Using GIS technologies to determine the weediness of agricultural crops in the example of the Akmola region

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Abstract. Data from the PlanetScope remote sensing mission were used to determine the infestation of crops in the Akmola region. Data were obtained from 17 districts and two municipal cities. The statistical analysis of objects is shown, and the minimum, maximum, average, and standard deviation of the indicators of the studied sown areas in the Akmola region are revealed. Spring-summer and summer-autumn surveys of weed infestation of agricultural crops showed that despite the implementation of regular agrotechnical and chemical protective measures, the general condition of crops was determined as satisfactory (medium). The study shows that a complete database of information about agricultural, arable, and fallow fields could be easily formed with GIS technologies, and survey data of digitized crops in the Akmola region are available in real time for most users.

1 Introduction

According to the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, the gross harvest of grains and legumes for 2018-2020 in the Republic of Kazakhstan amounted to 2018 - 20,273.7 thousand tons, 2019 - 17,428.6 thousand tons, 2020 - 20,065.3 thousand tons [2].

Statistical data analysis states that wheat crops occupy a significant part of the harvest. In 2020, three regions became leaders in wheat-producing: Akmola (4,127.6 thousand tons), Kostanay (3,455.0 thousand tons), and North Kazakhstan (3,299.8 thousand tons) [2].

The preservation of high-quality and safe raw materials is one of modern Kazakhstan's most important strategic tasks. Due to the improvement of agricultural technologies over the past decade, there has been a positive trend in wheat yields in most areas of Akmola and other regions.

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It should be noted that the Turkestan, Zhambyl, and Almaty regions showed the best results in terms of wheat yield in 2021, 19.9, 19.8, and 19.7 centners per hectare, respectively (Table 1).

Table 1. Wheat yield (quintals per hectare) [2].

Region	2018	2019	2020	2021
Akmola	11.1	10.9	11.1	9.2
Aktobe	11.7	12.7	11.0	8.2
Almaty	20.0	20.1	20.3	19.7
West Kazakhstan	15.6	16.2	7.7	10.8
Zhambyl	21.3	21.1	22.5	19.8
Karaganda	11.9	9.6	11.9	9.1
Kostanay	10.5	11.3	11.4	7.3
Kyzylorda	14.9	15.1	16.8	16.3
South Kazakhstan	21.1	16.4	-	-
Turkestan	-	-	14.9	19.9
Pavlodar	10.1	10.0	11.2	7.9
North Kazakhstan	14.8	16.7	15.4	14.2
East Kazakhstan	12.7	11.3	14.4	16.2
Nur-Sultan city	7.4	6.3	5.8	8.5
Almaty city	8.0	6.9	6.1	-
Shymkent city	-	-	8.6	13.4

Obtaining data on agriculture, mainly field weeds, yields, and soil conditions, is time-consuming and costly, so proper statistical analysis of the data is often a challenge for producers [5]. However, many studies state that obtaining data using remote sensing and satellite imagery may significantly change the game, this imagery becomes an alternative data source for determining crop productivity indicators. They are easy and relatively inexpensive to obtain, and they are statistically reliable compared with ground data [6,7,8,9].

Satellite-based remote sensing is a high-performance tool for obtaining agricultural information with spatial and temporal resolution [10].

Crop remote sensing provides mapping, monitoring, and modeling of crop types, epidemics, and crop quality and quantity. The resulting maps of individual agricultural fields are considered informative [11].

In 2015, two optical spacecraft, KazEOSat-1 (high resolution – 1 m) and KazEOSat-2 (medium-resolution - 6.5 m), were put into operation in Kazakhstan, with which a space remote control system was created and successfully operated remote sensing. The system is designed to conduct space surveys of the Earth's surface and provide operational monitoring information to solve different problems in the economic sector of the Republic of Kazakhstan (Figure 1) [1].

According to statistical data from the official source [3], developed as part of the resolutions from the Kazakhstan President, K.K. Tokayev on the introduction of digital monitoring and control over the rational use of agricultural land, the share of digitized land, the total area of fields in the Akmola region amounted to 5,957,097 hectares, the area of digitized land - 6,136,397.89 ha, the number of land users - 3,556, the total number of electronic land -27 418. In the context of districts, the share of digitized lands from the entire area is 96.7 -100% (Table 2) [3].

