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Application Of Differentiated Technologies In The Precision Agriculture System Of Northern Kazakhstan

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Abstract

The most important stage of the transition to precision agriculture is the assessment of spatial heterogeneity of fields and the calculation of doses of differentiated fertilization. Modern means of differentiated application of fertilizers allow you to make different doses of mineral fertilizers in the designated elementary areas. Therefore, when composing soil and agrochemical maps, it is necessary to take into account the characteristics of each field with high accuracy. To do this, in the conditions of production of «AES «Zarechnoye» LLC, scientists conducted agrochemical surveys and compiled digital agrochemical maps. Based on the results of calculating the economic efficiency of differentiated application of mineral fertilizers, it is worth noting an increase in the cost of fertilizer application at different levels of mobile phosphorus availability. However, this event was profitable in all its variants. Thus, the application of mineral fertilizers during sowing provided an increase in profitability relative to the control options from 11.7 to 40.3%. These indicators were achieved not only due to the growth of the crop, but also due to the higher price for high-quality products.Differentiated use of plant protection products – pre-sowing chemical treatment with a John Deere 4730 sprayer equipped with an autopilot system and a WeedSeeker system, reduced the number of overlaps, thereby increasing the accuracy of the unit's movement along the lines and improving its productivity, saving glyphosate up to 7%.

Key words: precision agriculture, differential application of fertilizers and plant protection products, agrochemical soil survey, intra-field variability of fertility, digital agrochemical map.

INTRODUCTION

For the Republic of Kazakhstan, issues of reforming the country's agrarian complex, introducing precision farming technologies that contribute to increasing soil fertility and obtaining stable crops at minimal cost are relevant.

One of the objectives of precision agriculture is to minimize the volume of herbicides by using site-specific weed management systems. To reach this goal, two major factors need to be considered: (1) the similarity of spectral signatures, shapes, and textures between weeds and crops and (2) irregular distribution of weeds within the crop [DeBaerdemaeker. 2000, McKinion et al. 2001, Tellaeche et al. 2008].

For differential application of plant protection products, systems operating in real time are of practical importance. All technological steps are carried out at the same time, that is, data collection, processing and control of the sprayer are carried out in one working pass. To implement this technological approach, various sensor systems and electronically controlled sprayers with direct and multicamera power are available on the market [Tian. 2002, Dammer, Wartenberg. 2007, Stark et al. 2013, Truflyak, Trubilin. 2016].

The most important stage in the transition to precision farming is the assessment of the spatial heterogeneity of the fields and the calculation of the doses of differential fertilizer application. Obtaining operational information on the properties of arable soils is necessary for monitoring and timely assessment of their condition. In precision farming, this information is used to spatially differentiate tillage technologies, fertilizers, meliorants, plant protection products and growth regulators, which allows for more efficient management of crops, lowering the environmental burden, reducing the costs of agricultural production and more efficiently utilizing the resource potential of agricultural lands [Nukeshevet al. 2015, Abuovaet al. 2019].

The differential application of fertilizers consists the fact that fertilizers are applied not with a single dose to the entire field being treated, but taking into account the needs of individual elementary sections of the field nutrition. At the same time, the dose of application and the ratio of nutrients are selected so that the payback of fertilizers is maximum and environmental pollution is minimized [Kurishbaev et al. 2012, Nukeshevet al. 2014].

The use of agricultural technologies without taking into account the intra-field variability of soil fertility parameters and the action of risk factors leads to an imbalance in agroecosystems [Konstantinov. 2015].

Remote sensing methods using satellite imagery have not found wide application in the differentiated accounting of field clogging, since the geometric resolution is not enough to determine weeds in the early phases of their development. In addition, optical shooting is possible only in cloudless weather. An alternative is monitoring weed fields by airplanes or remotely controlled ultralight aircraft, which require an algorithm for analyzing the processing of numerous data [Truflyaket al. 2015].

For the rational organization of on-farm arrangement, the proper use of agricultural land, the maximum yield, preservation and improvement of fertility, as well as for the effective use of fertilizers, you need to have accurate information about soil properties. The effectiveness of the differentiated use of fertilizers and other agrochemicals, as you know, largely depends on the intra-field variability of soil fertility and the state of crops. In areas aligned by fertility, differentiation of doses of fertilizers, according to the logic of things, is not required at all. Many studies on the effectiveness of differential fertilizer application abroad have shown that it is far from always economically justified, since the level and severity of the underfloor diversity of soil fertility are not taken into account.

Modern means of differential fertilizer application allow you to make various doses of mineral fertilizers in the designated elementary areas. Therefore, when compiling soil and agrochemical maps, it is necessary to take into account the characteristics of each field with high accuracy.

To do this, under the conditions of production of «AES «Zarechnoye» LLC, scientists conducted agrochemical surveys and compiled digital agrochemical maps.

The aim of this work is:

1) Study of the degree of supply of soils with basic nutrients.

2) Preparation of agrochemical maps necessary for deciding on the use of fertilizers.

