CHEMICAL ENGINEERING TRANSACTIONS
VOL. 94, 2022

A publication of
AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Petar S. Varbanov, Yee Van Fan, Jiří J. Klemeš, Sandro Nižetić

ISBN 978-88-95608-93-8; **ISSN** 2283-9216

DOI: 10.3303/CET2294147

Using Remote Sensing Data to Support Intelligent Agricultural GIS to Monitor the Condition of Arable Land and Crops

Marzhan Yessenbekovna Rakhymberdina[a,*], Natalya Anatolyevna Kulenova[b], Zhasulan Kudaibergenovich Shaimardanov[b], Zhanna Alexandrovna Assylkhanova[a], Marzhan Melsovna Toguzova[a], Dauren Kuttybayevich Kassymov[a]

[a]School of Earth Sciences, D. Serikbayev East Kazakhstan Technical University, Serikbayev str. 19, 070000 Ust-Kamenogorsk, Kazakhstan
[b]Centre of excellence «Veritas», D. Serikbayev East Kazakhstan Technical University, Serikbayev str. 19, 070000 Ust-Kamenogorsk, Kazakhstan
MRahymberdina@ektu.kz

The article reviews the modern state of the multi-level agricultural land monitoring system in Kazakhstan, as an element of the precision farming system, carried out both at the state level and in the context of land users. The main constraints to the widespread use of remote sensing (RS) and unmanned aerial vehicles (UAV) data were identified. The large extent of the country's territory, different climatic conditions, large differences in the altitude of the terrain impose an impact on the choice of methods of data processing and interpretation. Data from Sentinel, Landsat, Modis satellites are used as input data, on which software applications of the most common in agriculture are based. On the basis of conducted monitoring of agricultural lands in KH "Mayak" farm in Pavlodar region with the use of available online applications, programs, native web services, UAV evaluated the potential of multi-level use of remote sensing in modern conditions of Kazakhstan. The results of the UAV survey with a mobile RTK station allow ensuring the accuracy of the map at a scale of 1: 1000.

1. Introduction

1.1 Innovative technologies in agriculture

In today's world, agriculture is at a level where the use of software with certain functionality and modern technology is necessary for efficient and rational work. Land is the main national treasure and wealth, the basis of life, especially where the population is engaged in agricultural production. Given the increasing dynamics of population growth in the world, much more effort and innovation are needed to improve food security.
The world market offers a variety of GIS for agriculture, where an important role is played by the ability to monitor the state of arable land, growth and development of crops. At the same time space images of different spatial and spectral resolution are used as the basis. All this allows in the future to scientifically substantiate the assessment of the state, compare with the data of previous years and model the process of crop development.
The main players in the development and implementation of innovative technologies in agriculture are such countries as the USA, China, India, Brazil and Japan. And they are leaders in the development of innovation not only in agriculture, but also leaders in the development of many other industries and the implementation of innovative technologies in these countries is developing everywhere.
Thus, the leader in terms of agricultural efficiency is the USA, yet only 2 % of the labor force is employed in this industry. In the USA, the level of penetration of innovation in agriculture reaches up to 80 % (Kutbitdinov, 2019). Japan has effectively developed robotics and their integration into agriculture is obvious. China and India are now very effectively developing university-based agriculture, equipping research and education centers with the necessary innovations in precision agriculture. Today, Brazil is experiencing a real "boom" in the development of precision agriculture. This is due to strong economic growth and the fact that the country is actively introducing resource-saving technologies (Salnikova and Rozhkova, 2021).

Paper Received: 27 June 2022; Revised: 12 July 2022; Accepted: 12 July 2022
Please cite this article as: Rakhymberdina M.Y., Kulenova N.A., Shaimardanov Z.K., Assylkhanova Z.A., Toguzova M.M., Kassymov D.K., 2022, Using Remote Sensing Data to Support Intelligent Agricultural GIS to Monitor the Condition of Arable Land and Crops, Chemical Engineering Transactions, 94, 883-888 DOI:10.3303/CET2294147

Now the population has increased demand for environmentally healthy food, as a consequence, organic farming is actively developing in the world. Here the leaders in the development of organic farming are countries with large land resources, and it is - the USA, Canada, Brazil, great prospects have today - Russia, Ukraine, Belarus and Kazakhstan (Bekmatova, 2018).

