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THE USE OF AERIAL PHOTOGRAPHY DATA AND INSTRUMENTAL DATA IN ADAPTIVE FARMING

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Abstract

This article reveals the practical experience of using aerial photography by drone in combination with analytical methods of chemical analysis of soil samples for solving problems of adaptive agriculture (application of nitrogen fertilizers) for winter wheat by equipment without precision sowing and GPS. In order to solve this problem, aerial photography was conducted according to the phases of winter wheat growth with simultaneous soil sampling and subsequent agrochemical analysis. Based on the obtained information, thematic maps were created in the GIS package ArcGis and flow charts for the application of nitrogen fertilizers. Additional soil samples were sampled in soil contours where winter wheat was lagging behind in growth, as well as additional general soil analysis and the reasons for the lag of wheat growth were identified. Recommendations on the further use of similar methodological approaches in the territory of Ukraine are given.

Key words*: adaptive farming, digital soil mapping (DSM), drone, GIS mapping, soil samples.*

INTRODUCTION

In recent years, due to the increase in the cost of mineral fertilizers, it has become important to decreasing it consumption on farm fields It is logical that the spatial distribution of mineral fertilizers on the field depends on the terrain (microrelief) and land productivity.

Therefore, identification of this relief on the field and continuous monitoring using any systems and methods (ground, remote, contact) comes to the fore. In general, this set of methods has received the name - precision farming.

For practical verification and implementation of the latest research methods (aerial monitoring and it data processing) and instrumental research methods (wet chemistry), a number of industrial experiments were carried out, that results were used as an example in the article.

The aim of the research was to verify the operation of monitoring methods on an industrial scale in a single farm. Adaptive agriculture was understood as the use of simple agricultural implements (without precise sowing and GPS) and the latest monitoring methods.

Simultaneous measurement by contact methods of soil samples was carried out, continuous monitoring with the help of a drone, obtaining orthophotomaps of test fields and their analysis, achieving results on productivity in test fields. A check was also carried out on the economic component of adaptive agriculture.

Tasks:

- laying a network of points for sampling by the "envelope" method and their subsequent optimization using the results of aerial photography;
- soil samples analysis and phyto-indication on test fields;
- development of recommendations for the mineral fertilizer's application, only on soil contours with oppressed vegetation;
- economic efficiency calculation of the results applying complex methods after harvesting.

The experiment processes

For a full-fledged experiment with adaptive farming elements in industrial conditions, at the customer's request, the maximum loading of their technical capacities was used. We are talking about using an unmanned aerial vehicle of the customer, such as a drone, controlled by operator.

A transfer of source information (aerial photographs) was organized through the web links of information array on special exchange servers to ensure fast processing of data received from the drone on the customer's fields.

Due to this, the total time consumption for survey, processing ("stitching", channel analysis) was reduced to 40 minutes per field. The customer (agronomist) got completely ready cluster graphic file for decision-making throughout for two hours.

MATERIALS AND METHODS

The field stage included the departure on area and soil samples collecting both by the "envelope" method and method based on the results of aerial photography (Solokha M.O., 2019).

Obtaining the aerial photographyresults and orthophotomap creation (Solokha M.O., 2014) were organized via the web-service.

The cameral stage included: channels analysis of the RGB model, systematization of channel indicators for each research object, statistical processing and obtaining dependencies between remote sensing data and laboratory analysis data (Solokha M.A., 2018).

The channels model analysis algorithm of the RGB model sequentially reproduced the stages of obtaining the result of vegetation analysis based on aerial photography.

Using the software ErdasImage 91 allowed obtaining the processed orthophotomap of the study object.

After loading the image into the ErdasImage environment, the following image processing sequence was performed (Figure 1).

