Implementation of digital penetrometer S600 skokagro in the technology of precision and digital agriculture

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Abstract: *The paper presents the method of combining the results of soil compaction, which were obtained by the penetrometer of Ukrainian production S 600, into the software of digital agriculture. For example, it is shown how to enter the obtained soil compaction data into the AFS software.*
KEYWORDS*: DIGITAL PETETROMETR, SOIL COMPACTION, DIGITAL FARMING, SOFTWARE.*

1. Introduction

As you know, the introduction of modern technologies for growing agricultural crops involves the solution of many tasks: reducing the use of resources, shortening the terms of sowing, care, harvesting; increasing soil fertility. The quality of the grown crop must meet world standards. Today, farmers of Ukraine use, along with traditional farming technologies, such as No-Tillage, Drill-Tillage, Strip-Till, Controll-Traffic. There is also the use of a mix of technologies within one agricultural enterprise. These technologies are effectively adapted to the conditions of agriculture in Ukraine. The main risk of agriculture before the war with the russian federation was the risk of low rainfall. Today, new limiting factors have appeared in agricultural production: mining of fields; reduced number of equipment and people. In order to obtain high yields with moderate expenditure of funds and other resources (human, material and technical), it is necessary to carry out technological operations in the shortest possible (short) period to compensate for these factors, powerful and high-performance machinery is used tractors: John Deere 8335R, John Deere 8345RT, Case IH STX 535/600 and others; combine harvesters Case IH 9420, Lexion 770, John Deere 670i; agricultural machines Horsch Maestro 36.5, Turbosem II 19-60, Ecolo-Tiger-730 and many other various machines. The use of unmanned aerial vehicles to perform various tasks is increasing: surveying fields, determining field boundaries, researching the state of plant development, spraying crops with protective agents, etc.

However, the use of high-performance equipment has its drawbacks - it is a large mass of tractors, combines and agricultural equipment. There is a threat of yield reduction due to excessive soil compaction. For example, the depth of action of the compacting effect from the wheels of a grain harvester weighing 13 tons or more reaches a depth of 0.8 m [1]. In the case of using traditional agricultural technology - with intensive tillage - the latter is also constantly exposed to the negative impact of the mass of tractors. And the depth of cultivation, as a rule, does not exceed 30...32 cm. In addition, it is calculated that the length of the path (traces) traveled by a combine harvester equipped with a harvester with a width of 6 meters, which harvested a crop in a field with an area of 100 hectares, reaches 125 ... 166 km , depending on the method of movement on the field. This leads to the formation of the so-called "plow sole" - a very compacted layer of soil, which significantly slows down the penetration of moisture and air into the deeper layers of the soil, and vice versa.

High compaction of the soil, of course, will lead to a significant decrease in productivity and may even provoke the death of plants (Fig. 1).

Thus, modern agriculture, regardless of the technology of growing agricultural crops, is characterized by the use of high-performance equipment that has a lot of weight. Based on this, it is necessary to implement additional methods of soil compaction control.

1. Statement of the problem

In the conditions of the implementation of agricultural technologies, in which high-performance and heavy machinery units are used, it is necessary to use tools for quick control and analysis of soil density. The existing penetrometers of the mechanical type (Fig. 2) cannot satisfy the requirements of farmers, since with their help it is not possible to obtain complete, accurate and, most importantly, quick information about the state of the soil.

Fig. 1 *– Sunflower crops, which stopped developing due to over-compaction of the soil (proved by measurements).*

Fig. 2 *– Penetrometer of mechanical type. No GPS tethering.*

The advantages of such a penetrometer include low cost, compactness, and ease of use. Disadvantages include: lack of GPS connection, lack of GSM, impossibility of creating compaction maps. Such and similar devices today do not meet modern requirements and cannot be used in precision and digital farming systems.

Thus, the goal of the work is to integrate the software of digital tools for determining the amount of soil compaction into programs for conducting digital agriculture. To achieve the goal, it is necessary to solve the following tasks:

- to provide a scheme of implementation of the technology from the "point of measurement - to the application of the results in the technology of cultivation of rural areas". cultures";
- to develop a technology for fixing soil hardness measurement points;
- conduct experimental measurements.