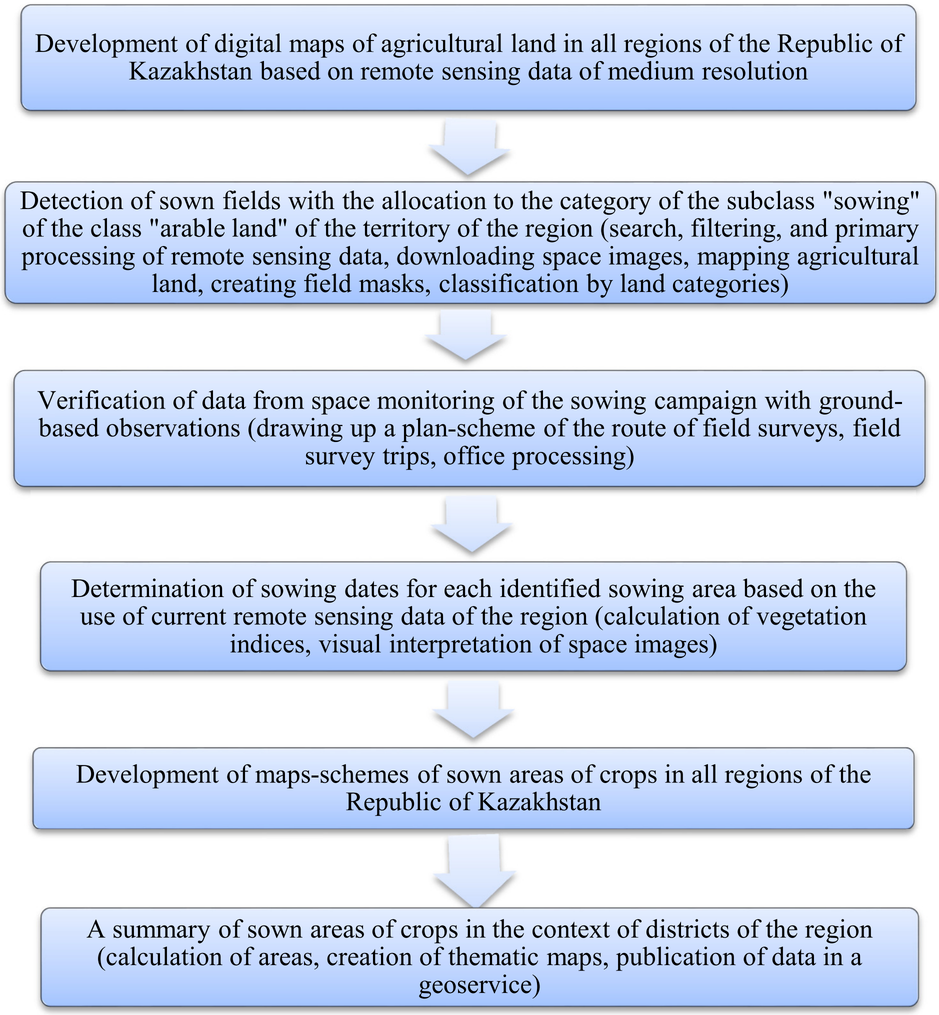

Fig. 1. Scheme of satellite estimation of sown areas of crops.

Using the data obtained from the PlanetScope geoinformation system, it is possible to get high-quality maps since the system has a high spatial resolution (3 m) [12]. Compared to the traditional data collection approach, the advantage of remote sensing in agricultural management is undeniable [13]. In addition, PlanetScope satellites are relatively inexpensive to manufacture, and available, which allows you to create a collection of images with both high spatial and temporal resolution (up to 1 week) at a lower cost [14].

In general, previous studies highlight the effectiveness of using space-based and ground-based monitoring data. The main purpose of this article is to explore the statistical indicators of the collected data using geographic information systems in determining the weediness of crops in the Akmola region.

Table 2. Digitization of arable land by districts of the Akmola region as of 2021 [3].