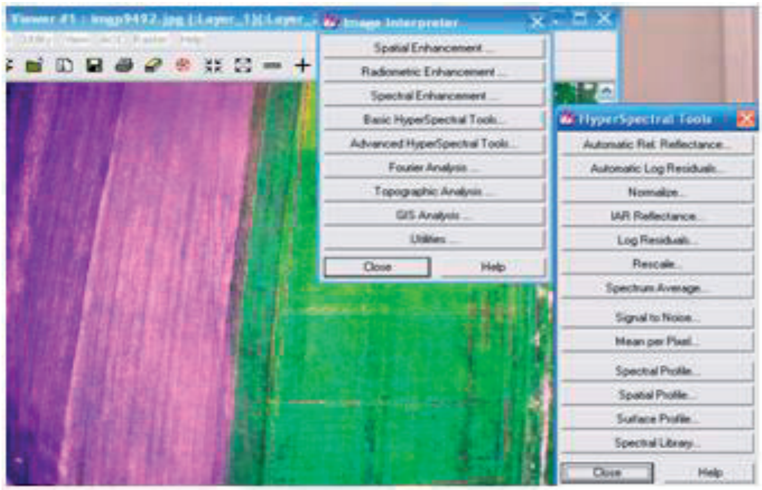

Figure 1 Image processing sequence in ErdasImage

1. At the first stage, RGB processing in ErdasImage was done Sequence Used: Image Interpreter: Basic Hyper Spectral Tools - Automatic Rel Reflectivity, which is due to RGB, which allows you to minimize the impact of negative meteorological factors.

2. The second stage of the processing of the orthophotomap was the gain of each of the channels of the RGB models, which dominate in each pixel. Doing this, we used the Auto Internal Average Relative Reflection menu, which allows obtaining the weighted average reflection coefficient of all three image channels (Figure 2).

A processed orthophotomap in this way allowed carrying out analysis to obtain digital values of each channel for further mathematical processing (Figure 3).

The image located on the right, enhanced after processing, allows us to differentiate visually from the translucent crop (winter wheat), which is clearly distinguished and can be mathematically processed using tools in ErdasImage software.

3. Obtaining digital numbers (DN) in the image, was selected in the Profile Tabular Data menu of the Statistics menu, where all statistical sampling parameters for the channel were. It allows statistically processing either one channel or a single set, or variants of sets.

As a result, we obtained: a sample for statistical calculations (Figure 4), statistical error, the total sample size and number of values in the calculation, the min-max and average values This allowed us to move on to the mathematical component of the analysis or quantitative analysis of aerial photography and also create a new model for the analysis of research objects, based on the use of ternary or three-dimensional graphs.

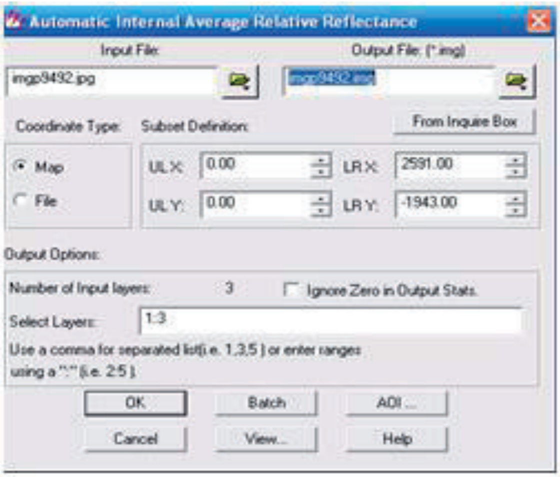

Figure 2. Relative average reflection coefficient analysis menu (based on all channels)