2. Solving the task

To implement the first task, we developed a technological scheme for the interaction of the penetrometer with software for precision and digital agriculture by recording and transmitting data using GPS and GSM communication. (Fig. 3).

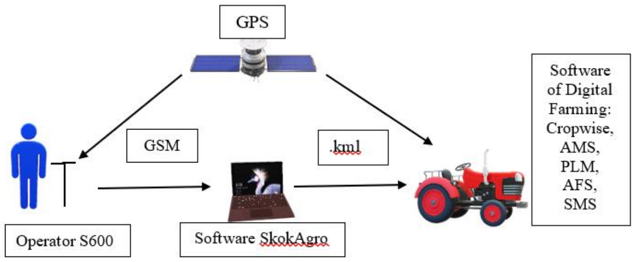

Fig. 3 – Scheme of data transfer of the amount of soil compaction from the moment of measurement to their entry into the task maps (prescriptions) in others software.

Such a technological scheme can be implemented using the digital penetrometer S600 of the Ukrainian manufacturer Skok Agro [2]. This penetrometer is equipped with a GPS receiver, GSM antenna and appropriate software for receiving, storing, analyzing and processing the received data (Fig. 4).

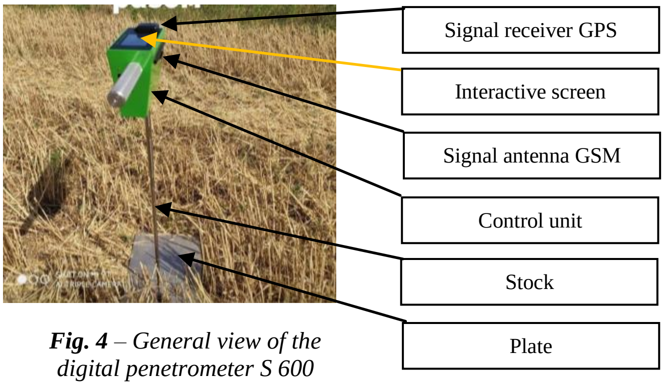

Fig. 4 *– General view of the digital penetrometer S 600*

A penetrometer measures soil hardness. This indicator is proportional to the compaction. The obtained hardness values are correlated with the amount of compaction. The received data of hardness (kPa) is transmitted to the server using GSM communication, from where they are read by the Skok Agro program, the interface of which is simple and convenient to use (Fig. 5). This software is connected to the Google Map service and has the following functions: "List of experiments" (measurements); "Reports on hardness" (completed works) and "Grid" [3]. Also, it is possible to limit the field on which hardness studies will be conducted with contours, which gives information about the area and configuration of the field. In the "Grid" mode, sampling points (points where soil hardness measurements will be taken) are automatically plotted on the map. Depending on the area of the field, you can choose the discreteness of measurements in the calculation: one measurement per 15 hectares; one measurement per 10 hectares, per 5 hectares or it is suggested to choose your own area smaller than 5 hectares (Fig. 6). The generated grid gives an understanding of where the operator needs to measure.

Fig. 5 *– General view of the Skok Agro interface.*

The operator who measures soil compaction must perform these measurements at the points determined by the Skok Agro software (Fig. 6).

In this case, the operator needed to find a measurement point on the field. Obviously, for this, it is necessary to match the coordinates of the points with another tracker, which must be installed on the operator's mobile device.

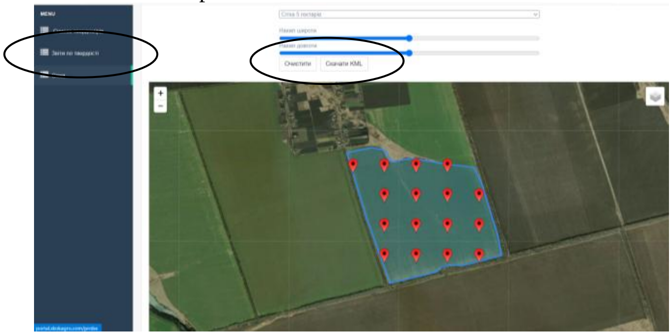

Fig. 6 *– Grid created automatically in Skok Agro software*

This task is implemented as follows. As can be seen from fig. 6, this information can be saved in a file with the extension ".kml". This file must be forwarded to the operator's e-mail box. The operator opens the received file in applications: GPX Viewer or Locus Map (Fig. 7 a, b), or any other application that accepts kml files. Thus, using this program and turning on the "Location" function on the smartphone, the operator moves along the field and combines the points of his location and the points on the field.