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MATERIAL AND METHODS

The main task of forming a map of soil sampling is to break down the entire study area into elementary sections of the same size. A more complex case of the formation of a map is the task of placing the points of soil sampling within the field contours. It is necessary to form elementary areas in such a way that they have a uniform soil composition and do not go beyond the boundaries of the field contours.

The division of the fields into elementary sections of 10 ha makes it possible to estimate the variation of the main nutrition elements within each field.

Assessment of variation indicators. The coefficient of variation is less than 10% – the variation is weak, the population is homogeneous, the average is typical. If the coefficient of variation is in the range from 10 to 30% – the variation (variability of the trait) is moderate, the population is homogeneous, the average is typical. If the coefficient of variation is more than 30% – the variation is significant, the population is qualitatively heterogeneous and the average is not a typical characteristic of the population.

So, starting in 2019, the Qoldau.kz service has become an alternative to dividing fields into elementary sections. On its basis, additional electronic grids of fields of «AES «Zarechnoye» LLC with an area of 1800 hectares were created for agrochemical examination in the coordinate system. After that, security cartograms were created for the content of humus, mobile phosphorus, exchange potassium, sulfur, as well as nitrate supply for farm fields. Based on these data, using the Qoldau.kz application, task maps will be prepared for the differential introduction of ammophos in 2020 in order to expand the landfill area (Fig. 1).

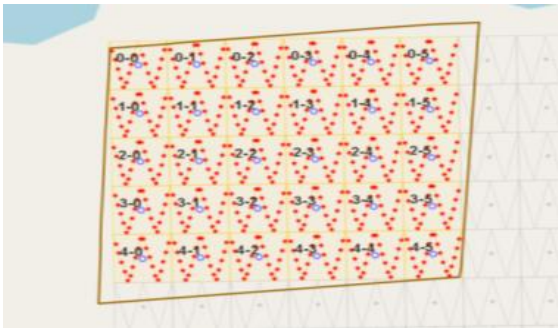


Fig. 1. Preparation of tasks for agrochemical examination

A task in your personal account is created in just a few actions. After that, a version for downloading in KML format is available, which is transferred to the tablet and opened in a special application.

Currently, modern production management systems include modern weather alert systems. Weather station Caipos, acquired and installed in the test area. This weather station is a universal autonomous system of instrumental monitoring, which provides: local agronomic weather forecast; models of the appearance of pests and infection of diseases on agricultural cultures; warning of adverse environmental factors; calculation of the growing season of crops; selection of the optimal time for chemical and biological treatments against pests and diseases; calculation of the protective action period pesticides; integration with any control and monitoring systems.

The climate in the research area is sharply continental with cold, little snowy winters and hot, dry summers. Lingering colds in spring, earlier cooling in autumn and late summer rainfall are typical of the region’s climate and distinguish it from other arid regions (for example, the Volga region). Large insolation, a sharp temperature difference day and night, low humidity, cloud cover and frequent winds cause intense evaporation of moisture, 2-5 times the amount of precipitation. Especially arid is the end of May, and most of June, when spring cereals are at the tillering stage – going into the tube. Before rainfall, plants have to spend rapidly disappearing moisture reserves accumulated in the soil as a result of winter rainfall. All climatic factors vary greatly in different years, both in tension and in time of manifestation.

According to long-term data, the annual rainfall in the experimental area is 340 mm. Precipitation of the warm period (April-October) is 71.2% of the annual amount. Most of them fall in the second half of summer.

The amount of precipitation for the period October-September in 2018 amounted to 328.8 mm or 96.7% of the annual norm, in 2019 – 285.1 mm (83.9% of the norm) and in 2020 – 449.2 mm (152.7% of the norm) (Tab.1).

Table 1. Distribution of precipitation by periods of the year in comparison with long-term norm

Year	Amount of precipitation, mm			
	Total for a year (October-September)	cold period (November-March)	warm period (April-October)	for the growing season (May-August)
Long-termnorm	340.0	98.0	242.0	162.0
2018	411.2	70.8	313.9	239.2
2019	285.1	74.7	217.1	106.9
2020	449.2	134.3	307.4	190.6

Considering the precipitation for the growing season of 2018, it is worth noting that precipitation in May, June and August exceeded the multi-year norm, while in August precipitation was 235.4% of the norm, which led to an extension of the growing season and created significant difficulties during the harvesting campaign. Precipitation for the entire growing season of 2019 was several times less than the multi-year norm, with the exception of August, which led to stress on cultivated crops and, accordingly, to a decrease in yield. The precipitation that fell in August fell on the last days of the month, which did not in any way affect the quantity and quality of agricultural crops, since the harvesting campaign was already underway. Precipitation in May and August 2020 was many times higher than the mult-iyear average. In May, most of the precipitation fell in the second decade of the month, which made it a little difficult to sow grain crops, but, nevertheless, contributed to friendly and good seedlings in the future. Precipitation in June and July was insignificant, and this led to acceleration in the phases of development of grain crops and subsequently to a decrease in grain yield (Tab. 2).