District	**Number of land users**	**Electronic lands**	**Area of digitized land, ha**	**Share of digitized lands, %**
Yereymentausky	143	567	150 856.06	100.0
Stepnogorsk	24	132	31 634.5	100.0
Kokshetau	17	59	7 275.34	100.0
Astrakhan	206	1 804	452 852.53	100.0
Yegindykolsky	229	1 344	355 901.85	100.0
Enbekshildersky	173	1 306	248 940.34	100.0
Zhaksinsky	247	2 172	596 601.51	100.0
Shortandinsky	94	1 226	287 109.94	100.0
Atbasar	211	1 855	487 579.8	100.0
Burabay	211	1 731	215 558.93	100.0
Zerenda	392	2 475	328 784.82	100.0
Bulandinsky	114	1 365	305 893.75	100.0
Zharkainsky	473	2 834	725 445.09	100.0
Tselinogradsky	201	1 380	322 981.09	100.0
Akkol	134	1 252	227 412.83	100.0
Arshaly	215	1 180	224 479.65	99.6
Sandyktau	241	2 153	383 289.56	96.9
Korgalzhyn	121	713	221 578.14	96.7
Esilsky	152	1 853	560 850.14	96.7

2 Materials and methods

This study focuses on agricultural crops in the Akmola region. The Akmola region includes 17 districts and 2 municipalities.

For further determination of weediness, the fields are measured by regular intervals along the largest diagonal of frames that are divided into sections of 25x100 cm. Inside the structure, the number of weeds by species is counted. Depending on the degree of infestation (number of weeds per square meter), the surveyed areas are grouped according to the following gradations: 1-5; 6-15; 16-50; 51-100; more than 100. After the registration of weeds and the determination of their biological groups, mapping the weediness of the fields begins [4].

The first stage is a spring-summer inspection of crops in the phase of weed regrowth for short-term forecasting of weediness and chemical weeding. The second stage - summer-autumn surveys before harvesting, is for long-term forecasting and planning of agrotechnical and chemical protective measures.

When assessing agricultural areas on the territory of Kazakhstan, space images from the following sources are used: images from the KazEOSat-2 remote sensing satellites (with a spatial resolution of 6.5 m/pixel), PlanetScope (with a spatial resolution of 3.5 m/pixel), images from the remote sensing satellite Landsat (with a spatial resolution of 30 m/pixel), images from the remote sensing satellite Sentinel-2 (with a spatial resolution of 10 m/pixel)

[1]. The images were taken in 2021. A controlled method was used to separate image pixels into different classes in the work. Supervised classification combines pixels into categories based on user data for training. The training data can come from an imported ROI file or user-created ROIs in the image. After the satellite image is loaded, it is processed for further use for classification. Next, noise is eliminated, and atmospheric correction is performed in order to reduce the influence of natural factors on the spectral data [1].

Figure 2 shows a digital map of agricultural land in the Akmola region, which includes 6 zones: fallow (orange), not plowed (red), lying fallow (blue), arable land (sown) (yellow), arable land (unsown) (dark green) and hayfield (light green).

