Research of the possibilities for determination of some basic soil properties using image processing

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***Abstract*— Modern agriculture is characterized by a tremendous increase in the complexity of agricultural systems and the transition to sustainable smart agriculture (Smart Agriculture), integrating into one agricultural, information, computer and communication technologies and new approaches, methods for organizing and managing production. Agricultural machinery and technologies are being intellectualized, new categories of knowledge and competences are being assimilated, inter disciplinarity is being saturated, information and knowledge are being transferred, new generations of materials, innovative and thinking techniques, technologies, methods and tools are being introduced. The paper presents the possibilities of identifying some of the major soil properties using image processing. A database of digital images of soil from the most common in the country is formed. Informative features for indirect determination of some basic soil quality parameters are selected and evaluated. The models of basic parameters of soil through selected informative features are developed.**

Keywords—soil, image analysis, mathematical models, , insert (key words)

I. Introduction

The growth of the quality of plants and crops depends on a large extent on the physical and chemical properties of the soil and soil composition: minerals and organic matter, water, gases such as oxygen and carbon dioxide and living things (mainly microorganisms such as fungi and bacteria). The soil is not only a support system, but also a nutrient source for the plants - it provides the necessary water and nutrients.

Each plant needs a specific soil composition in which it can better express its potential growth. For this reason, the right balance of soil components is essential to ensure optimal crop growth. In crop production, when grown in soil substrates, different values such as temperature, humidity and the value of the main nutrients in the soil - nitrogen, phosphorus and potassium (N, P, K) are of great importance. These elements are called essential nutrients or macronutrients and are usually added to the soil by fertilization. Other elements, the so-called trace elements are usually present in sufficient quantities in the soil and plants need them in smaller doses. The introduction of some basic mineral elements in the form of mineral fertilizers into the soil is a powerful factor in managing soil fertility and plant productivity. Fertilization of agricultural crops is carried out in order to support the realization of their genetic potential for high yields. With well-balanced fertilization, conditions are created for a full supply of cultivated crops with nutrients and no preconditions are created for their washing.

Soil analyzes are crucial in helping farmers with land management issues. The results are important criteria for determining the necessary agro-technical measures such as tillage, fertilization, watering, drainage, introduction of improvers and plant protection products. With modern techniques for soil analysis can be established imported and exported quantities of elements important for the vegetation of plants in order to achieve a balance in agriculture.

Three of the main quality parameters of soil condition are acidity, salinity and soil moisture. There are different methods and tools for measurement of these three parameters that are necessary for normal growing of plants. A lot of laboratory equipment is used for measurement of pH, EC and moisture of soil but they have to be used in special conditions.

Different methods for soil moisture measurement are presented by Dobriyal [1]. In Xiaoshuai [2] is proposed an method based on direct digital synthesizer (DDS) and device - digital oscilloscope for measurement of soil EC electrical conductivity (EC).

In recent years, computer vision has been increasingly used as an indirect method for measuring soil acidity and electrical conductivity [3,4,5,6]. But mostly the values of the components or indices obtained by mathematical transformation of the components are used directly.

The paper presents an approach for modeling the dependences of acidity, electrical conductivity and soil moisture on the color components of the digital images of the samples.

II. Materials and Methods

A. Soil samples

In the paper is presented analysis of soils from several regions in and around Ruse. Soil samples were taken from vineyards, fields and regions in Ruse, Bulgaria. The samples images are acquired with a 3MP digital camera in daylight.

Some of the digital images of soil samples are presented on Fig. 1.

Fig. 1. Digital images of soil samples

A database of 150 digital images of the most common soils in the country is formed. The digital images are acquired in the main color space RGB.

Main color components R, G and B of soil digital images are obtained in MATLAB [7] and transformed into HSV and Lab color space. The mean values of color components for six values of pH, EC and moisture are shown in Table 1.

TABLE I. Color Components of Soil Digital Images

N	R	G	B	H	S	V	L	a	b
1	131.75	129.71	129.37	119.90	0.06	0.52	53.60	0.78	0.49
2	113.17	110.61	110.39	122.93	0.06	0.45	46.14	0.99	0.48
3	122.84	120.28	121.61	165.50	0.07	0.49	49.95	1.34	-0.40
4	142.30	141.36	143.19	157.28	0.06	0.57	58.25	0.84	-0.90
5	135.56	113.46	102.24	67.14	0.29	0.54	49.01	7.39	9.72
6	118.86	116.94	117.80	138.90	0.08	0.48	48.55	1.02	-0.22

B. Measurement of main quality parameters of soil

The main quality parameters of the soil samples electrical conductivity, moisture, acidity and temperature are measured with the following measuring instruments: Bluelab Pulse Multimedia EC/MC Meter and Bluelab Soil pH Pen (Fig. 2).