Table 2. Distribution of precipitation by months of the growing season, mm

Year	May	June	July	August
Long-term norm	36.0	35.0	56.0	35.0
2018	44.7	76.4	35.7	82.4
2019	18.1	12.8	23.0	53.0
2020	80.6	23.1	17.4	69.5

It is also worth noting that our analysis of the relationship between the grain yield and the amount and time of precipitation showed that in northern Kazakhstan, its height is determined (among other factors) by precipitation in June-July, and the quality of grain by precipitation in August-September (Fig. 2). In the first case, the more precipitation in June-July, the higher the yield; in the second, the less precipitation and the higher the temperature at the end of ripening and harvesting, the better the technological qualities of the grain.

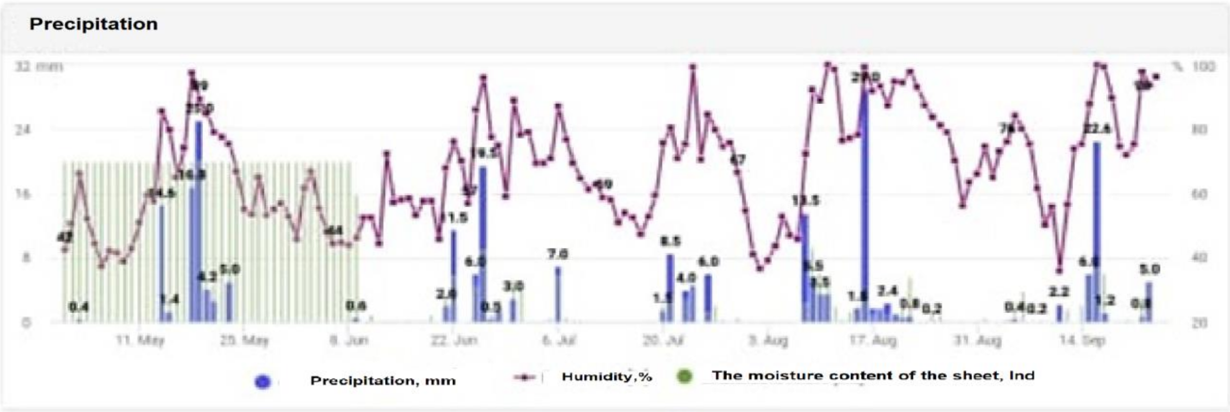


Fig. 2. Distribution of precipitation in the study area according to the Caipos automatic weather station, 2020

Regarding the average daily air temperature, it should be noted that in the warm period of 2018 it was close to the average long-term values. There is a significant increase in the average daily temperature in July in comparison with long-term values. During the warm period of 2019 and 2020 the average daily air temperature was higher than the average long-term values, with the exception of June 2020. There is also an increase in the average daily temperature in July compared to long-term values. High air temperatures during the flowering period lead to a decrease in the grain content in the ear and negatively affect the quality of wheat grain (Tab. 3, Fig. 3).

Table 3. Average daily air temperature, 0C

Year	April	May	June	July	August	September	October
Long-term norm	5.3	13.7	20.0	20.9	18.9	12.5	4.9
2018	4.5	11.9	16.6	22.1	18.1	13.2	6.2
2019	5.4	15.4	18.5	23.1	19.4	10.9	7.3
2020	7.7	17.2	17.8	23.3	19.8	11.9	5.4

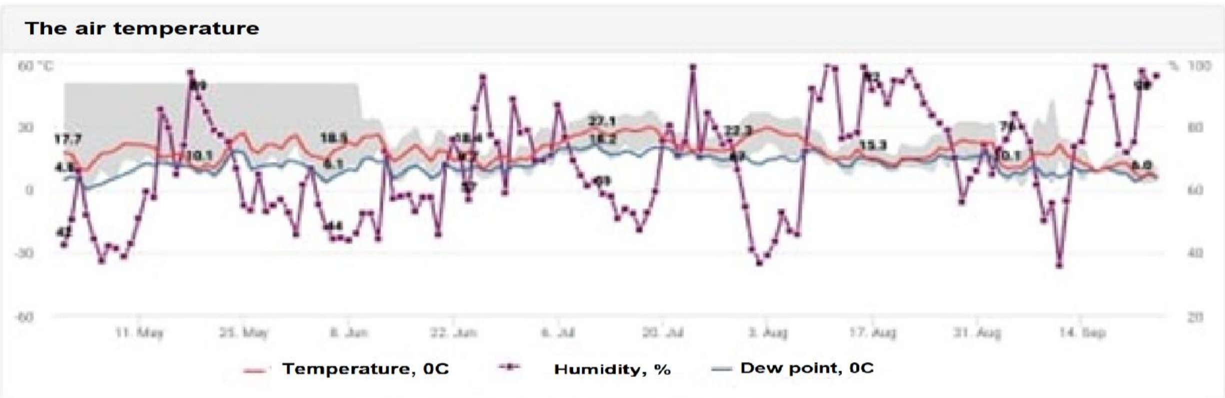


Fig. 3. The graph of the temperature regime in the research area according to the Agrosmart system, 2020

RESULTS AND DISCUSSION

In 2018, a demonstration site for precision agriculture with an area of 2,000 hectares was created on the basis of the production and demonstration testing area of «AES «Zarechnoye» LLC, which in 2019 amounted to 2,500 hectares and in 2020 reached 3,800 hectares.

