SOIL COLOUR SPECTRAL ANALYSIS

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Abstract. The aim of the research: to check whether it is possible to use the results of soil color analysis from digital SLR photography to make digital cartograms of the content of humus substances in the soil. The experimental analysis of the theoretical modules proves that there is a perspective in performing soil humus content analysis using robots and in advance compiled data base.

Keywords: winter wheat, precision agriculture, soil colour spectral analysis, humus content.

Introduction

In areas with uneven soil properties the execution of technological difference based on the data of projects of soil survey is a current matter. The analysis of the soil is one of the conditions to develop a stable harvest of cultivated plants and it is used to make a fertilisation plan. In order to determine the content of organic and humus substances in the soil and develop digital GPS cartograms, farmers in Latvia have to face expenditures of the amount of 8-14 LVL per hectare. If the sown area where the analysis of the soil is needed is 100 ha large, the expenditures are added up to 800-1400 LVL. In conditions of unstable prime cost and sale price of the produced products any money saved is essential to the farmer hence the necessity of optimized expenses of soil analysis. In the global agriculture practice use of robot technology and sensor technology is a perspective trend of which there is too little scientific agronomic information in Latvia. The Munsell scale is often used to describe soil colors [2] but the RGB scale is more suitable for obtaining scalar defined descriptions. Scientific researches prove that the results of RGB spectrum analysis of the soil color can be successfully used in description of soils with less financial capacity of analysis. There are works and theoretical modules of the use of color sensors in terms of robotics and GPS elements in conditions of heterogeneous soil properties [3]. The aim of the research: to check whether it is possible to use the results of soil color analysis from digital SLR photography to make digital cartograms of the content of humus substances in the soil.

Materials and methods

The field experiment basis was the Latvia University of Agriculture Research and Study Farm "Vecauce", during the years 2006 to 2012 in the field Kurpnieki. The field is characterized by wavy mesorelief with the height of points above the sea level differences from 88.5 till 106.7 m. On the top part of the field: typical sod-calcareous soil (*Hypocutani-Hypocalcic Luvisol* (*Hypochromic*)), in the middle slope part of the hummock to confluence: typical sod-calcareous soil with indications to top gleying in the soil layer of 122-181 cm (*Bathystagni-Luvic Phaeozem* (*Abruptic, Calcaric*)) and on the lower part of the hummock with confluence: mucky-humus gley soil (*Ombri-Sapric Histosol* (*Hypereutric*)) [1]. 37 observation points (distributed as grid 50x50 m) were selected in the winter wheat *Triticum aestivum* L. sowing. The coordinates of the observation points were defined by GPS receiver Garmin IQ 3600 and Trimble GeoXT using CLAAS Agrosystems software AgroMAP Professional. The soil samples from topsoil for agrochemical analyses were taken with a probe to determine humus, $g \cdot kg^{-1}$. The analyses were performed in the State Plant Protective Service Agrochemical Department. The humus content was photo metrically determined with the Tjurin method (LV ST ZM 80-97). Digital images of soil and sowing fields were taken using Nikon D5000 camera, the soil samples were used for humus composition analysis and modeling 5, 10, 15 and 20 % soil moisture adding the corresponding amount of water to the soil samples. To specify the thesis of the work in the field experiment modules for soil moisture gradation GPS points with characteristic humus content for a specific field were chosen: 1.7; 1.9; 2.5; 3.4; 3.8 and 7.6 %. With HP Officejet 3600 scanner using specific soil sample forms images were obtained and further processed using Adobe Photoshop CS3 for RGB analysis (Fig. 1). For soil image color analysis following characteristic were used: hue (HUE) and saturation (S) and brightness (Br) as well as red (R) green (G) and blue (B).