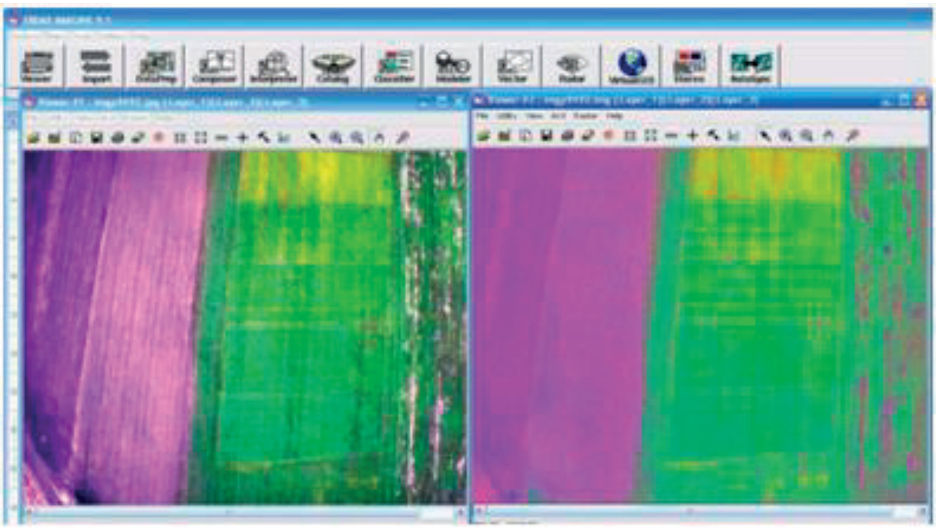

Figure 3. Aerial image before (left) and after processing (right)

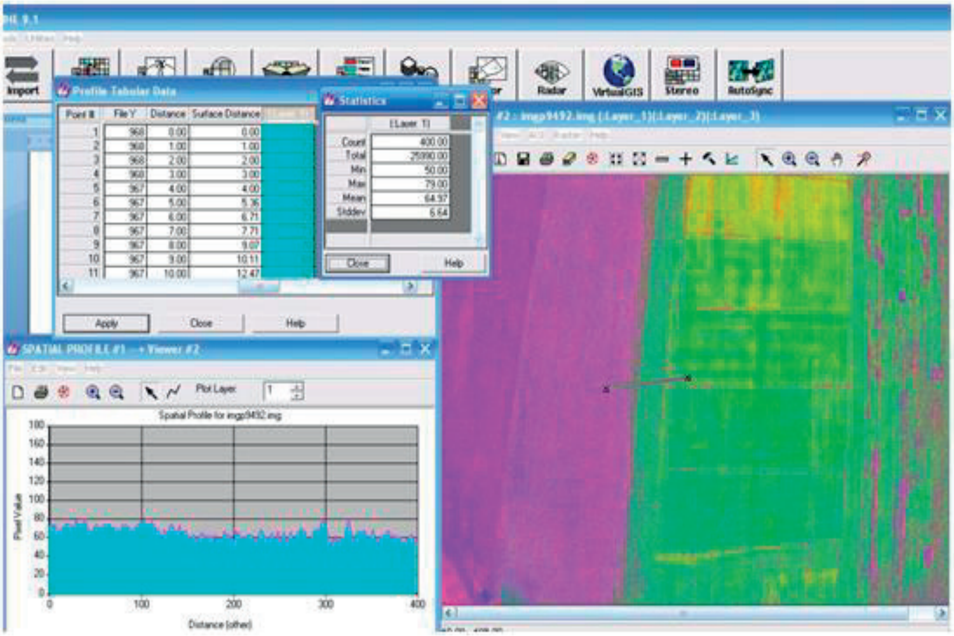

Figure 4. Calculation of R-channel statistics in an aerial photograph

4. The data obtained were entered either in the corresponding software "Statistica" or "Microsoft Excel" and calculated in the form of ternary graphs (in the form of a triangle), or three-dimensional graphs used to study the correlation between several variables Methodical approach developed by (ShMDavis, DMLandgrebe, TLPhillips 1983), is based on spectral responses of measurements of natural objects, was used basis They invent own methodological approach using all three channels of the RGB model, in the form of three-dimensional (ternary) graphs (Figure 5).

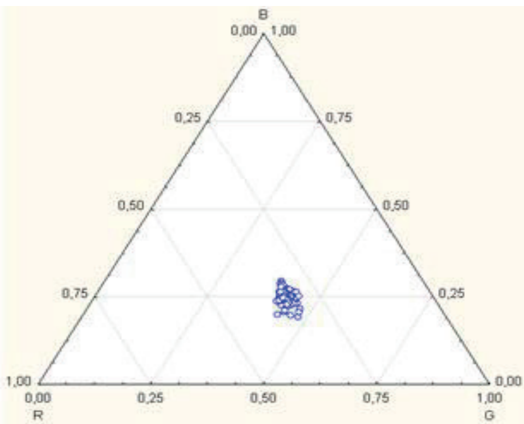

Figure 5. Ternary channel graph of the RGB model

To determine the crops classes or the crop state on the field, which was shown in aerial photographs a mathematical analysis of ternary graphs was carried out. During changing the value of all RGB model channels determinate, is the value optimal for the culture (based on many years of experience) or not. After that an appropriate managerial decision is make.

