not allowed without the approval of the editor. In such case please contact the Editor-in-chief before returning the proofs.

Free copy

Each author will receive one complimentary copy of the current journal. All copies are supplied to the communicating author.

Cena 30,00 PLN (w tym 5% VAT)

Please mail orders and inquiries to:
Institute of Geodesy and Cartography
27 Jacka Kaczmarskiego St.
02-679 Warsaw, Poland
tel. +48 22 3291920, fax +48 22 3291950
e-mail: boi@igik.edu.pl

Zamówienie krajowe można składać do:
Instytutu Geodezji i Kartografii
ul. Jacka Kaczmarskiego 27
02-679 Warszawa
tel. +48 22 3291920, fax +48 22 3291950
e-mail: boi@igik.edu.pl