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IMPLEMENTATION OF THE ERS FOR YIELD ANALYZING OF IRRIGATED LANDS OF SOUTH KAZAKHSTAN

Abstract. Today the agricultural industry of Kazakhstan faces the challenge to make the country enter the list of leaders of agricultural export. Due to the necessity for ensuring food security and competitiveness of domestic farmers in the foreign markets, the Ministry of Agriculture of the Republic of Kazakhstan is going to need more objective information about volumes of crop production. Therefore, Kazakhstan must be very interested in the development of methods to monitor the agricultural production with the use of information from satellite [1].

This article demonstrates the results of the analysis of cotton yield in the irrigated fields of Maktaaraldistrict of Turkestan region of the Republic of Kazakhstan; the analysis has been conducted with the use of the Earth remote sensing data.

Work performed in two stages. At the first stage, field surveys of irrigated tracts were conducted, the state of cotton fields was assessed. At the second stage, a GIS model of irrigated arrays of the Maktaaral district was built, NDVI (Normalized Difference Vegetation Index) was calculated during the vegetation period for the period from 2013 to 2018, NDVI change charts were constructed, data on cotton yield were collected, NDVI dependency graph on yield.

The results of the study showed a high efficiency of applying the methods of remote sensing of the Earth (hereinafter, RSE) in monitoring irrigated agriculture, in the analysis and in the yield forecast with an accuracy of 0.1-0.3 t/ha.

Key words: Maktaaral district, cotton, irrigated lands, NDVI, ERS, yield, GIS, database.

Introduction. The modern space technologies make an important contribution to the development of the agro-industrial complex of the Republic of Kazakhstan. The method of using of the Earth Remote Sensing datato monitor agricultural lands is very relevant for Kazakhstan due to its enormous spaces [2].

One of the most important issues of the Agro-industrial sector of the Republic of Kazakhstan is improvement of yield and competitiveness of agricultural products, including cotton. The soil of the biggest south part of the South Kazakhstan region, where cotton is grown is light sierozem soil [3]. Cotton cultivation has an important role in the economy of the Maktaaral district and in the country's economy. As of 2016, the share of cotton fiber in the export of agricultural crops is 3.8%, but the export of cotton exceeds imports by 21.5% [4].

Cotton fields are located in Maktaaraldistrict of Turkestan region (figure 1). The district center Zhetysayis connected with the villages by asphalt roads. The distance between cotton fields and the regional center Shymkent is about 330 km.

People of different nationalities live in the district. Most of them are the Kazakhs; there are also the Russians, Uzbeks, Tajiks, Ukrainians, and Germans. The district is mainly agricultural.The most developed activities are cotton growing, fruit growingand grape growing.

