Accurate ground scanning of the day surface of tilled soil to determine its agro-technical characteristics

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Abstract. The aim of the research is to determine the agro-technical characteristics of the day surface of tilled soil on sloping agricultural landscapes by applying the method of accurate ground scanning along the circumference. The specific difficulties that arise in developing and implementation of agro-technical measures are often associated with significant change of the main parameters of the day surface of tilled soil depending on space and time. Agro-technical parameters according to the agro-technical requirements for the main and pre-sowing tillage, the direction and value of the average slope of the soil surface, as well as the lumpiness and cloddiness of the tilled day soil surface are determined while controlling. According to the results obtained using the developed software, it was found that the deviation angle of the projection of the line of the maximum change in height from the direction of the tillage machine movement is α=-32.4 and the slope of the studied site is 4.8 degrees. The aggregates of 1-4 centimeters in diameter are prevailing in quantity that is crumbling is ensured. The weighted average diameter of the lumps was 4.07 cm, and the standard deviation was 5.05 cm.

1 Introduction

The specific difficulties that arise in developing and implementation of agro-technical measures on sloping agricultural landscapes are often associated with significant change of the main parameters (average slope, lumpiness, cloddiness) of the day surface of tilled soil depending on space and time.

The most popular methods for obtaining information about the underlying surface used in Russia and foreign countries are: profiling, stereo photography, shadow method, laser scanning, circuit and acoustic scattering method [1-5]. The review of the known technical means of control of the underlying surface in [6-11] allowed us to note the following: the considered technical means do not provide the acceptable accuracy of measuring the unevenness of the underlying surface and violate the technological shape of lumps and aggregates on the soil surface; a number of technical means of control are bulky and inconvenient for use in field conditions; using some tools, it is not possible to determine and record the measured parameters of the underlying field surface at the same time.

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In this paper, statistical processing of actual data obtained from a distance sensor moving along the circumference in a horizontal plane allows us to determine a number of parameters of the tilled surface:

- value of slope;
- deviation of the projection of the line of maximum change in height (by which the slope is measured) from the direction of the tillage machine movement.
- distribution of soil aggregates by size to determine the lumpiness and cloddiness of ploughing.

2 Materials and methods

To carry on experimental studies on slope lands, a method for determining the profile of the day soil surface along the circumference has been developed [12] to establish the agro-technical parameters of the day surface of the tilled soil on an elementary site in the field, as well as profilographs for its implementation, taking into account the works [2, 8, 12]. Figure 1 shows a general view of the non-contact profilograph in operation.

The device consists of a massive base with legs for fixing on the soil surface. On the base there is a rod mounted by means of a bearing. At the lower end of the rod there is an encoder – angle sensor and a movable arm fixed perpendicularly at its upper end.

There is a counterweight at one end of the movable arm and a laser position sensor 6 installed by means of a rod at the other end. It allows moving the laser sensor. At the upper end of the rod there is an electronic signal processing unit which is connected to the laptop via a USB cable. A level is also attached to the rod.

Fig. 1. General view of a non - contact profilograph in operation.

First, the profilograph is leveled vertically in all directions by moving the arm around the circle. The angle and position sensors are powered from the laptop. The "RF 605+encoder" computer program is run on the laptop. Then the arm is slowly rotated around the base. Performing one revolution, the laser position sensor scans the soil surface and transmits the data to the electronic signal processing unit. The principle of operation of the laser sensor is based on the method of determining the distance with a laser.

At the same time, the encoder measures the position of the rod relative to the base and also sends instantaneous values of the rotation angle to the electronic signal processing unit. Thus, the electronic signal processing unit receives signals simultaneously, which are transmitted to the laptop after processing. The computer program allows you to present information in polar coordinates for 2 parameters: the distance between the position sensor and the soil surface, as well as the corresponding rotation angle from zero.

Figure 2 shows surface shape diagrams found on slope lands and their detailed graphs: a convex surface intersects with a cylindrical surface; a concave surface intersects with a cylindrical surface; a flat surface intersects with a cylindrical surface. In case of an ideal flat surface, where the gradient projection is parallel to the direction of the tillage machine movement the detailed graph (angular) of the measured height values has the form of a cosine curve. Zero degree angle (α=0) coincides with the maximum value when moving "uphill", or the angle coincides with the minimum value when moving "downhill" (α=180).