1.2 Introduction of digital technologies in agriculture in Kazakhstan

Kazakhstan ranks 52nd among 176 countries in the world ranking on the Information and Communication Technology (ICT) development index (Bogatova, 2021). ICT is calculated according to the methodology of the International Telecommunication Union, a specialized unit of the UN that defines global standards in the field of ICT (2022). According to the ICT index, Kazakhstan is ahead of such countries as Saudi Arabia, Turkey, Georgia, Armenia, Ukraine, China, Uzbekistan, India, etc. and is included in the so-called promising zone of economic development with a digitalization rate of 51 % and a digitalization rate of 55 % (2020). According to the IMD (World Digital Competitiveness Ranking), which is formed on the basis of 50 criteria, Kazakhstan took 32nd place in 2021, against 36th place in 2020 (2021).

This demonstrates the rather high potential of Kazakhstan and its ability to implement ICT in the agricultural sector. Digitalization of agriculture levels out the disadvantages associated with the long production and technological cycle, natural and climatic risks, large crop losses during cultivation, harvesting and storage. It allows for rapid monitoring of cultivated areas, updating field maps to establish navigation systems, reduce theft of material assets, fuel, crop protection products and seed materials (Akhmetov and Galikeev, 2019). The formation of new technological concepts of information and communication technologies leads to a constant increase in the number of connected devices and, as a consequence, a constant increase in the volume of information transmitted over all types of communication networks. Such concepts include the Internet of Things (IoT) and artificial intelligence (Harsimran, 2020). These two methods underlie the creation of intelligent agricultural systems. IoT is mainly used to automatically collect agricultural data and transmit the collected data to data centers (Zhang et al., 2019), while artificial intelligence techniques such as artificial neural networks and clustering are used to analyze agricultural data for intelligent decision making (Gubbi et al., 2013). The work (Roopaei et al., 2017) considers some methods of Internet of Things for solving practical problems of irrigation optimization, which can be applied in the conditions of Eastern Kazakhstan. Deployment of the Cloud of Things (CoT) network, which includes the Internet of Things and cyber-physical system, can make a breakthrough in intelligent agriculture. For example, analysis of data collected in the CoT network (weather conditions, land condition, soil type and others) can provide necessary information when used in combination with data obtained by sensors measuring heat, moisture, chemicals, water stress, its level, etc. This will allow farmers to use water resources, fertilizers and pesticides in more accurate quantities and positions, which is especially important because agriculture is one of the water- and energy-intensive industries.

In Kazakhstan, as well as in the modern world, the deterioration of the ecological state of lands, the development of erosion processes, desertification, salinization, pollution with chemical and radioactive substances, overgrowth with forests and shrubs is of particular concern, and therefore, significant areas of land exclude agricultural use of land.

Rational use of land is possible only on the basis of in-depth study of the soil cover, knowledge of the specifics of soil fertility, their ecological properties and constant monitoring of both qualitative and qualitative characteristics of the land fund.

In Kazakhstan, "smart" agriculture is at the stage of implementation of technologies in large agricultural enterprises. In accordance with the state program Digital Kazakhstan (2017) and the Action Plan to implement the Message of the President of the Republic of Kazakhstan by 2022 in the context of the East Kazakhstan region its planned to introduce elements of precision farming on 150 advanced farms of the region until 2022.

In accordance with the strategy of agricultural development for the coming years the following stages of introduction of precision farming are allocated:

- First stage (2018-2019) - digitization of arable lands;
- Second stage (2021) - soil analysis, electronic agrochemical cartograms;
- Third stage (2021 - 2022) - acquisition of weather stations, compilation of electronic maps of weeds;
- Fourth stage (2022) is the introduction of process management software.

For full-scale digitalization of arable land and coverage of 100 % of the territory it is necessary to use satellite imagery data.