«AES «Zarechnoye» LLC digitized agricultural elementary plots using the Qoldau digital platform on a total area of 22984.3 hectares, including hayfields and pastures (4231.4 hectares).

The use of glyphosate-containing products during pre-sowing treatments is an important component of conservation agriculture. So during the period of its implementation, a qualitative assessment of the contamination of fields gives tangible savings in protection means and money.

The data obtained under the conditions of 2020 before sowing indicate that all fields at the time of the chemical pre-sowing treatment had a low degree of weediness – for stubble predecessors, the second crop after fallow, and to medium – in all other fields. Thus, using the example of field No. 104.106, it can be seen that in the conditions of the year it was not possible to use selective spraying, while remote monitoring of satellite images made it possible to timely carry out high-quality pre-sowing treatment, which in early spring 2020 was carried out earlier than usual (Fig. 4).

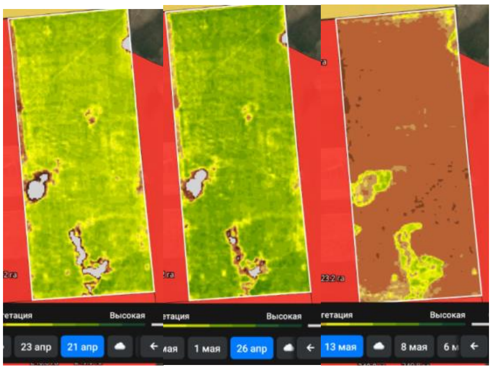


Fig.4. Monitoring of the vegetation index of weediness in order to timely combat weeds during the pre-sowing treatment

The simplest stage of introducing elements of digital technologies into crop production is the use of parallel driving and autopilot systems. Well-known world brands install this equipment on their machinery, but there are other solutions on the market that allow equipping most of the used machinery with parallel driving and autopilot systems.

A John Deere 4730 sprayer equipped with an autopilot system and a WeedSeeker system was used at the testing area of «AES «Zarechnoye» LLC for the introduction of precision agriculture elements. Pre-sowing chemical treatment was carried out on the testing area. The use of the automatic driving system made it possible to reduce the number of overlaps, thereby increasing the accuracy of the unit's movement along the lines and improving its performance (Fig.5). Thus, savings of up to 7% of glyphosate were achieved.

Fig.5. Using a parallel driving system, «AES «Zarechnoye» LL

On the contrary, the use of only a direction indicator led to a significant increase in lines of intersection. Thus, the use of manual control of the machine leads to an over consumption of the drug, as well as an increase in the consumption of fuel and lubricants and has a direct relationship with the experience of the operator.

In addition, one of the main factors restraining the growth of crop yields is the low supply of soil with nutrients. It is possible to compensate for their deficiency by applying fertilizers. However, the effectiveness of this agricultural admission significantly depends on the compliance of the accepted doses with the actual content of nutrients in the soil. Existing technique, in which agricultural commodity producers assess the condition of the entire field with an elementary survey area of 75 hectares, outdated and ineffective. It is being replaced by technologies of differential fertilizer application, which allow you to change the dose of application during the movement of the unit across the field.

The smaller the area of elementary soil areas into which the field will be divided, the more accurate the information about the presence of nutrients in the soil will be. In this case, the area of elementary sites is recommended to be determined – 0.5-1.0 ha. The relief, the hydrological system, the amount of precipitation, the variegation of the soil cover can affect the area of the elementary site. Under more leveled conditions, the area of the elementary site can be increased to 5-10 ha. This is very relevant for the conditions of Northern Kazakhstan. Since, among other factors, increased areas of elementary plots here are more preferable from an economic point of view at the initial stages of the introduction of precision agriculture systems in farms.

An agrochemical survey of the fields of «AES «Zarechnoye» LLC in 2019 was carried out on an area of 1800 hectares for differentiated fertilizer application in 2020. Samples of soil handed over to the laboratory.

According to the results of laboratory analyzes of soil samples taken on an area of 1300 ha, the content of nitrate nitrogen ($N-NO_3$), mobile phosphorus (P_2O_5), exchange potassium (K_2O) and mobile sulfur (S), humus, soil pH in the soil was determined. The results of the agrochemical inspection of the fields are shown in Tab. 4.