a) b)

Fig. 7. *– Measurement points and operator movement tracker in applications: a - GPX Viewer; b - Locus Map*

After measuring the soil hardness at the specified points, the operator transmits the results to the server using GSM communication. These results are displayed in the Skok Agro software (Fig. 8). The hardness of the soil is determined at each given point to a depth of 60 cm with a resolution of 1 cm. Thus, we have a map of the soil hardness of the entire field to a depth of 60 cm.

Fig. 8 *– Soil hardness results of one of the agricultural enterprises on the border of Dnipropetrovska, Zaporizka and Donetska oblast (August 2021).*

Since the Skok Agro software has the ability to create files with the ".shape" extension, the results can be integrated into other precision and digital agriculture software.

3. Experimental part

14 measurements were made on the T18 experimental field of one of the agricultural enterprises. Crop cultivation technology - No Tillage since 2006. The obtained results were transferred to the Skok Agro portal. It was established that at a depth of up to 40 cm, the hardness of the soil is optimal and favorable for the development of the root system of plants (the effort of introducing the penetrometer pyramid into the soil was up to 3500 kPa). In fig. 9 shows the data of the soil hardness at a depth of 40 cm. In this case, such compaction is caused not by the action of the wheels of the machines, but by the soil's own weight. The received compaction data of the T18 field were transferred to AFS Software - and this was the beginning of the collection of information about the history of this field (Fig. 10).

Fig. 9 – Results of soil hardness measurements of field T18.

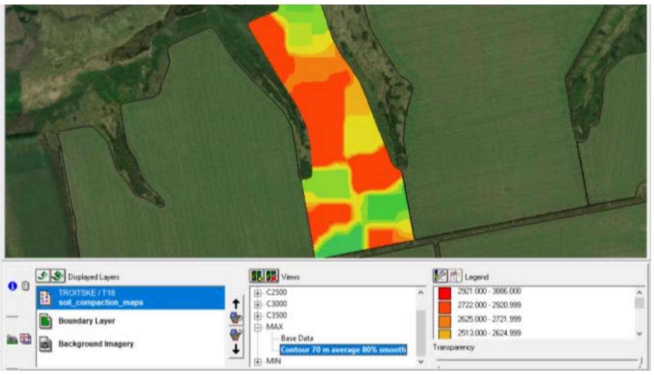

***Fig. 10** – T18 field compaction map after processing the results in AFS Software. Such maps can be built for different depths with a resolution of 5 cm.*

What gave us the definition of soil compaction? First, electronic maps of soil compaction help to adjust, for example, a deep loosener to the correct working depth. Each additional incorrectly identified centimeter of soil compaction, which is below the level of 20 cm, leads to an increase in fuel consumption by an average of 1 l/ha. But since the company where the research was conducted works on No-till technology, these soil compaction maps will go to the history of the field to further determine the zones of high, normal and low yield and their causes. In this case, we established that there is no excessive compaction of the soil in the root system development zone, and the effect of different soil density will not cause a significant negative effect on the crop. Therefore, for the agronomist there are other factors that will influence the formation of the crop: the availability of nutrients, soil moisture, etc. It is necessary to constantly monitor the NDVI index.

Note that in the process of implementing precision and digital farming technologies, at least three major factors play a significant role:

- amount of soil compaction;
- availability of soil moisture;
- availability of nutrients (organic and mineral).

The use of this penetrometer and software significantly accelerates the acquisition of data, their integration into other software [4] and ensures high accuracy of the obtained results.

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5. Literature

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