In Kazakhstan, such studies were carried out by the Sultagazin Space Research Institute, where TERRA/MODIS IRS/Resourcesat/Awifs satellite information of medium spatial resolution with a wide swath was used for agricultural land studies (Zhantayev et al., 2012). The studies included on-line determination of the sowing area of spring crops and fallow fields, control over the timing of spring sowing, assessment of the

condition and weediness of spring crops, forecast of gross grain harvest, control over the timing and volume of harvesting work (Spivak and Muratova, 2011).
The availability of KazSat's own domestic space system makes it possible to expand the range of work for agriculture, providing high-precision space images of agricultural fields.
As a rule, the accuracy of field digitization is tied to the scale of the updated map. Thus, the following foreign and domestic Earth satellites, providing the territory with high-resolution images, are most commonly used (Table 1).

Table 1: Earth satellites providing high-resolution satellite imagery according to map scale

Satellite		Space resolution (m)		Map scale (up to)
		panchrome	multispectrum	
optoelectronic	KazEOSat-1	1	4	1: 10,000
	Formosat-2	2	8	1: 25,000
	RapidEye	-	5	1: 25,000 - 1: 5,000
	SPOT-5	5	10	1: 25,000
	KOMPSAT-2	1	4	1: 10,000
	Pleiades-1A, Pleiades-1B	0.7	2.8	1: 2,000
radar	COSMO-SkyMed 1-4	3 - 5		1: 10,000
	TerraSAR-X, TanDEM-X	2		1: 10,000

Besides, space images from Sentinel and Landsat satellites freely available allow using them practically for the solution of most tasks in agriculture. Available 10 m spatial resolution of images, 3 - 5 d updating frequency, availability of archived images enables to analyze a number of temporal data and to model the process of agricultural crops development.

2. Use of remote sensing data for monitoring arable land and crops in East Kazakhstan

In Kazakhstan, monitoring of the state of agricultural fields using satellite images is carried out both at the state level and by private companies. At the state level, monitoring of land use through the application of remote sensing data is carried out on the web portal of monitoring of agricultural land use. In order to organize state control over the rational use of agricultural land since April 2020 a pilot project on space monitoring in 4 regions of the Republic of Kazakhstan (Akmola, Kostanay, East Kazakhstan and Mangistau) was launched on the web portal Qoldau.kz (Figure 1). When monitoring the use and irrational use of land on the web portal Qoldau.kz, the analysis is carried out using data:

- remote sensing of lands;
- information databases;
- annual land balance of districts (cities of regional importance);
- database of identification of farm animals to obtain information on the availability of livestock of agricultural animals belonging to the land user.

Figure 1: Fragment of the map showing the boundaries of arable land on Qoldau.kz web portal

The output data on monitoring of agricultural land in the Qoldau portal are:

- Analysis of agricultural land for the formation of history books of fields / pastures;
- Analysis of field history books completeness for entering data on crop rotations for the previous three, current and next years;

- comparative analysis of field history books data with remote sensing data for presence/absence of crops in the last two years;
- analysis of pasture history book data for load norms.

Space monitoring of land use in the Republic of Kazakhstan has also been carried out by NC Kazakhstan Garysh Sapary JSC since 2019. The results of monitoring of agricultural lands are presented on the geoservice zher.gharysh.kz (Figure 2).

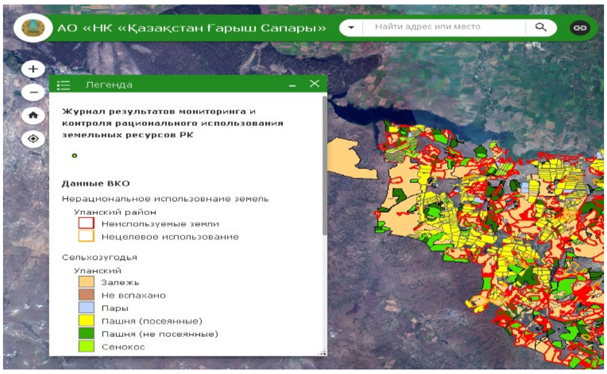


Figure 2: Results of arable land monitoring on the geoservice https://zher.gharysh.kz/