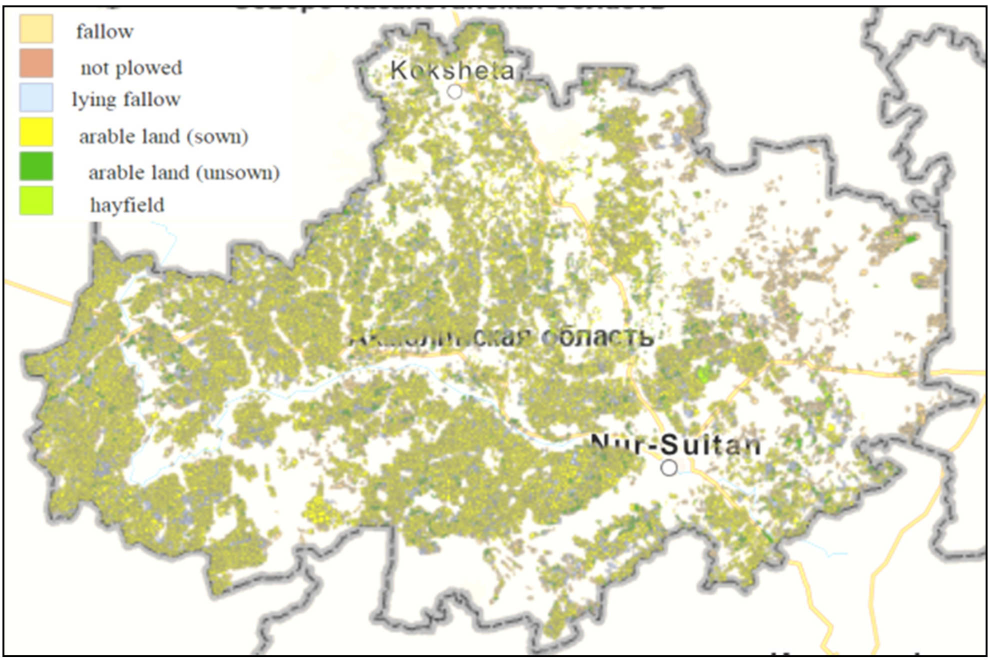

Fig. 2. Zoning of agricultural lands in the Akmola region [1].

To obtain reliable information on the weed infestation of agricultural land, the authors have collected data from the professionals of the “Republican Methodological Center for Phytosanitary Diagnostics and Forecasts” of the State Inspection Committee in the Agroindustry Complex of the Ministry of Agriculture of the Akmola Region [15]. The collected sample data on the weediness of agricultural land at different stages of ripeness from 11 districts of the Akmola region are shown in Table 3.

3 Results and discussion

The analysis of the field survey data showed in Table 3 that the wheat crops of the Akkol, Astrakhan, Bulandinsky, Zerenda, Sandyktau, and Atbasar districts in the stage of milky ripeness were mostly infested to an average degree, and the visual yield for wheat was 8.8-15.1 centner/ha, the condition of the crops is good, while the barley crops mainly were infested to a low degree, the yield of barley was 13.2-19.8 centner/ha, and the condition of the crops is good.

The main methods of weed control are agrotechnical and chemical. When using mechanical tillage, using tools with paw working parts is necessary. With a delay in the emergence of weeds, intermediate mechanical tillage before sowing is effective. It is necessary to know their biological characteristics and methods for successful weed control. One of the most common control methods is the use of combined 2- or 3-component preparations that combine the properties of herbicides of various groups, which expands the range of their action [4].

Filtered data statistics (minimum, maximum, average, standard deviation) were determined for all the numbers of surveys conducted in the agricultural fields of the Akmola region (Table 4).

Table 3. Study of weed infestation of agricultural crops in the districts of Akmola region at different stages of ripeness.

District	Culture	Stages of ripeness	Condition	Infestation	Yield
Akkol	wheat	milky ripe	good	mean	12.8
	wheat	milky ripe	good	mean	12.1
	wheat	milky ripe	good	mean	11.5
Astrakhan	wheat	milky ripe	good	mean	13.8
	wheat	milky ripe	mean	mean	8.8
	wheat	milky ripe	good	low	13.3
Atbassar	barley	milky ripe	good	mean	13.3
	wheat	milky ripe	good	mean	14.3
	barley	milky ripe	good	mean	13.5
Bulandinsky	barley	milky ripe	good	low	18
	wheat	milky ripe	good	mean	11.8
	wheat	full ripeness	good	low	15.1
Burabay	wheat	milky ripe	good	mean	11.8
	wheat	milky ripe	good	mean	9.3
Enbekshildersky	barley	full ripeness	mean	low	7.8
	barley	milky ripe	mean	mean	8.4
	wheat	milky ripe	mean	mean	8.4
Zerendinskiy	barley	milky ripe	good	mean	13.2
	barley	milky ripe	good	low	19.8
Korgalzhynsky	barley	milky ripe	mean	mean	13.1
	wheat	milky ripe	good	mean	15.8
	wheat	milky ripe	mean	mean	11.8
Sandyktau	wheat	milky ripe	good	mean	12.6
	barley	milky ripe	good	mean	19.5
	wheat	milky ripe	good	low	12.1
Tselinogradsky	wheat	milky ripe	mean	low	11.3
	wheat	milky ripe	mean	heavy	10.8
	wheat	milky ripe	good	mean	12.1

Table 4. Statistical indicators of the studied areas of agricultural land in the districts of the Akmola region, ha.

