Rating of soil heterogeneity using by satellite images

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Abstract: Knowledge of the level of variability of site conditions is the basis for deciding on deployment of technologies locally targeted farming, known under the term precision agriculture. The aim of this paper is to compare two sets of remote sensing data, acquired between 2012 and 2013, for assessing the variability of arable land. Data are capturing the South Moravien Region with a total area of 1100 km^2 by Rapid Eye (2012) and Landsat 8 (2013) satellites. As the other input data, field boundaries from government database LPIS were used to identify the blocks of arable land. The first step was a selection of arable land through polygons from the LPIS and identification of bare soil by calculation of normalized differential vegetation index (NDVI) from spectral data. An image classification was performed on these grounds in order to create class of information describing the spectrum of surfaces forming the bare soils.
Comparison of both satellite datasets proved difference between the images. Landsat 8 data showed higher error, probably due to the lower spatial resolution of data. (30 m per pixel). In this case Rapid Eye imagery offers higher spatial resolution (5 m per pixel), which seems to be more suitable for identification of soil heterogeneity, especially in smaller fields.

Key-Words: remote sensing, Rapid Eye, Landsat 8, NDVI, soil heterogeneity, coefficient of variation

Introduction
Knowledge of the level of variability of site conditions is the basis for deciding on deployment of technologies locally targeted farming, known under the term precision agriculture. The goal of precision agriculture is to adapt the intensity of cultivation interventions to specific habitat conditions. Determine the heterogeneity of land is therefore first and necessary step. Remote sensing (RS), one of non-invasive mapping methods, is special, very powerful way to mapping soil variability performed by air planes or Satellite carriers of sensors. Its greatest advantage is the possibility of monitoring the spatial variability over time with high resolution and performance. Extensive areas can be mapped in a short time and with high complexity output. By RS can be indicated the soil properties that affect reflectivity, such as organic matter content, soil moisture, soil texture and presence of iron oxides[1]. All above is referred to the upper layer of soil surface[2].

For mapping are used the sensors with several levels of spatial or radiometric resolution. High-resolution (spatial) sensors (e.g., SPOT-HRV, Landsat 8 OLI) with resolutions of approximately 20–30 m can detect objects within the canopy level, which is fine enough to describe the landscape [3]. The using of different variables derived from remote sensing data (e.g., vegetation index, reflectivity of surface, *etc*.) regarding to spatial heterogeneity, however, need to be considered.

For the differentiation of bare arable land in the blocks was used NDVI index in this study. The Normalized Difference Vegetation Index (NDVI) [4] has been widely used for monitoring the biophysical condition and vegetation cover[5]. It is frequently used to describe surface spatial heterogeneity [6, 7]. The using of NDVI may not be always the best choice. The NDVI may be limited to capturing the landscape properties for the saturation of the red or near-infrared bands and the sensitivity to soil [3].

Assessment of soil variability is done by traditional statistical and geostatistical methods.

The aim of this work was to verify the procedure for determining the variability of soil blocks remote sensing data in the selected area of southern Moravia. For these purposes were selected two sets of satellite images – Rapid Eye offered commercially and freely available Landsat 8 LDCM.

Material and Methods

Introduction of used data sets

The RapidEye images are a proper source of information for soil mapping [8, 9]. The Rapid Eye data sets have a spatial resolution of 6.5 m in five spectral bands: Blue (440-510 nm), Green (520-590 nm), Red (630-685 nm), Red Edge (690-730 nm), and Near Infrared (760-850 nm).

Data were purchased as the Level 1B product, which needs to be geometrically processed. The orthorectification was processed by digital elevation model from ASTER satellite and subsequently new bitmap mosaics were created in the Arc GIS 10.1. Landsat 8 data were downloaded from the U.S. Geological Survey website as the free product geometric and radiometric corrected. It consists of eleven bands with a resolution of 15-100 m / pixel. Landsat 8 data set are mentioned for example by [10] in study of soil sealing. Four images (taken in March 2012, April 2012 and September 2012) were used as an input depicting the 1100 km^2 of South Moravian Region by the Rapid Eye satellite. Second part of imagery was completed by Landsat 8 images immediately after Landsat mission launching in April and September 2013. Both sets of data captured approximately the same area of the South Moravian region (Czech Republic). More than 90% of agricultural land in the region, where agricultural subsidies are provided, an arable land, which part is not in the above mentioned periods covered by vegetation. At this time there was an assumption of the largest area of bare soil before the start of the growing season (March and April) and after harvest (September). The rate of soil variability is expressed in this paper by the coefficient of variation (V_x).

The data processing

For selecting of bare soil was also used the data set from Land Parcel Information System (LPIS), managed by Ministry of Agriculture, in form of spatial and descriptive representation of blocks of arable land in SHP format.