Table 4. Results of an agrochemical soil survey, 2019

Number of fied	Coordinates	Contained, mg/kg of soil				Humus, %	pH
		NO_3	P_2O_5	K_2O	S		
Field No. 132							
1	52°58'37.2'' N 63°40'58.4'' E	<2.8	136	481	5.17	4.08	6.35
2	52°58'37.9'' N 63°41'14.6'' E	<2.8	152	496	7.52	3.90	6.61
3	52°58'39.1'' N 63°41'31.9'' E	<2.8	154	456	0.94	3.74	6.95
4	52°58'40.1'' N 63°41'49.7'' E	<2.8	132	420	4.70	3.75	7.04
5	52°58'40.6'' N 63°42'06.8'' E	<2.8	131	426	1.65	3.95	7.22
6	52°58'41.3'' N 63°42'24.5'' E	<2.8	129	350	3.53	3.83	7.08
7	52°58'27.3'' N 63°40'57.0'' E	<2.8	143	406	3.43	3.74	6.86
8	52°58'27.9'' N 63°41'14.9'' E	<2.8	136	440	4.70	4.06	6.59
9	52°58'28.9'' N 63°41'31.3'' E	<2.8	103	360	3.76	3.99	6.80
10	52°58'29.8'' N 63°41'49.5'' E	<2.8	143	358	2.12	4.04	7.15
11	52°58'30.1'' N 63°42'05.6'' E	<2.8	123	392	2.12	3.69	7.24
13	52°58'31.5'' N 63°42'24.0'' E	<2.8	149	532	0.94	3.67	7.17
12	52°58'16.8'' N 63°40'56.4'' E	<2.8	113	420	3.06	3.65	5.80
14	52°58'18.0'' N 63°41'14.2'' E	<2.8	116	420	4.47	3.68	6.55
15	52°58'18.5'' N 63°41'31.2'' E	<2.8	109	448	2.82	4.02	6.52
16	52°58'19.4'' N 63°41'47.8'' E	<2.8	124	440	3.29	3.92	7.14
17	52°58'20.5'' N 63°42'05.3'' E	<2.8	104	426	4.47	4.15	7.26
18	52°58'20.9'' N 63°42'23.1'' E	<2.8	117	499	1.65	3.87	7.25
19	52°58'07.1'' N 63°40'55.9'' E	<2.8	73	322	4.23	3.60	5.59
20	52°58'07.7'' N 63°41'12.5'' E	<2.8	70	312	3.46	3.50	5.42
21	52°58'08.5'' N 63°41'30.2'' E	<2.8	53	288	6.35	3.32	5.58
22	52°58'09.4'' N 63°41'47.5'' E	<2.8	91	408	5.64	3.84	5.87
23	52°58'10.3'' N 63°42'04.4'' E	<2.8	92	403	3.06	3.67	5.80
24	52°58'11.1'' N 63°42'23.4'' E	<2.8	51	264	1.65	3.42	5.43
25	52°57'55.9'' N 63°40'55.5'' E	<2.8	65	288	5.17	3.38	5.45

26	52°57'56.5'' N 63°41'12.8'' E	<2.8	49	288	4.23	3.42	5.39
27	52°57'57.7'' N 63°41'29.9'' E	<2.8	64	244	4.23	3.54	5.35
28	52°57'58.0'' N 63°41'46.8'' E	<2.8	68	408	2.59	3.50	5.49
29	52°57'59.5'' N 63°42'03.6'' E	<2.8	71	298	6.35	3.64	5.98
30	52°58'00.5'' N 63°42'22.3'' E	<2.8	53	226	7.99	3.53	5.88
V		–	33.1	20.9	47	6.1	11.2
Field No. 91							
1	53°02'53.9'' N 63°47'03.7'' E	4.60	250	380	4.87	3.37	6.78
2	53°02'51.1'' N 63°47'20.6'' E	4.30	119	375	1.97	3.69	6.80
3	53°02'47.9'' N 63°47'37.9'' E	4.60	103	257	3.22	3.31	7.01
4	53°02'44.8'' N 63°47'55.0'' E	4.70	106	284	2.70	3.34	7.13
5	53°02'42.0'' N 63°48'12.4'' E	9.60	96	295	6.20	3.56	7.01
6	53°02'38.9'' N 63°48'29.8'' E	8.30	93	405	>15.00	3.21	7.10
7	53°02'44.9'' N 63°46'58.8'' E	4.80	104	334	7.05	3.63	6.18
8	53°02'41.8'' N 63°47'16.8'' E	6.90	101	389	>15.00	3.74	7.08
9	53°02'38.9'' N 63°47'32.9'' E	5.60	89	303	>15.00	3.51	6.97
10	53°02'36.0'' N 63°47'50.4'' E	7.20	104	342	6.81	3.42	7.33
11	53°02'33.4'' N 63°48'07.1'' E	8.50	87	375	9.79	3.73	7.01
12	53°02'30.3'' N 63°48'25.2'' E	10.50	109	461	>15.00	3.50	7.02
13	53°02'35.8'' N 63°46'53.7'' E	5.40	111	305	11.02	3.82	6.75
14	53°02'32.7'' N 63°47'10.7'' E	6.80	182	353	7.33	3.60	6.71
15	53°02'29.8'' N 63°47'27.4'' E	5.60	93	257	5.20	3.32	7.22
16	53°02'27.0'' N 63°47'45.0'' E	6.80	114	334	11.11	2.92	7.27
17	53°02'23.9'' N 63°48'01.8'' E	6.30	74	334	5.16	2.96	6.15
18	53°02'21.1'' N 63°48'20.3'' E	5.50	53	415	>15.00	2.85	5.98
19	53°02'26.3'' N 63°46'48.6'' E	5.00	122	457	6.67	3.57	6.42
20	53°02'23.8'' N 63°47'05.5'' E	6.60	210	426	6.72	3.37	6.47
21	53°02'21.0'' N 63°47'22.5'' E	4.70	100	397	3.36	3.31	7.35
22	53°02'17.5'' N 63°47'39.3'' E	<2.80	90	421	9.18	2.64	6.92
23	53°02'14.5'' N 63°47'57.0'' E	6.20	76	364	>15.00	3.19	7.32
24	53°02'11.5'' N 63°48'15.1'' E	10.50	103	354	>15.00	3.09	7.26
25	53°02'17.3'' N 63°46'44.0'' E	3.90	121	372	>15.00	3.96	6.90
26	53°02'14.6'' N 63°47'00.3'' E	4.20	96	374	>15.00	3.58	7.33
27	53°02'11.4'' N 63°47'17.0'' E	2.80	50	405	11.40	2.80	7.43