Bluelab pulse multimedia EC/MC meter [8] is digital soil moisture handheld meter that measures plant-health. The Bluelab Pulse Meter measures moisture, nutrient (EC) & temperature in. Measurement range of conductivity is 0-15 EC, mS; moisture content - 5% - 70% Mcvol and temperature 5-40°C. Measurement accuracy of conductivity for range 0.0 - 6.0 EC, mS is +/- 0.1 mS; for range 6.1 - 15.0, mS is +/- 0.2 mS. For moisture content is +/-5 % and for MCvol Temperature is +/-1 °C.

Bluelab soil pH pen [9] is direct tool for pH and temperature measurements from soils. Measurement range is 0.0 - 14.0 pH, 0 - 50 °C.

Values of moisture, EC and moisture of soil samples are presented in Table 2.

Fig. 2. Measurement of soil moisture, EC and pH

TABLE II. Values of Moisture, EC and pH of Soil Samples

N	pH	EC, mS	Moisture, %
1	6.70	1.45	31.00
2	6.80	1.46	36.00
3	6.90	1.58	32.20
4	7.00	1.92	30.00
5	7.10	1.45	24.83
6	7.30	1.52	33.00

III. Statistical Analysis of Color Components and Matemathical Modelling of Main Soil Quality Parameters

A. Statistical Analysis of Color Components

Correlation coefficient is used for analysis of relationship between color components and main soil quality parameters. The values of the correlation coefficient are presented in Table 3.

TABLE III. Values of The Correlation Coefficient

Soil Para meter	R	G	B	S	V	L	a	b
pH	0.021	-0.178	-0.214	0.352	0.053	-0.139	0.315	0.230
EC	0.566	0.798	0.790	-0.330	0.617	0.788	-0.318	-0.416
Moistu re	-0.777	-0.167	0.131	-0.829	-0.746	-0.314	-0.819	-0.785

The obtained results show that the acidity of the soil has a moderate dependence on the color components S (HSV) and a (Lab).

The electrical conductivity of the soil has a significant dependence with V (HSV) and a strong dependence with the following color components G (RGB), B (RGB) and L (Lab).

Soil moisture strongly depends on the following components R (RGB), S (HSV), V (HSV), a (Lab) and b (Lab).

B. Matemathical modelling of main soil quality parameters

For the two main quality parameters of the soil, acidity and electrical conductivity, the obtained data are approximated with suitable models, which are presented in Fig. 3, 4 and 5.

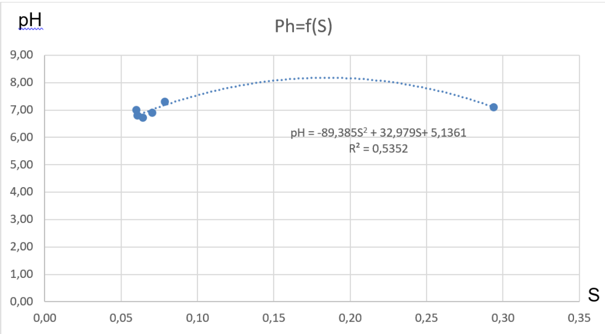

Fig. 3. Dependency of acidity and color component S

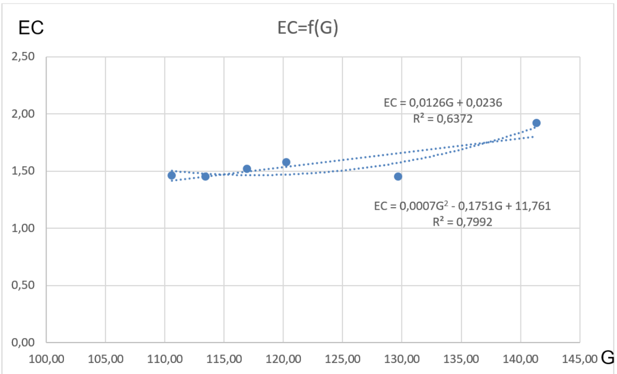

Fig. 4. Dependency of EC and color component G

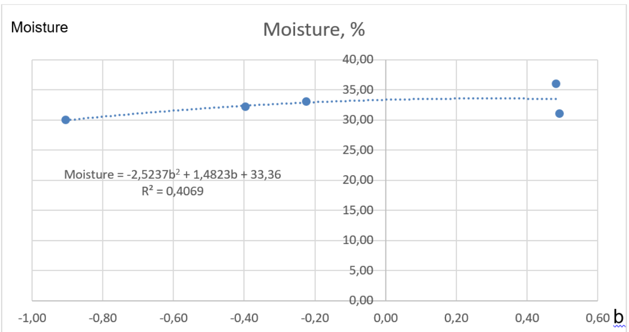

Fig. 5. Dependency of Moisture and color component b

The results show that data for all dependencies are best described using the second-order polynomial.

The following errors are calculated for all dependencies:

- absolute error

$$\alpha(\tilde{x}) = |x - \tilde{x}| \quad (1)$$

- percentage relative error

$$\Delta(\tilde{x}) = \frac{\alpha(\tilde{x})}{|x|}.100\% \quad (2)$$

The results for the error calculation are presented in Tables from IV to IX. For EC the errors are calculated for all color components with significant dependence of EC - V (HSV), G (RGB), B (RGB) and L (Lab).