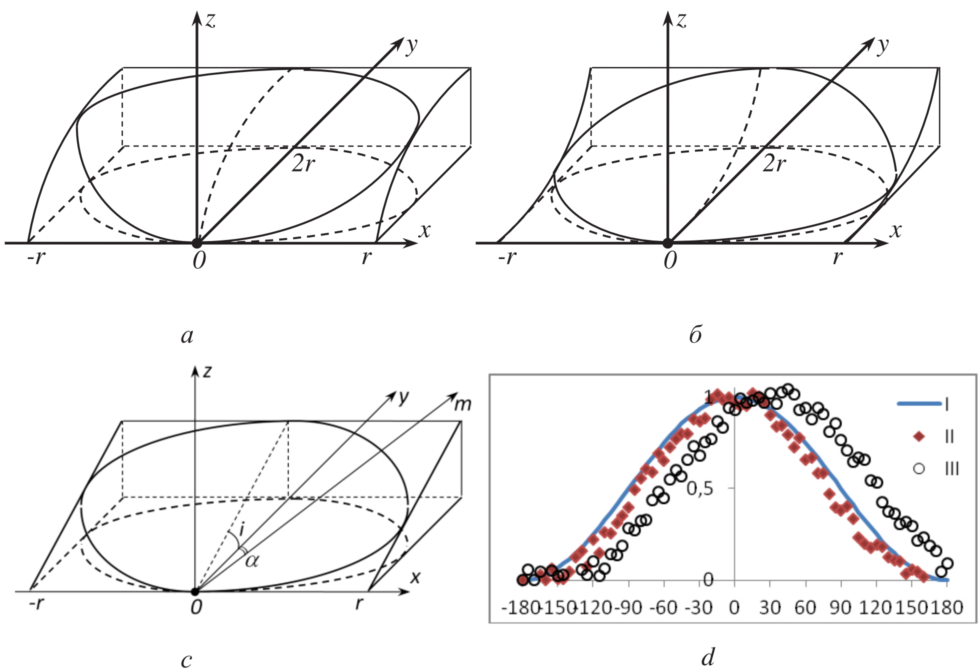

Fig. 2. Diagrams of surfaces shapes that are found on slope lands and their detailed graphs: *a* – convex surface intersects with a cylindrical surface; *b* – the concave surface intersects with the cylindrical surface; *c* – flat surface intersects with a cylindrical surface; *d* – the diagram of dependence of surfaces coordinates change on the circumference angle: I – an ideal case, II – surface deviation from flat shape, III – gradient projection is not parallel to the direction of the movement.

As a rule, α is not equal to zero ($\alpha \neq 0$) in real conditions, which changes the obtained detailed graphs. In conventional tillage, it is desirable that α=90, i.e. tillage is to be done along, but not across the slope. In addition, the fact that the shape of the soil surface is not always flat and the presence of soil aggregates of various size and shape on the surface changes the picture of the detailed graph.

The total result of such distortions significantly complicates the analysis of the surface. Therefore, preliminary additional processing of experimental data becomes necessary to carry out some measurements.

The total set of experimental data is z_t (φ_t), where t=1, 2,…,n.

Moving average is calculated according to the following formulas:

$$Z_1=(z_1+z_2+\ldots+z_k)/k$$
$$Z_2=(z_2+z_3+\ldots+z_{k+1})/k \quad (1)$$
$$\ldots$$
$$Z_m=(z_m+z_{m+1}+\ldots+z_{m+k-1})/k.$$

Exponential smoothing is calculated by the formula

$$Z_t=\begin{cases} z_1 & : t=1 \\ Z_{t-1}+\mu(z_t-Z_{t-1}) & : t>1 \end{cases}. \quad (2)$$

As a preliminary processing, data is first smoothed using moving average or exponential smoothing methods.

The choice in favor of a particular smoothing method is made depending on a specific set of experimental data. Then, aggregates of different sizes are counted.

Using the smoothed data, the cosine curve parameters such as amplitude A and the displacement of the maximum point relative to zero are selected to determine the degree of angle α. The selection is based on the condition that the total sum of squares of deviations is minimal. The slope is determined by the expression

$$i=arctg\ (A/r). \quad (3)$$

In order to automate this procedure, we have developed software that performs the proposed calculation method.

3 Results and discussion

The developed technical means of control were used in agro-technical studies of the day surface of tilled soils on the territory of «Orinino» agricultural complex in Morgaushy district of the Chuvash Republic. Field studies were conducted on various agricultural backgrounds of slope lands with a slope of up to 6 degrees [13-17], especially after under-winter ploughing (figure 3). For the main tillage a wheeled agricultural tractor and a mounted share plough PLN-3-35 were used.

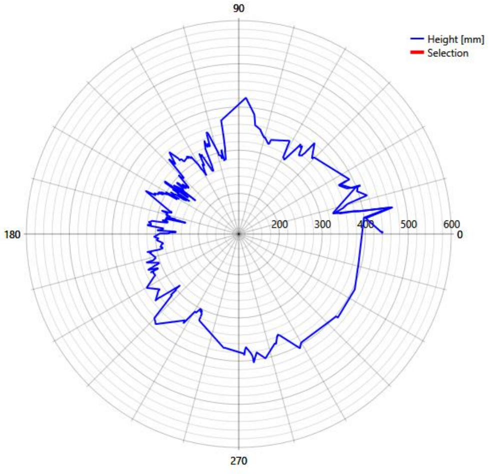

Fig. 3. The data obtained on ploughed soil surface in polar coordinates: rotation angle and distance from the soil surface to the sensor.

The results of the processing are shown in Fig. 4,5. The figures show: the deviation of the projection of the line of the maximum change in height (by which the slope is measured) from the direction of the tillage machine movement makes angle α=-32,4, the slope is 4.8. The aggregates of 1-4 centimeters in diameter are prevailing in quantity. The weighted average diameter of the lumps was 4.07 cm.