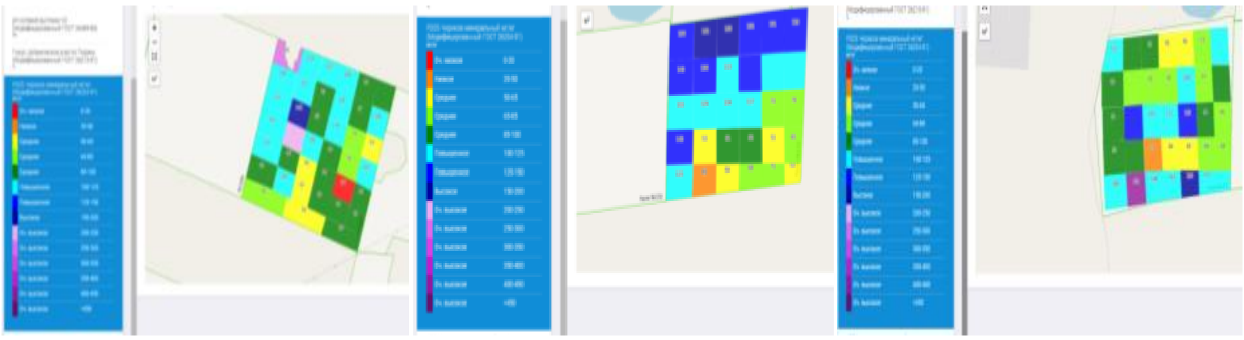
28	53°02'08.2'' N 63°47'33.8'' E	<2.80	90	421	9.18	2.64	6.92
29	53°02'05.0'' N 63°47'51.3'' E	3.70	80	449	>15.00	2.96	4.26
30	53°02'02.2'' N 63°48'10.4'' E	6.80	86	325	>15.00	3.41	7.29
31	53°02'07.7'' N 63°46'38.4'' E	6.50	99	371	11.82	3.64	6.35
32	53°02'05.1'' N 63°46'55.2'' E	<2.80	101	502	7.76	3.48	6.91
33	53°02'02.4'' N 63°47'13.3'' E	2.80	50	405	11.40	2.80	7.43
34	53°01'59.8'' N 63°47'29.0'' E	<2.80	90	421	9.18	2.64	6.92
35	53°01'56.1'' N 63°47'45.9'' E	5.50	90	509	11.92	3.11	7.50
36	53°01'52.8'' N 63°48'05.0'' E	5.50	90	509	11.92	3.11	7.50
37	53°01'59.3'' N 63°46'43.0'' E	5.80	81	354	7.14	3.49	6.25
38	53°01'52.6'' N 63°47'16.7'' E	2.80	50	405	11.40	2.80	7.43
39	53°01'45.8'' N 63°47'52.5'' E	5.50	90	509	11.92	3.11	7.50
V		33	37.9	17.2	39.4	10.8	8.6
Field No. 133							
1-1	52°57'48.8'' N 63°38'58.9'' E	<2.80	100	312	2.70	3.12	6.97
1-2	52°57'59.0'' N 63°38'57.3'' E	<2.80	93	256	>15.00	3.41	6.30
1-3	52°58'09.2'' N 63°38'55.8'' E	<2.80	94	254	7.43	3.29	5.82
1-4	52°58'19.4'' N 63°38'54.2'' E	4.50	88	287	>15.00	3.44	6.34
1-5	52°58'29.6'' N 63°38'52.7'' E	4.70	123	430	5.11	3.56	6.66
2-1	52°57'49.8'' N 63°39'15.8'' E	<2.80	404	179	7.10	2.92	5.74
2-2	52°58'00.0'' N 63°39'14.2'' E	<2.80	92	171	6.15	2.85	5.75
2-3	52°58'10.2'' N 63°39'12.7'' E	<2.80	126	444	>15.00	3.28	6.60
2-4	52°58'20.3'' N 63°39'11.1'' E	<2.80	70	198	4.12	2.95	5.60
2-5	52°58'30.5'' N 63°39'09.6'' E	3.50	98	306	2.93	3.34	7.10
3-1	52°57'50.7'' N 63°39'32.7'' E	4.50	108	292	7.57	3.12	5.74
3-2	52°58'00.9'' N 63°39'31.2'' E	9.10	31	504	3.31	3.72	5.52
3-3	52°58'11.1'' N 63°39'29.6'' E	<2.80	101	410	9.74	3.38	6.11
3-4	52°58'21.3'' N 63°39'28.1'' E	4.00	81	350	3.26	3.25	5.79
3-5	52°58'31.5'' N 63°39'26.5'' E	3.90	91	590	2.13	3.17	5.74
4-1	52°57'51.6'' N 63°39'49.6'' E	4.10	101	469	4.40	3.43	6.01
4-2	52°58'01.8'' N 63°39'48.1'' E	10.50	60	557	>15.00	4.07	6.10
4-3	52°58'12.0'' N 63°39'46.6'' E	4.30	111	590	4.49	3.35	6.29
4-4	52°58'22.2'' N 63°39'45.0'' E	<2.80	78	330	>15.00	2.95	5.64
4-5	52°58'32.4'' N 63°39'43.5'' E	<2.80	61	168	3.88	2.82	5.62