TABLE IV. ABSOLUTE AND RELATIVE ERRORS FOR PH AS A FUNCTION OF COLOR COMPONENT S

S	Ph, Measurement	pH, Model	Absolute error	Relative error,%
0.06	6.70	6.89	0.19	2.86
0.06	6.80	6.82	0.02	0.22
0.07	6.90	7.02	0.12	1.73
0.06	7.00	6.79	0.21	2.96
0.29	7.10	7.10	0.00	0.00
0.08	7.30	7.18	0.12	1.65

TABLE V. ABSOLUTE AND RELATIVE ERRORS FOR EC AS A FUNACTION OF COLOR COMPONENT G

G	EC, mS, Measurement	EC, Model	Absolute error	Relative error,%
129.71	1.45	1.66	0.21	14.34
113.46	1.45	1.45	0.00	0.33
110.61	1.46	1.42	0.04	2.92
116.94	1.52	1.50	0.02	1.51
120.28	1.58	1.54	0.04	2.34
141.36	1.92	1.80	0.12	6.00

TABLE VI. ABSOLUTE AND RELATIVE ERRORS FOR EC AS A FUNCTION OF COLOR COMPONENT B

B	EC, mS, Measurement	EC, Model	Absolute error	Relative error,%
129.37	1.45	1.51	0.06	4.00
102.24	1.45	1.43	0.02	1.58
110.39	1.46	1.39	0.07	4.91
117.80	1.52	1.40	0.12	7.84
121.61	1.58	1.42	0.15	9.63
143.19	1.92	1.78	0.14	7.48

TABLE VII. ABSOLUTE AND RELATIVE ERRORS FOR EC AS A FUNCTION OF COLOR COMPONENT V

V	EC, mS, Measurement	EC, Model	Absolute error	Relative error,%
0.52	1.45	1.52	0.07	4.55
0.54	1.45	1.58	0.13	8.87
0.45	1.46	1.54	0.08	5.22
0.48	1.52	1.45	0.07	4.58
0.49	1.58	1.44	0.13	8.39
0.57	1.92	1.85	0.07	3.68

The calculated values for the absolute error show that for the electrical conductivity and acidity the models give a difference of a maximum of 0.2 of the measured value.

Only in moisture, the difference between the measured and modeled value of the parameter reaches 2.51.

TABLE VIII. ABSOLUTE AND RELATIVE ERRORS FOR EC AS A FUNCTION OF COLOR COMPONENT A

a	EC, mS, Measurement	EC, Model	Absolute error	Relative error,%
0.84	1.45	1.53	0.08	5.48
0.78	1.46	1.42	0.04	2.79
1.34	1.52	1.52	0.00	0.14
1.02	1.58	1.74	0.16	10.28
0.99	1.92	1.72	0.20	10.31

TABLE IX. ABSOLUTE AND RELATIVE ERRORS FOR MOISTURE=F(B)

b	Moisture, % Measurement	Moisture, %, Model	Absolute error	Relative error,%
-0.90	30.00	29.95	0.05	0.15
0.49	31.00	33.48	2.48	7.99
-0.40	32.20	32.38	0.18	0.56
-0.22	33.00	32.90	0.10	0.29
0.48	36.00	33.49	2.51	6.98

The relative error indicates what part of the measured value is an error. The results obtained for the relative error show that for the acidity it reaches a value of 2.96%. For EC the error is as follow:

EC = f (G) - 6%;

EC = f (B) - 9.63%;

EC = f (V) - 8.87%;

EC = f (a) - 10.31%.

Fof Moisture = f (b) the relative error is 7.99%.

The results indicates that the acidity could be modeled and predicted using the resulting second-order model of one color component. For electrical conductivity, it is necessary to make new models using two or more color components, which would reduce the relative measurement error. For moisture, it would also be good to repeat the calculations and try to reduce the relative error.

IV. CONCLUSIONS

A database of images of soil samples taken from areas in and around the city of Ruse has been formed. For the samples their main quality parameters acidity, electrical conductivity, humidity and temperature were measured.

The values of the color components of three color models RGB, HSV and Lab were obtained in the software MATLAB. The dependence between the main quality parameters of the soil and the color components is evaluated. The obtained results show that the acidity of the soil has a moderate dependence on the color components S (HSV) and a (Lab). The electrical conductivity of the soil has a significant dependence with V (HSV) and a strong dependence with the following color components G (RGB), B (RGB) and L (Lab). Soil moisture strongly depends on the following components R (RGB), S (HSV), V (HSV), a (Lab) and b (Lab).

For the two main quality parameters of the soil acidity and electrical conductivity, the obtained data are approximated with appropriate models. The results show that it best describes the second-order polynomial data for all dependencies.

Absolute and relative errors are calculated for all dependencies. The results obtained for the relative error show that for the acidity it reaches a value of 2.96%. For EC minimum relative error of 6% is when for the model is used G color component. For moisture, it is necessary to repeat the calculations to reduce the relative error.

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