The points shown in Figure 5 are located on the ternary plot depending on the factors of influence (wheat sort and the influence of the microrelief), which indicates whether the crop is in the optimal growth or not.

Mapping

Office work was carried out using methods of analysis, synthesis and digital soil mapping (DSM) using GIS technologies.

Cartographic work was performed in the ArcGIS 105 software product. On the basis of aerial photographs and analytical information on the physical and chemical parameters of the soil using GIS, agrochemical maps have been built. To solve issues, the most important information is the presence of trace elements and the amount of organic carbon (humus) in the soil. Maps were constructed for four key indicators: phosphorus (mg/kg), nitrogen (mg/kg), potassium (mg/kg), humus (%).

The construction of maps was carried out by interpolation by aninverse distance weighted (IDW) technique (Watson D.F., Philip G.M., 1985). The output value for the cell, calculated using the IDW method, is limited to the range of values used for interpolation. Since the IDW method finds the average based on the weighted distance to the reference points, the average cannot exceed the highest input value and cannot be less than the lowest value. For the best qualitative and proportional distribution of spatial information, using the most optimal values for this territory. The output cell size is 238. Degree, i.e. the significance of points located in the vicinity of the interpolated value equal to 2. The search radius is variable. The number of nearest input control points is used by default.

RESULTS AND DISCUSSIONS

On the test fields before the season of winter wheat top dressing (Shestopalovka sort), samples were taken according to DSTU 4287: 2004 (DSTU 4287: 2004). Location of soil sampling points on the Izyum city cluster - Lipchanivka village is shown in Figure 6 using field № 21 as an example.

Note:

point 1: X = 37387676, Y = 49329106;
point 2: X = 37391143, Y = 49331970;
point 3: X =3 7392325, Y = 49334545;
point 4: X = 37397743, Y = 49332000;
point 5: X = 37392530, Y = 49328729

The following data were obtained, as a result of chemical analysis (Table 1)

Figure 6. Coordinates of field № 21 sampling points

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Table 1. The results of the agrochemical analysis of soil samples taken in field № 21

№	Field number - the first two figures, sample's number - the last figure	Ammonium and nitrate nitrogen DSTU 4729:2007		Phosphorus and potassium by Chiricov method DSTU 4115-2002		Organic carbon DSTU 4289:2004		pH of a water extract DSTU 8346:2015
		$N\text{-}NO_3$ mg/kg	$N\text{-}NH_4$ mg/kg	P_2O_5 mg/kg	K_2O mg/kg	C %	Humus %	pH units
1	211	6.70	4.56	14.66	224.13	3.10	5.3	7.85
2	211	9.60	5.67	25.65	238.59	3.08	5.3	7.60
3	213	4.50	3.97	18.55	180.75	2.92	5.0	6.90
4	214	6.60	6.51	21.07	231.36	2.68	4.6	8.15
5	215	3.40	5.11	11.91	209.67	2.68	4.6	8.14

According to the conditions of the experiment, it was not planned to measure soil quality indicators, except for agrochemical and pH. The result of constructing maps - distribution of macronutrients over field № 21 (Figure 7a-d).

The humus content in the soil on field № 21 at points 1 and 2 is very high; 3, 4 and 5 - high. According to pH value, the soil of point 3 of is neutral; points 1 and 2 - slightly alkaline and points 4 and 5 - medium alkaline. The content of mineral nitrogen in the soil of points 1, 2 and 4 is low, the remaining points of all fields are lowest (less than 10 mg/kg with a fluctuation in the range of 69-97 mg/kg). This shows expediency top dressing by nitrogen in spring.