Thus, provided services on web-portals allow to solve tasks of monitoring, control at the level of the state, regions, administrative districts, within the boundaries of land use. Analysis of the provided data allows to reveal violations in land use, develop a number of measures to prevent untargeted use of land, land degradation, etc. So, in 2021 on the East Kazakhstan region 120 land users on the area of 34.8 thousand ha, which do not use the provided arable lands, were revealed. The accuracy of space monitoring of rational use of land in the Republic of Kazakhstan is estimated at more than 97 %. This is achieved through the use of the society's long-term geodatabase, integration with state systems AIS SLDaTS (Automated Information System of the State Land Cadastre and Technical Support), land balance, own methods and department of land use monitoring. Applications that include functions for handling, processing and interpreting aerospace information to support intelligent agricultural GIS to monitor the condition of arable land and crops are not insignificant. As a rule, the leading programs for farmers offer ready-made solutions - the format of providing information with subsequent interpretation. For example, the programs provide for the function of normalized difference vegetation index (NDVI) analysis by space imagery in the form of NDVI distribution maps. A color scale is used for visual assessment. Thus, to perform the work on monitoring and analysis of crop growth and development using the dynamics of changes in the vegetation index NDVI on the experimental plot of “KH Mayak” LLP, we used satellite images from Sentinel-2 satellite received through the main EO Browse Sentinel-hub service with a specified time period. In order to compare the research results, NDVI maps were constructed in the application EO Browse Sentinel-hub and online platform for precision farming - OneSoil. The results of the constructed NDVI maps are shown in Figure 3. Data are presented as of 8 May, 2020. The average NDVI value was 0.3 within the boundaries of the field. The undoubted advantages of the program are a user-friendly interface, the creation of a database in the context of fields, considering many factors, visualization of results.

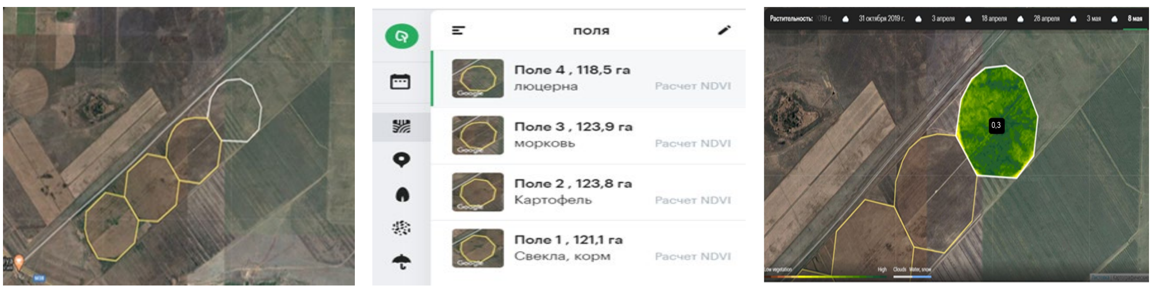
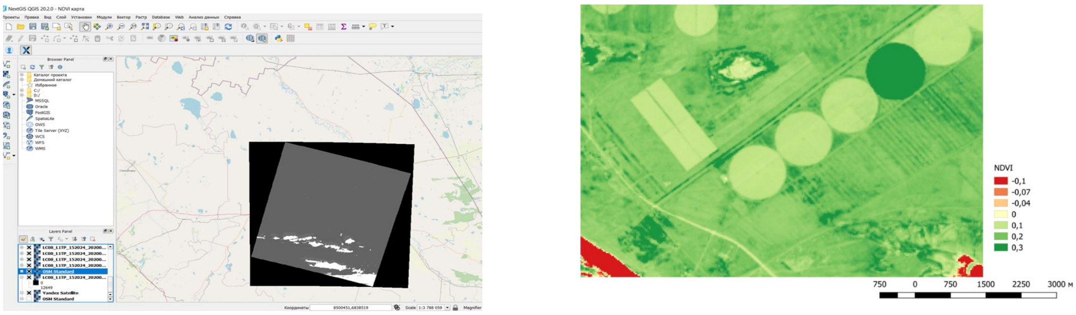


Figure 3: NDVI index calculation for “KH Mayak“ LLP fields in online platform for precision farming - OneSoil