5-1	52°57'52.6'' N 63°40'06.6'' E	3.60	150	331	>15.00	3.38	6.96
5-2	52°58'02.7'' N 63°40'05.0'' E	3.90	62	480	11.40	3.35	5.88
5-3	52°58'12.9'' N 63°40'03.5'' E	6.60	125	585	8.51	3.76	6.06
5-4	52°58'23.1'' N 63°40'01.9'' E	5.50	100	500	>15.00	3.70	5.93
5-5	52°58'33.3'' N 63°40'00.4'' E	<2.80	56	189	4.02	2.91	5.62
6-1	52°57'53.5'' N 63°40'23.5'' E	<2.80	117	293	>15.00	3.11	5.91
6-2	52°58'03.7'' N 63°40'22.0'' E	4.50	69	300	11.83	3.43	5.70
6-3	52°58'13.9'' N 63°40'20.4'' E	5.90	94	441	>15.00	3.69	6.19
6-4	52°58'24.1'' N 63°40'18.9'' E	5.60	67	498	>15.00	3.77	6.36
6-5	52°58'34.3'' N 63°40'17.3'' E	6.20	73	434	>15.00	3.25	5.87
7-1	52°57'54.4'' N 63°40'40.4'' E	4.00	108	306	>15.00	3.12	5.65
7-2	52°58'04.6'' N 63°40'38.9'' E	6.30	84	435	>15.00	3.68	5.86
7-3	52°58'14.8'' N 63°40'37.3'' E	4.20	66	354	3.50	3.10	5.78
7-4	52°58'25.0'' N 63°40'35.8'' E	<2.80	89	512	1.94	3.23	6.67
7-5	52°58'35.2'' N 63°40'34.2'' E	4.20	114	334	4.97	2.95	6.90
V		34,2	58.5	33.7	33.7	9.1	7.4

Thus, evaluating the variability of the content of plant nutrients in the area during the crop sowing period, it is worth noting at the time of the survey the extremely low content of nitrate nitrogen in field No. 132, which is used in production for different varieties and crops. Low indicators were also noted in other fields – No. 91 and No. 133.

Analyzing the indicators of variation of the main elements of nutrition and sulfur within the fields, it must be emphasized that for the most part it was at a high level, i.e. the variability of these indicators was strong and indicated heterogeneity. The soil variability in organic matter content was generally low.

Assessing the fluctuation of mobile phosphorus within one field over elementary sections, it is worth noting the highest heterogeneity of fieldsNo. 91 and No. 132 and No. 133 (Fig.6).



a b c

Fig.6. The content of mobile phosphorus in the fields of the demonstration site, autumn 2019: a – field No. 91; b – field No. 132; c – field No. 133

At the same time, it is important to emphasize that this element in the open spaces of Northern Kazakhstan plays a leading role along with nitrate nitrogen in the formation of a high-quality crop. Moreover, it is also worth noting that it is the soils of Northern Kazakhstan, as a rule, poor in phosphorus.

On the basis of the data, cartograms of supply of humus, mobile phosphorus, exchangeable potassium, sulfur, as well as supply of nitrate nitrogen in the fields of the farm were created.