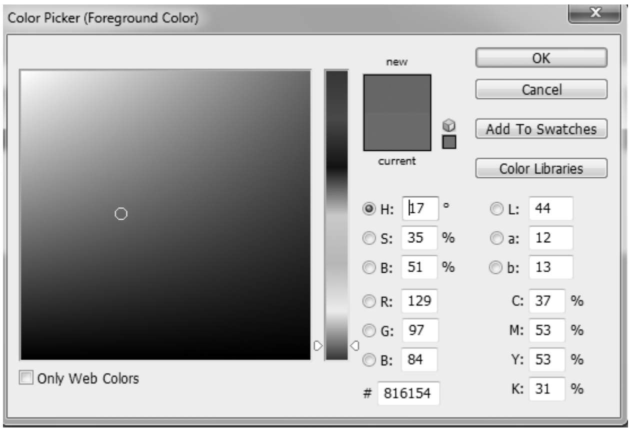

Fig. 1. **Use of Photoshop CS4 colour classificator**

The yield of winter wheat was harvested with the harvester ClAAS Lexion 420 to create the yield map using CLAAS Agrosystems software in 2005 to 2007, but the yield of winter wheat in 2012 was determined by taking 3 plant samples in each observation point. Determination of the winter wheat yield formatting elements was done in the same time. Mathematical data processing was performed using Microsoft Excel and SPSS.

Results and discussion

The evaluation of the importance of the content of humus substances in differences of the amount of winter wheat harvest showed that its effect differs from year to year and the level of importance is inconsistent. The coherence was considerable (Table 1).

Table 1

Spearman's linear correlation coefficients between the harvest of winter wheat (*y*) and the content of humus substances in the soil (*x*)

Indices	2007	2012	Average in 2 years
r_{yx}	0.524	0.253	0.470
Sign. (1-tailed)	0.0003	0.0575	0.0011

Two important facts came clear while analyzing the first photographed and scanned soil samples. First, the photographed samples showed weak and unimportant linear correlation between RGB and HUE, which means the obtained image does not project the real-life soil color. There were many colors for a single sample due to the changing environment, angle of solar beams, clouds, shadows on uneven soil and other factors (Table 2).

Table 2

Linear correlation coefficients between HUE and RGB indexes

Indices	R	G	B
Scanned images	0.93*	0.88*	0.68*
Images with SLR	-0.04	0.07	0.04

Symbols: *important coherence $p < 0.05$

It can be solved by ensuring darkness if possible, but even then the fact remains that the camera must be precisely adjusted. Proper white balance must be ensured in order not to change the real color of the image. From this it can be concluded that using the camera to obtain an image which projects real-life colours is difficult, so other solutions must be found.

A scanner was used in order to eliminate the influence of the environment and lessen the human factor. It means that the soil samples cannot be fully analyzed and evaluated on the field, and previous work in the lab and development of a data base is needed. The results showed that the spectrum content of the soil in RGB scale was affected by the soil moisture level, but this level can be precisely diagnosed using sensor technologies while robots are working [3; 4]. In the researches nonlinear polynomial coherences between the content of humic substances and the colour of the soil in RGB spectrum analysis results were made precise.

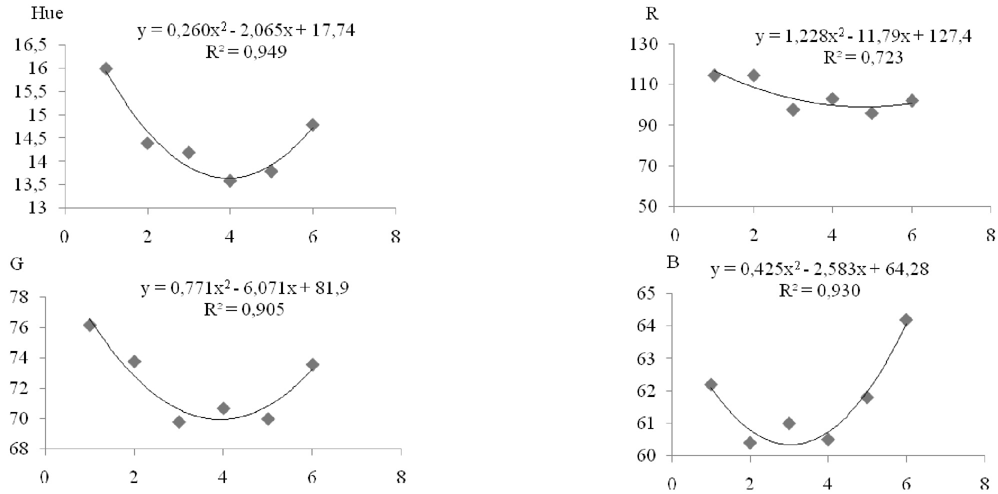

Fig. 2. **Characteristic of nonlinear polynomial coherences between the content of humic substances (*x*) and the color of soil in RGB spectrum analysis results (*y*) in all modeling variants of soil moisture**