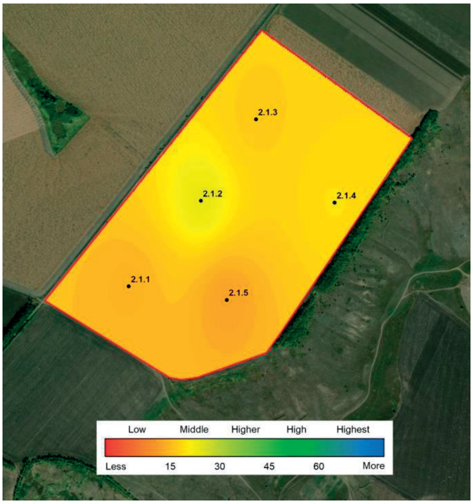
Based on the results of the analysis, doses of nitrogen fertilizer application were developed to Lipchanivka village in 2019 an example for the field № 21 given below.

Recommended doses of nitrogen fertilizers in kilograms of active substance per hectare, according to the analysis on the field № 21, are: Point 211 - N45, point 212 - N40, point 213 - N70, point 214 - N40, point 215 - N70.

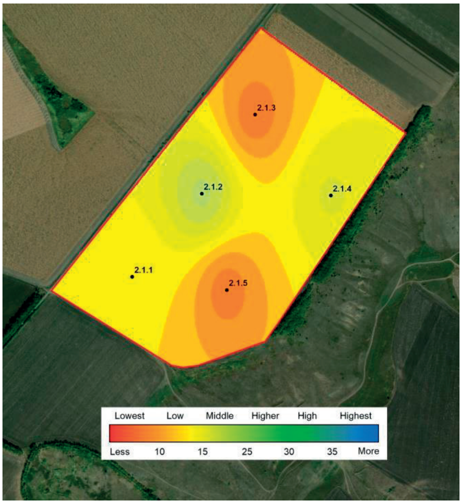
Given doses to prevent nitrogen loss, it is advisable to applicate in 2 doses – half on frost-thawed soil, half – after the resumption of plant vegetation.

Since the soil of field 21 is characterized by a low and medium content of mobile phosphorus, it is advisable to applicate ammophos or nitroammophos in it.

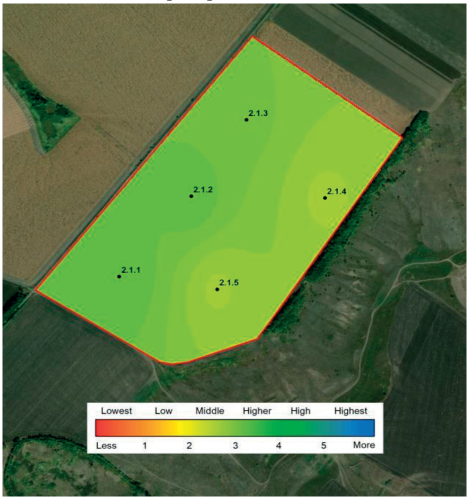
After obtaining data on the state of macro-indicators on the field using GIS tools, routes were developed for the differential application of mineral fertilizers using ordinary agricultural equipment (MTZ, etc). Figure 8 Several rounds of aerial photography from a drone were carried out after making the planned fertilizers in the fields. The main goal is to assess the state of agricultural vegetation in these fields (monitoring) Figure 9 (a-d).



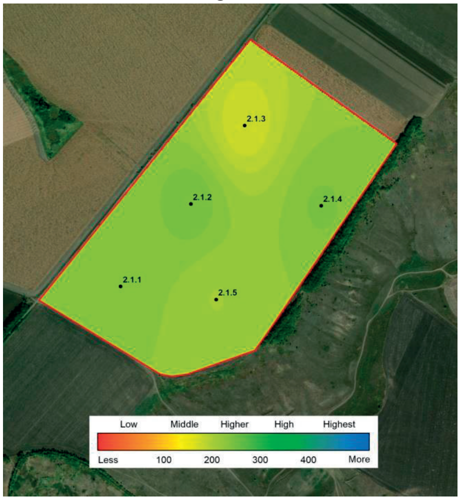
a – phosphorus content



b - nitrogen content



c - humus content



d - potassium content

Figure 7. Distribution of humus and macronutrients in the field № 21 (a-d)