For each slide NDVI index was calculated using a Raster calculator and set a limit for arable land based on the values of the index. Through LPIS blocks of bare arable land were selected. However, this method of data selection (combination of intervals of arable land and polygons with arable land) considerably reduced the area which truly represents the arable land. Therefore, the blocks of bare arable land with the number of pixels greater than or equal to 50 % of the original number of pixels of areas of bare soil selected by data from the system iLpis were added to classification. This condition was implemented because of the highest possible selection of the most representative data in the respective periods. After classifying the images were again analysed in an Arc GIS 10.1 to calculate the coefficient of variation. To determine the coefficient of variation and descriptive statistics a tool called Zonall statistic was used. Areas of bare soil were divided, based on the values of the variation coefficient, according to the following clue:

Table 1 The clue for the classification of land according to the coefficient of variation

The value of Cv	Soil variability
0 - 49%	slightly variable soil
50 - 100%	variable soil
More then100%	highly variable soil

This clue is based on the classification of the coefficient of variation based on the statistics.

Results and Discussion

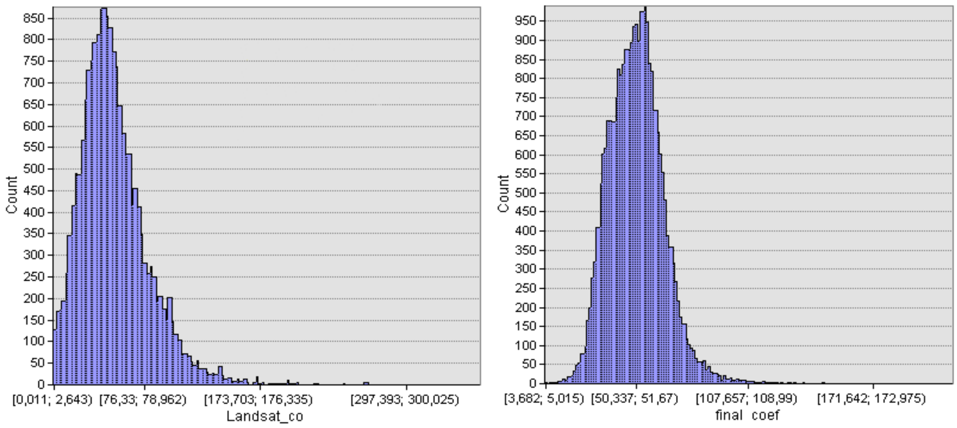
Due to the region of South Moravia, arable land predominates in all scenes and images and therefore provide the ideal material for the study of variability of bare arable land. The trend of reducing of arable land, which participated in the analysis, captures interesting facts. Data taken at the end of March make possible to appreciate the greatest amount of arable land and seem to be from all the scenes information-rich.

Fig. 1 Summary of arable land blocks and blocks satisfying the condition of coverage

Analyzed scenes	Total area of blocks in the scene (ha)	The total area of arable land		The total area of arable land meeting the conditions	
		In ha	% in total area of blocks	In ha	% in total area of blocks
March 25, 2012	209 226	193 445	92,46	129 466	61,88
April 27, 2012	222 529	204 092	91,71	73 913	33,22
Sept 9, 2012	209 100	193 024	92,31	113 221	54,15
Sept 11, 2012	176 805	155 425	87,91	93 360	52,80
April 15, 2013	347 368	314 011	90,39	122 811	32,47
Sept 6, 2013	347 368	314 001	90,39	166 040	47,79

The April term is the smallest of all the scenes of arable land satisfying the condition in both cases. April is thus informative poorest month. The Period at the end of April was not the best choice. The relatively low proportion of bare arable land, satisfying the condition, also shows data taken in September. In both cases, is bare cropland represented in more than half of the image. If we compare the information value of both satellites (the percentage of blocks satisfying the conditions) appear to be data from Landsat 8 overall information less convenient choice. The performance of the coefficient of variation for all four scenes is captured in the following figure:

Fig. 2 Histograms of V_x for each of data set



Both data sets have a sharper division. Median and average data of Rapid eye are virtually a viable. Skewness is close to zero here. Data have almost normal distribution, which spoils the only value of kurtosis. Values are relatively evenly distributed around the center. Data set of Landsat 8 are slightly left of the positively skewed with an excess of small values. Higher value of maximum is probably the result of errors and hangs lower resolution data. Also, a higher standard deviation indicates higher variability data from LANDSAT 8 exact opposite is then the Rapid Eye data.