District	Number of values	Sum of values	Minimum	Maximum	The average	Standard deviation
Esilsky	1815	602174.677	2.409569	1148.07109	331.776681	133.858229
Tselinogradsky	1174	349864.569	0.065101	1287.06105	298.010706	209.106309
Shortandinsky	1127	296236.804	2.292341	1858.42718	262.854307	198.348095
Sandyktau	1901	398302.300	0.000103	1362.16868	209.522514	155.859846
Korgalzhynsky	673	229021.342	0.003730	1422.46597	340.299171	203.975295
Yereymentau	1379	385462.627	0.000180	2493.80484	279.523297	246.614840
Egindykolsky	1099	372587.246	12.103743	1266.26405	339.023882	167.217218
Zerendinskiy	2101	313354.904	1.840335	1013.96229	149.145599	119.526190
Zharkainsky	2322	752114.996	0.349320	1655.10655	323.908267	177.089640
Zhaksynsky	1191	388636.185	4.694266	1296.62570	326.310819	148.103360
Stepnogorsk	177	22330.6233	1.525208	1188.49831	126.161714	158.096418
Kokshetau	57	7002.17646	4.542125	338.307090	122.845201	84.862894
Burabay	1683	218083.274	0.000020	1283.87922	129.580080	120.098980
Bulandinsky	1359	289288.293	0.004431	1049.88642	212.868501	173.064277
Birzhan Sala	624	97858.3750	0.000929	1202.65094	156.824319	171.822970
Atbassar	2174	567596.450	0.000117	2205.74482	261.083923	204.367408
Astrakhan	961	221723.776	0.001916	904.616894	230.721931	166.145222
Arshalynsky	1653	277331.638	0.129817	1533.02069	167.774736	157.145733
Akkol	2111	323661.500	0.016796	1809.66758	153.321411	164.240046

4 Conclusions

In 2020, three regions became leaders in wheat-producing: Akmola (4,127.6 thousand tons), Kostanay (3,455.0 thousand tons), and North Kazakhstan (3,299.8 thousand tons). On the other hand, in terms of wheat yield characteristics, Turkestan, Zhambyl, and Almaty regions were in the lead in 2021, with 19.9, 19.8, and 19.7 centners per hectare, respectively. Data collection is a rather laborious process, that could be significantly facilitated if the digitalization of land is present. According to statistics, digitized land in the Akmola region ranged from 96.7 to 100%. The digital map of agricultural land in the Akmola region includes 6 zones: fallow (orange), not plowed (red), lying fallow (blue), arable land (sown) (yellow), arable land (unsown) (dark green) and hayfield (light green). At the milky ripeness stage, the condition of wheat crops in the Akkol, Astrakhan, Bulandinsky, Zerenda, Sandyktau, and Atbasar regions was mainly good, with the moderate weed infestation and the visual yield for wheat varying from 8.8 to 15.1 c/ha. The condition of barley crops in the same districts also showed good results: weed infestation is weak, and barley yield ranges from 13.2 to 19.8 q/ha. The statistics of filtered data on the state of agricultural lands in the Akmola region showed that in Zharkainsky, Atbasarsky, Akkolsky, and Zerenda districts, the weeds accounting and data introduction was the most systematic and frequent, which in turn makes it possible to compile a detailed map of their infestation.

The use of Earth remote sensing data for monitoring agricultural production makes it possible to create a database of complete information on agricultural, arable, and fallow fields. Detailed information on the state of agricultural land, the productivity of areas, and the state of fallow fields is not available in official statistics or contains scattered information; data collection on them requires high costs and human resources, so the most complete and reliable information can be obtained using satellite surveillance systems. Thus, it could be argued that the assessment of the areas of agricultural fields allows you to collect information on the state of crops, compile data on the effectiveness of agrotechnical and chemical measures to eliminate weeds, and further develop recommendations for their implementation.

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