In order to establish the effectiveness of fertilization in individual areas with varying degrees of provision, control plots were provided where fertilizers were either not applied at all, or an average dose of 29 kg in physical weight was applied. Task maps are shown in Fig.7-9.

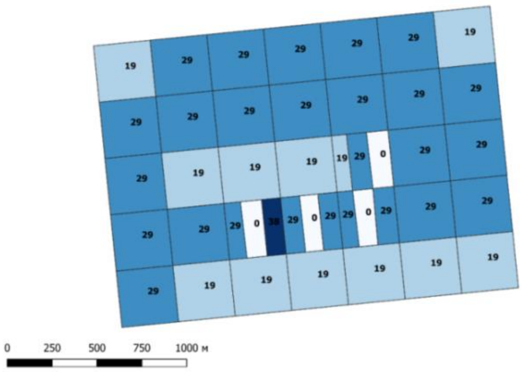


Fig. 7. Field No. 133, «AES «Zarechnoye» LLC, 2020

On the field No. 133, a total of 8.65 tons of fertilizers were applied on a total area of 350 hectares, of which with a rate of 38 kg/ha per 3.35 hectares, 29 kg/ha on an area of 219.88 hectares, 19 kg/ha per area of 112.71 hectares, and 14.06 hectares were without fertilization.

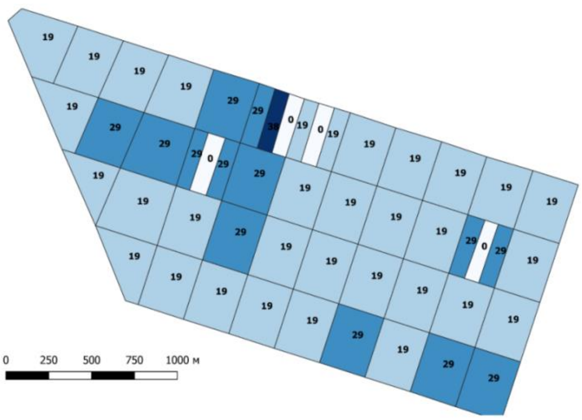


Fig. 8. Field No. 94, «AES «Zarechnoye» LLC, 2020

On the field No. 94, a total of 8.73 tons of fertilizers were applied on a total area of 417.74 hectares, of which with a rate of 38 kg/ha per 3.2 hectares, 29 kg/ha on an area of 97.94 hectares, 19 kg/hectares on an area of 303.45 hectares, and 13.15 hectares were without fertilization.

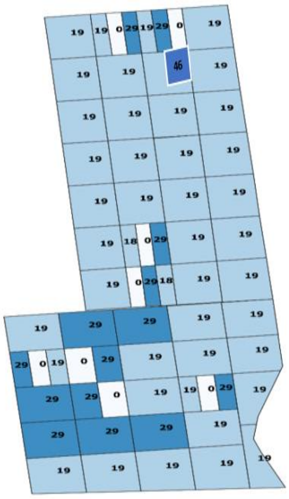


Fig. 9. Fields No. 101-103 and No. 104-106, «AES «Zarechnoye» LLC, 2020

On the field No. 101-103, a total of 5.6 tons of fertilizers were applied on a total area of 255.5 hectares, of which with a rate of 29 kg/ha on an area of 93.27 hectares, 19 kg/ha on an area of 145.56 hectares, and 16.63 hectares were without fertilization.

On the field No. 104-106, a total of 5.3 tons were applied on a total area of 281.5 hectares, of which with a rate of 46 kg/ha on an area of 2 hectares, 29 kg/ha each on an area of 12.99 hectares, 19 kg/ha on an area of 253.61 ha, and 12.93 ha were without fertilization.

On the field No. 109, a total of 4.2 tons of fertilizers were applied on a total area of 163.1 hectares, of which with a rate of 40 kg/ha on an area of 2 hectares, with a rate of 29 kg/ha on an area of 114.2 hectares, 19 kg/ha, on an area of 33.59 ha, and 13.35 ha were without fertilization.

CONCLUSIONS

Differentiated use of plant protection products – pre-sowing chemical treatment with a John Deere 4730 sprayer equipped with an autopilot system and a WeedSeeker system, reduced the number of overlaps, thereby increasing the accuracy of the unit's movement along the lines and improving its productivity, saving glyphosate up to 7%.

According to the results of the calculation of economic efficiency with the differentiated application of mineral fertilizers, it is worth noting the increase in the cost of fertilizing at different degrees of availability of mobile phosphorus. However, this event in all cases was profitable. So, the application of mineral fertilizers when sowing was more effective on the option of an average degree of phosphorus supply – profitability is higher than the control by 13.2%. With a high and medium degree of security, the highest profitability of 86.0 and 85.3% was obtained, which was 40.3 and 11.7% higher than their control options, respectively.

It should also be emphasized that, the introduction differentiated application of mineral fertilizers improved the economy of spring wheat grain production not only due to the difference in yield, but also often due to the difference in the cost of products of different classes in quality.

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