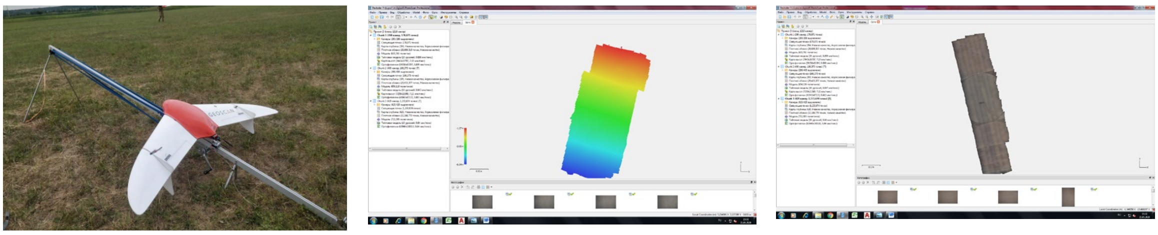
Monitoring the state of arable land and controlling the growth and development of crops are carried out using specialized programs. QGIS open access program is very popular. The program functionality allows to solve a wide range of mapping tasks, including NDVI mapping for agriculture (Figure 4). It should be noted that satellite images with 10 m spatial resolution were used for the work, which allows digitizing the fields with an accuracy of 1: 25,000 scale.



a b

Figure 4: NDVI index calculation for " KH Mayak " LLP fields: a) work in QGIS program with Landsat 8 satellite image, b) NDVI map as of 10 May 2020

Unmanned aerial vehicles are undoubtedly advantageous for monitoring at the local level in the context of land use. High resolution of aerial images, the ability to perform work at the required time, the availability of several cameras, allowing to digitize fields, the construction of NDVI maps, elevation maps (Figure 5), etc. put these technologies in the category of advanced. Thus, in studies of the impact of fullerenols on soybean growth and development (Rakhymberdina et al., 2021) the results of airborne survey work identified areas where the NDVI indicator had a higher value compared to the control area of 10 m^2 plots. Thus, satellite images are effective for monitoring studies (for obtaining aggregate indicators), and UAV aerial survey materials for detailed coordinate study of fields, taking into account all crop growing conditions (Sadenova et al., 2021). The results of the UAV survey with a RTK station mobile allow the map to be accurate to a scale of 1: 1,000.



a b c

Figure 5: Geoscan 201 Agro UAV data processing in Agisoft Photoscan of field "KH Mayak" LLC: a) Geoscan 201 Agro UAV, b) DEM in the program, c) orthophotomap of the area

When processing remote sensing data and aerial survey materials, it is necessary to have powerful computers with a connection to the server part, which will increase the efficiency of data processing. When developing software products and applications for farmers' work, it is necessary to take into account the specifics of the region (climatic features, soils, topography, etc.), agricultural technology of crops cultivation.

3. Conclusions

Based on conducted analysis and results of field and cameral work with the use of programs, applications available for working with space images, drones, the following conclusions can be made:

- for effective implementation of innovative technologies in agriculture and ensuring uninterrupted operation of applications, UAV launches it is necessary to cover the territories of agricultural fields by high-speed mobile network;
- to improve the work on the training of personnel for agriculture, possessing competencies for the implementation of precision farming technologies;
- It is necessary to create university-based research laboratories for the development and adaptation of precision farming technologies to the conditions of Kazakhstan.

Together with the authorized bodies to work on the improvement of the web portal Qoldau.kz and geoservice zher.gharysh.kz of state importance to monitor agricultural land, namely the unification of information on areas of agricultural land, indicating the cadastral number, output data of space survey, elimination of errors in digitizing land borders, made by land users, which will further allow to promptly eliminate and prevent the consequences of irrational land use, effectively carry out main goal of the project is to improve soil fertility and improve the ecological condition of the land.

Acknowledgments

This research has been supported by the Project IRN BR10965186 “Development and implementation of geoinformation support for "smart" agriculture to improve the management of the agro-industrial complex”, funded by the Science Committee of The Ministry of Education and Science of the Republic of Kazakhstan.

References

Ahmetov V.Ya., Galikeev R.N., 2019, Prospects of socio-economic development of rural areas in the context of digitalization of the economy, Bulletin of Eurasian Science,11, 6, 1-12 (in Russian).