The critical functional coherence change point on the content of humic substance of 4 $mg \cdot kg^{-1}$ must be indicated in the characteristic of nonlinear coherences (Fig. 2). It means that grading composition content for every soil type must have a larger number of observation cases above and below 4 $mg \cdot kg^{-1}$ in the data base in order to ensure the importance of all polynomial function domains. Considering it is easier to ensure the soil moisture level during robotic work on the field, it is essential to explain the coherences of soil moisture using RGB scale (Fig. 3 and Fig. 4).

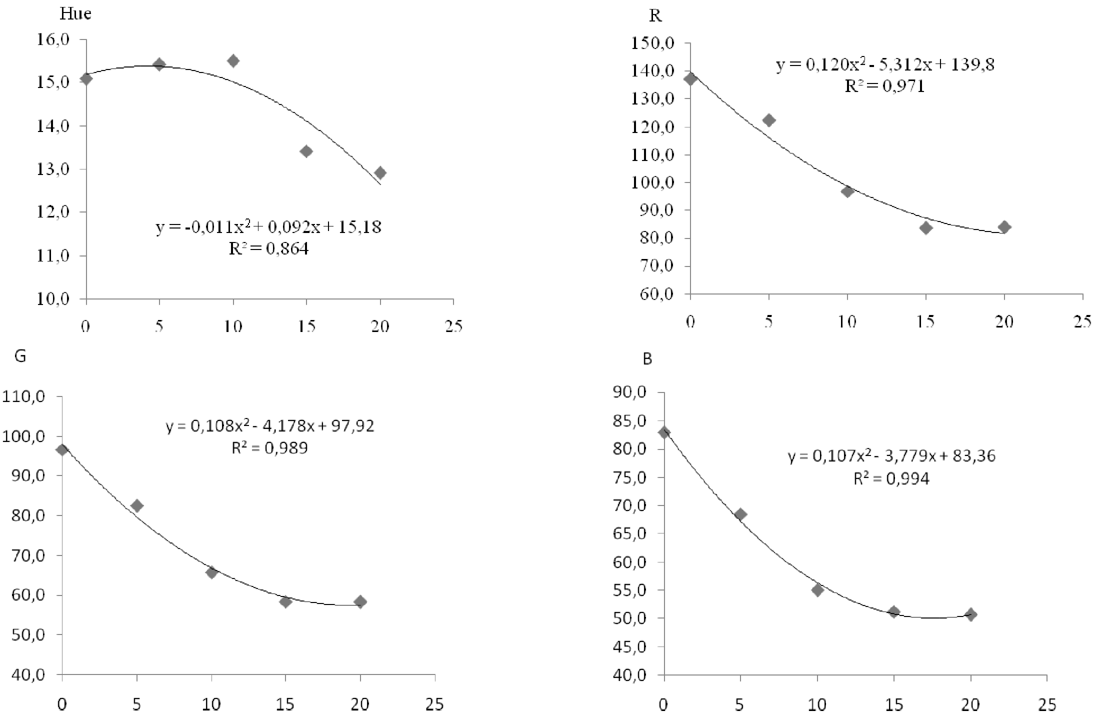

Fig. 3. **Polynomial coherences between modeled changes in soil moisture (*x*) and colour spectrum indexes (*y*) on average all variants of humic substance characteristics**

The hypotheses of the work did not prove that by adding only water the tone and separate RGB spectrum indexes will not change. It can be explained with interaction of increase of the moisture level and changes in the content of humus substances. That is the reason why suitable separate polynomial coherence was obtained for every content of humus substance according to execution of moisture modeling.