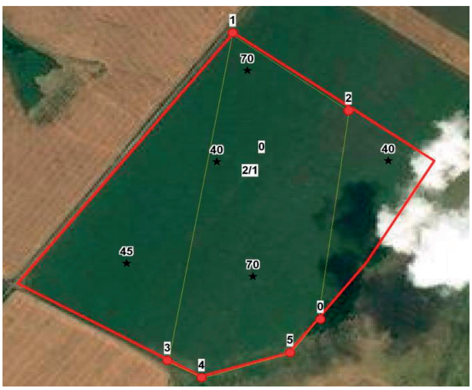


Figure 8. Estimated routes of agricultural machinery in the field № 21

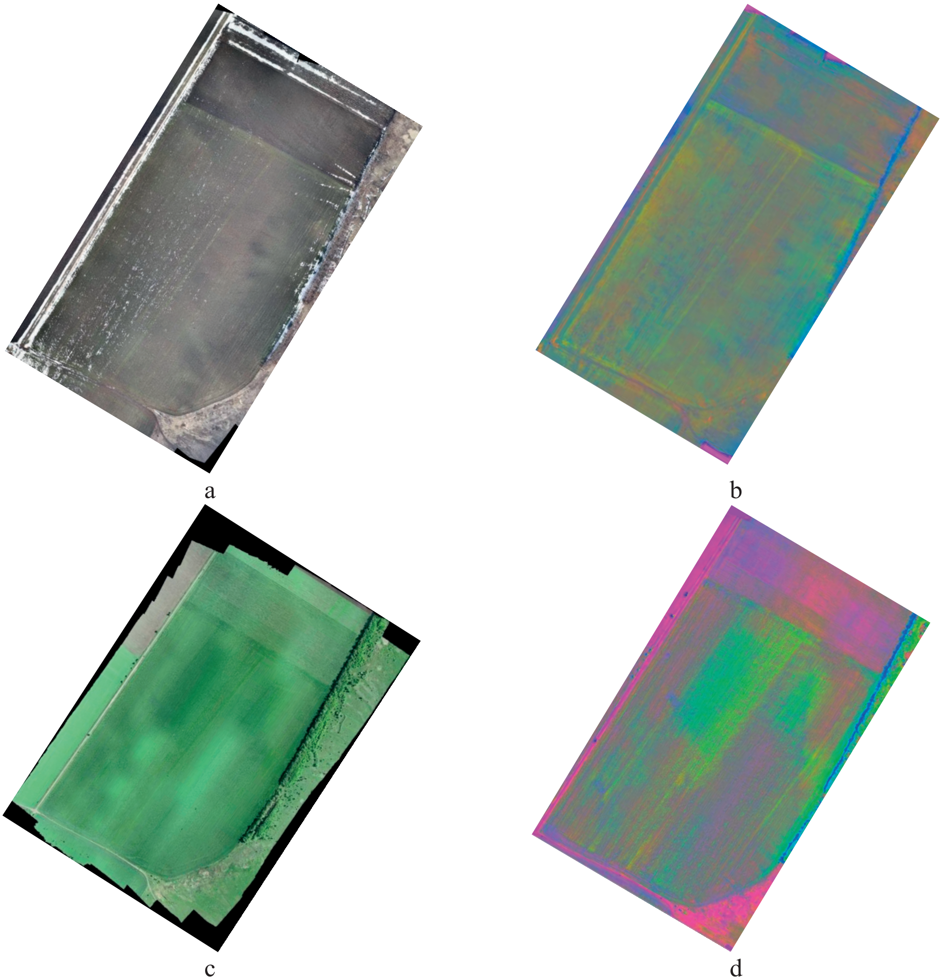


Figure 9. Field № 21 Image obtained in March (a), spectrally processed image (b) of the same date, image obtained in May (c), spectrally processed image (d) of the same date

According to the results of the flight, the dynamics of growth of winter wheat in the field № 21 was watched It has been established that since April, the lag in the growth of culture was observed in the eastern part of the field (a, b), and in the south of the field. The overflights in May showed (c, d) that the culture continues to be stunted and will not be able to produce the planned crop. Therefore, an additional survey of field № 21 was carried out on agrochemical indicators (Tables 2, 3, 4) and an added soil sample was taken in the south part of the field.