Bekmatova A.Zh., 2018, Experience of Kazakhstan and Foreign Countries in Development Organic Farming, Proceedings of the II International Scientific Conference "Problems of Environmental Education in the 21st Century", 255-267 (in Russian).

Bogatova E., 2021, By 2025, the share of renewable energy in Kazakhstan will reach 6 %, <kapital.kz/economic/93292/k-2025-godu-dolya-vie-v-kazakhstane-dostignet-6.html>, accessed 20.04.2022 (in Russian).

Gubbi J., Buyya R., Marusic S., Palaniswami M., 2013, Internet of things (IoT): A vision, architectural elements, and future directions, Future Gener. Comput. Syst., 29 (7), 1645–1660.

Harsimran J.K., Himansh, Harshdeep, 2020, The Role of Internet of Things in Agriculture, 2020 International Conference on Smart Electronics and Communication (ICOSEC), doi: 10.1109/ICOSEC49089.2020.9215460.

Imd World Digital Competitiveness Ranking 2021, 2021, <www.imd.org/centers/world-competitiveness-center/rankings/world-digital-competitiveness/>, accessed 25.04.2022.

Information and Communication Technology Development Index, 2022, <gtmarket.ru/ratings/ict-development-index>, accessed 15.04.2022 (in Russian).

Kutbitdinov Yu., 2019, "Smart" tools of agriculture, Economic Review, 3 (231), <review.uz/post/umniye-instrumentiy-selskogo-xozyaystva>, accessed.10.04.2022 (in Russian).

National report on the transition of the Republic of Kazakhstan to a "Green Economy" for 2017-2019, 2020, <igtipc.org/images/docs/2021/nd2021.pdf>, accessed 10.04.2022 (in Russian).

Rakhymberdina M.Ye., Sadenova M.A., Kulenova N.A., Asangaliyev Ye.A., Shaimardanova B.Kh., Toguzova M.M., Varbanov P.S., Shaimardanov Zh.K., 2021, Nanopreparations Impact on Soybeans Growth and Development under Conditions of Piedmont Zone of East Kazakhstan, Chemical Engineering Transactions, 88, 1219-1224, doi:10.3303/CET2188216.

Roopaei M., Rad P., Choo K-K.R., 2017, Cloud of Things in Smart Agriculture: Intelligent Irrigation Monitoring by Thermal Imaging. IEEE Cloud Computing, 4(1), 10-15, doi:10.1109/mcc.2017.5.

Sadenova M.A., Rakhymberdina M.Ye., Kulenova N.A., Mamysheva A.M. Assylkhanova Z.A., Klemeš J.J., 2021, The indicators of agricultural crops based on the remote sensing of the Earth (ERS), 6th International Conference on Smart and Sustainable Technologies (SpliTech 2021), doi:1023919/ SpliTech52315.2021.9566469.

Salnikova O.V., Rozhkova L.V., 2021, Innovative technologies application in agriculture of the BRICS countries, University proceedings, Volga region, Social sciences, 1, 115-125, doi:10.21685/2072-3016-2021-1-10 (in Russian).

Spivak L., Muratova N., 2011, Space Monitoring of Agricultural Production in Kazakhstan, Earth from Space, 9, 57-65 (in Russian).

The State program "Digital Kazakhstan", 2017, < online.zakon.kz>, accessed 02.17.2022 (in Russian).

Zhang Q., Yang L.T., Chen Z., Li P., Bu F., 2019, An Adaptive Dropout Deep Computation Model for Industrial IoT Big Data Learning With Crowdsourcing to Cloud Computing, IEEE Transactions on Industrial Informatics, 15, 4, doi: 10.1109/TII.2018.2791424.

Zhantayev Zh.Sh., Absametov M.K., Bekmuhamedov B.E., Aknazarova R.B., Muhamedgaliev A.F., Muratova N.R., Shagarova L.V., Babyrbaeva M.Zh., 2012, A modern condition and prospects of development of Remote Sensing of the Earth in the National Center of Space Research and Technology of the Republic of Kazakhstan, Modern problems of Remote Sensing of the Earth from Kosmos, 9(5), 77-88 (in Russian).