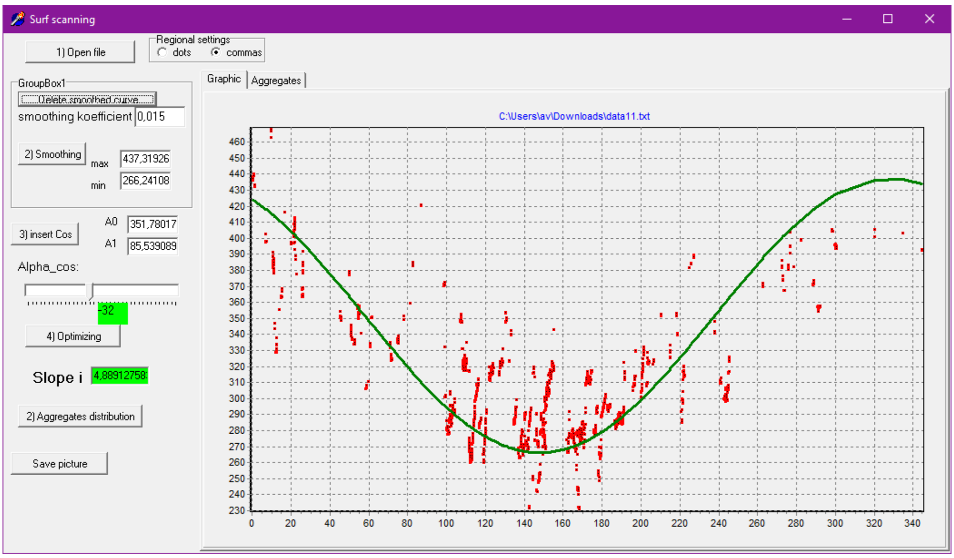

Fig. 4. The results of processing presenting the detailed graphs of angles and height.

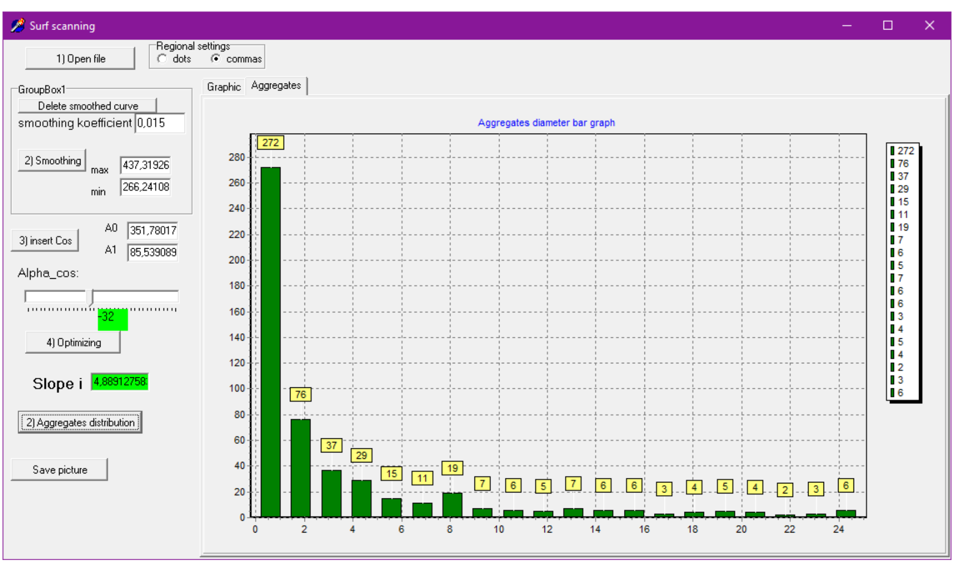

Fig. 5. The results of processing presenting the distribution of lumps on the site.

To monitor agro-technical technologies on sloping agricultural landscapes [18], an accurate ground method for determining agro-technical characteristics after soil tillage by profiling the studied surface is proposed. In order to determine these parameters, an accurate ground method is used to determine the agro-technical characteristics after tillage by profiling the studied surface along the circumference. To introduce this method it is proposed to use a non-contact profilograph. Agro-technical parameters according to the agro-technical requirements for the main and pre-sowing tillage, the direction and value of the average slope of the soil surface, as well as the lumpiness and cloddiness of the tilled day soil surface are determined while controlling. Field studies were conducted on various agricultural backgrounds of slope lands with a slope of up to 6 degrees, especially after under-winter ploughing. According to the results obtained using the developed software, it was found that the deviation angle of the projection of the line of the maximum change in height (by which the slope is measured) from the direction of the tillage machine movement is α=-32.4 and the slope of the studied site is 4.8 degrees. The aggregates of 1-4 centimeters in diameter are prevailing in quantity that is, crumbling is ensured. The weighted average diameter of the lumps was 4.07 cm, and the standard deviation was 5.05 cm.

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