Fig. 3 Levels of variability captured by Rapid Eye

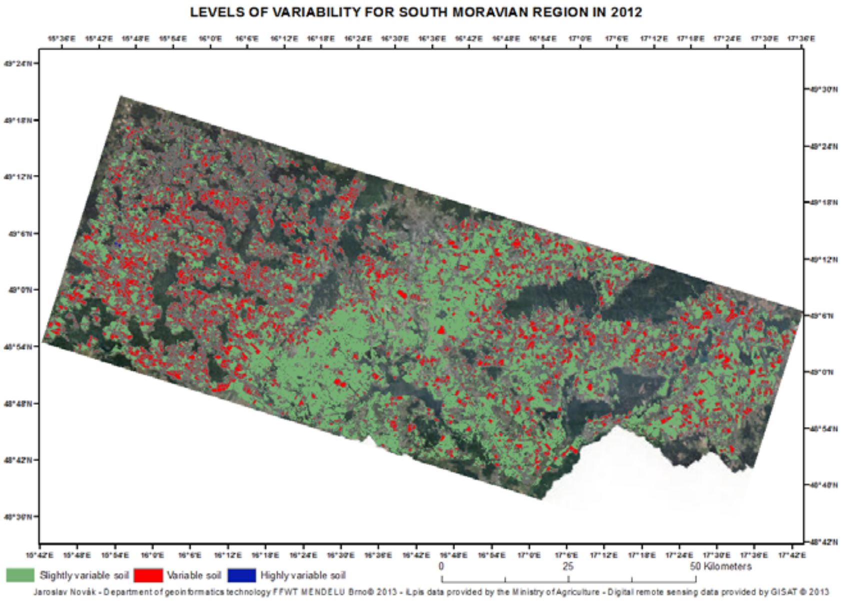


Fig. 3 shows a map with the resulting output variability derived from Rapid Eye data. Most of notably, it seems at first glance the western side of the region overlapping the Highlands, in which is concentrated the largest percentage of variable soil. Rather then, it is a land with a smaller than average specific occupation of the area. Similar interpretation is valid for eastern part of the country and in adjacent areas of the Zlín region too. The central part of the region is an area of slightly variable soil with occasional occurrence of variable land. The occurrence of variable soil is lower than in the western part.

Fig. 4 Levels of variability captured by Landsat 8

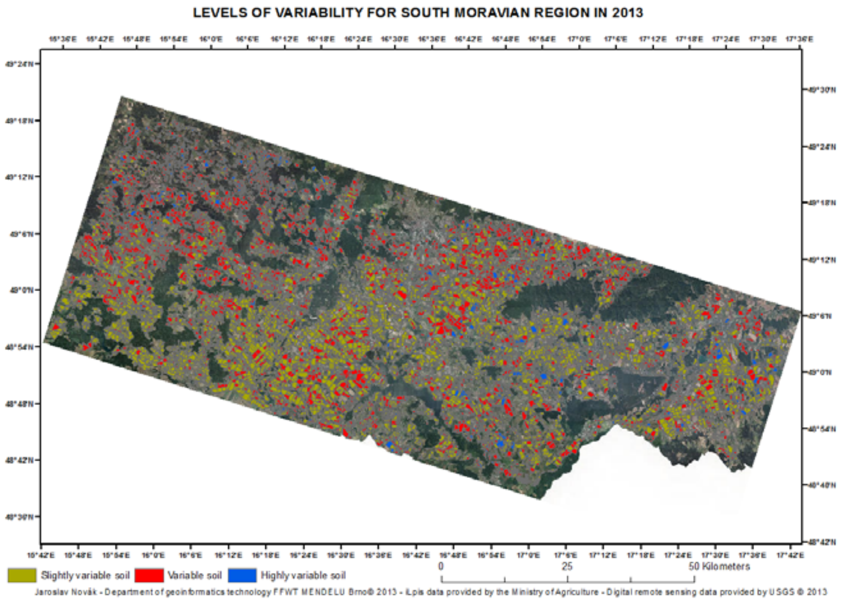


Fig. 4 shows the evaluated data from LANDSAT satellite eighth. Variable soil is here randomly occured throughout almost the whole monitored area and is not correlated with particular places. Quite often is here, in comparison with Rapid Eye data, highly variable soil occured. This exist probably due to the low spatial resolution Landsat 8 data (30 m per pixel) compared with Rapid Eye data (5 m per pixel), which thus appear to be more suitable for the identification of heterogeneity, especially on land with an area less than 10 hectares.

Conclusion

Both data sets can certainly be used as a preview to the variability of soil, however, data Rapid eye seem to be more suitable due to their higher spatial resolution. Their main disadvantage is the cost and the necessity to pre-processing of data sets at this level of quality. Data of Landsat 8 data are free available, but their low resolution can distort the possible variability, especially on land with an area less than 10 ha. Selected process of variability evaluation and classification into three grades are only the first steps in creating of a relevant information source. For more detailed description of spatial variability of soil parameters and their effects on the crop management, more specific soil survey is needed.

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