Table 2. Hydrolytic acidity and exchangeable cations on the field № 21

№, depth of selection	Hydrolytic acidity DSTU 7537:2014 cmolc kg^{-1}	Exchangeable cations ДСТУ 7861:2015 Number of equivalents of exchangeable cations cmolc kg^{-1}				
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	∑
10-30 cm	1.86	16.70	2.58	0.09	0.37	19.74
230-60 cm	1.06	16.12	1.94	0.09	0.28	18.43

Table 3. Cationic-anionic composition of the soil sample from field 21

Laboratory number	pH	Cl^-		SO_4^{2-}		Ca^{2+}		Mg^{2+}		Na^+		K^+		∑ equiv of cations, cmolc kg^{-1}
		Number of equiv cmolc kg^{-1}	Mass fraction, %	Number of equiv cmolc kg^{-1}	Mass fraction, %	Number of equiv cmolc kg^{-1}	Mass fraction, %	Number of equiv cmolc kg^{-1}	Mass fraction, %	Number of equiv cmolc kg^{-1}	Mass fraction, %	Number of equiv cmolc kg^{-1}	Mass fraction, %	
1	6.29	0.09	0.003	0.26	0.012	0.18	0.004	0.22	0.003	0.03	0.001	0.02	0.0008	0.45
2	6.30	0.09	0.003	0.18	0.009	0.18	0.004	0.17	0.002	0.03	0.001	0.02	0.0008	0.40

Table 4. Granulometric composition of the soil sample from field 21

DSTU 4730: 2007, №	Granulometric fraction content, %						
	1-0.25 mm	0.25-0.05 mm	0.05-0.01 mm	0.01-0.005 mm	0.005-0.001 mm	< 0.001 mm	Sum of fractions < 0.01
1	9.7	24.90	26.57	6.38	6.02	26.16	38.56
2	10.79	32.46	21.32	5.66	7.21	22.56	35.43

The analysis of soil samples showed that the sum of salts in the 0-30 cm layer is 19.74 cmolc kg^{-1}, in the 30-60 cm layer – 18.43 cmolc kg^{-1} of soil, which indicates that no salinization in the field №21 (Table 3), the capacity of the absorbed bases is small (Table 2) and the content of physical clay is quite high (Table 4).

Table 5 The results of the bunkering of winter wheat grain sort "Shestopalovka" on the field № 21

Field №	Area, ha	Ammonium nitrate, t/ha	Grinding, centners	Yield, centners/ha
2/01 (test part)	38	67	121 660	32
2/1 (part of the field where conventional technology was used)	34	5	108 620	319
Total	3435	595	1365 950	

The economic effect of an adaptive farming experiment

The results of the economic effect of the adaptive farming experiment are given in Table 5.

According to the data of Table 5 in the field (test plot under adaptive farming) № 2/01 with an area of 38 ha with the addition of ammonium nitrate of 67 t/ha, with a grinding of 121660 centners, the yield was 32 centners/ha. On the field № 2/1 with an area of 34 ha, with fertilizer application of 5 t/ha, with grinding of 108 620 centners, the yield was 319 centner/ha. In general, on an area of 343.5 ha and an ammonium nitrate application of 59.5 t/ha, the grinding made up 1 365 950 centners, while the economic effect amounted to 344 604.17 UAH.

CONCLUSIONS

1. Before conducting research and sowing crops, it is necessary to analyze the soil of the studying area for the granulometric composition as well as the content of absorbed bases.
2. After receiving the results of soil analysis for the content of absorbed bases and the granulometric composition, it is necessary put in order the technological map of soil contours processing into the field (if, as a result of the analysis, the granulometric composition is lightweight - top dressing should be done according to the sheet, if not, in the traditional way).
3. It is imperative to orient the passes of equipment for the soil cultivating and fertilizing plants based on the identified soil contours and contours of agricultural vegetation with different colors in aerial photographs.
4. The approach with sending operational monitoring information (aerial photography) via the web has completely paid off, which has reduced the time for analyzing information to several hours and seriously reduced errors in creating orthophotomaps.

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