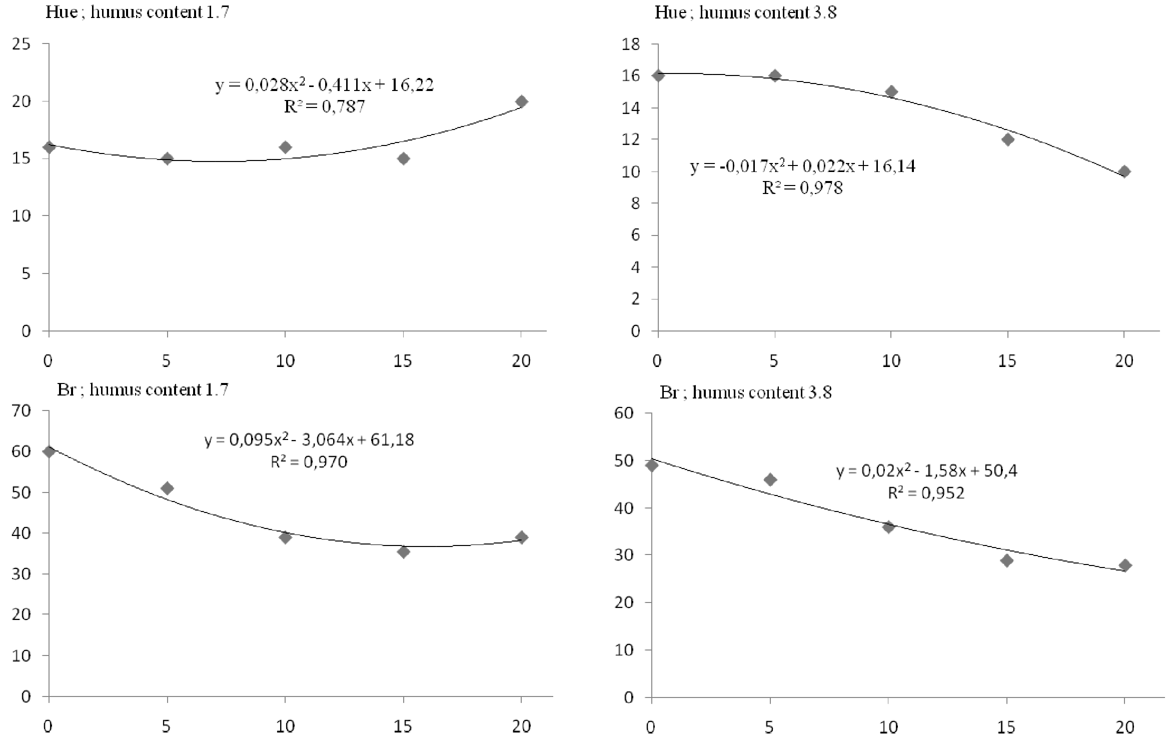

Fig. 4. **Example of coherence between variants of humic substance and soil moisture changes**

Conclusion

Analyzing the photographies both taken and scanned showed a large variation of some particular results of RGB and unsubstantial ($p > 0.05$) difference between RGB and HUE which means that the digital result does not reflect the natural tone of the soil. The humus content difference proved to be an important factor where with winter wheat there was substantial closeness of linear coherency $r_{yx}{}^{40}$ = 0.4699, p = 0.001. We concluded that it is too difficult to obtain true colors and correct white balance in dynamic environment using SLR camera and some other solution must be found for getting and processing images using scanners. It was concluded that the humus interval samples from GPS points defined in the area with characteristic hue (HUE) and saturation (S) and brightness (Br) as well as red (R) green (G) and blue (B) can be used for laboratory analysis and development of a data base for robotics module operation. In all 6 soils content groups dynamic second level polynomial coherence with high multiple regression ratio $R^2 > 0.80$ was found between the modeled soil moisture gradation and RGB spectrum indices. Polynomial coherence characterizes the linearity change in the critical point – 10 % moisture. Optimization model development number of soil moisture gradation classes in modules must be at least doubled. The experimental analysis of the theoretical modules proves that there is a perspective in performing soil humus content analysis using robots and in advance compiled data base.

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