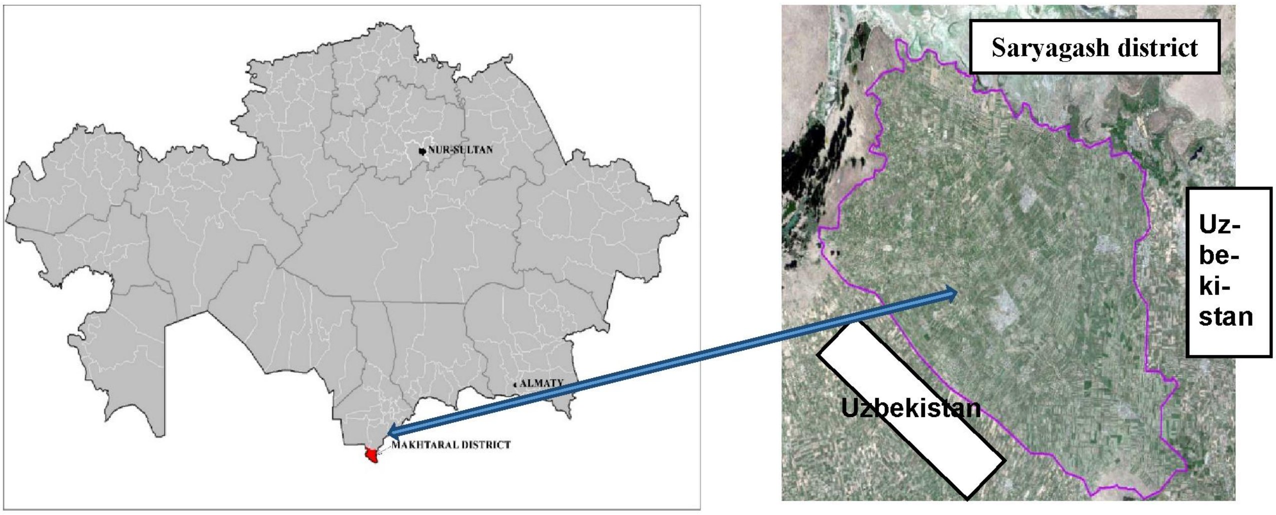


Figure 1 – Location of Maktaaral district on the map of the Republic of Kazakhstan

The climate of the district is characterized by high average annual temperature, relatively small amount of precipitation, low relative humidity of the air.According to long-term observations, the average annual air temperature in the district is 13-14^{0}C. The lowest temperature is in January (-0.7^{0}C) and the highest is in July (+ 26.8^{0}C).The maximum temperature during winter is +18-+24^{0}C. The minimum temperature is -35^{0}C. The annual amount of precipitation is between 279.7 and 306.9 (m/s Maktaaral). The maximum amount of precipitation falls in spring, in March and April. There is almost no precipitation in the warm period from July to October. Air humidityis different during the year. The average absolute humidity is 8.3 mb, the relative humidity is about 79% in February and 42% in July (Maktaaralmeteo-rological station).Wind conditions are relatively stable during the year.There is mainly south-eastern wind. The average annual speed of wind is 1.9 m/s in the western part and 2.5 m/s in the eastern part [5].

Methods. In order to analyze the yield in Maktaaraldistrict, satellitedatahas been interpreted. The cloudless medium resolution images from archives (Landsat and Sentinel-2) for the vegetation period 2013-2018 have been processed in order to calculate spectral indices and identify changes within the studied district. The licensed software ArcGIS and Geomatica 2016has been used for processing the ERS data.

In order to interpret and increase the information content of the ERS data, spectral transformations of the original satellite images have been carried out. The atmospheric correction of satellite images was carried out based on the analysis of the spectral profiles of cotton fields on satellite images with the use of spectral libraries; the calibration factors from Landsat metadata for MTL spectral ranges have been taken into account, as well as the estimated information on the azimuth/zenith of the Sun at the time of satellite survey. The matrices of the reflected solar radiation's actual values have been applied for the mathematical analysis, that is, the calculation of indices.

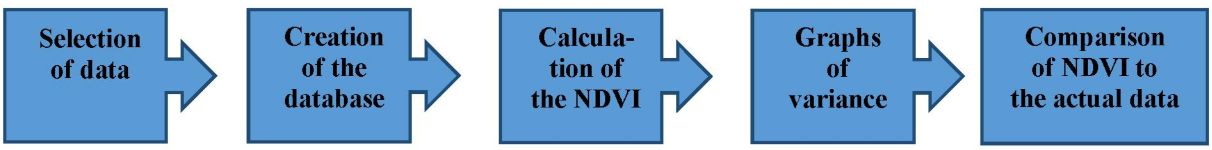


Figure 2 – Procedure for analysis

The following works have been executed in order to analyze the cotton yield in Maktaaraldistrict (figure 2):

1. The medium resolution data from satellites Sentinel – 2 andLandSat – 7, 8 have been selected and downloaded;

2. The database, including vector polygons in ArcGIS as the borders of irrigated fields has been created (figure 3, 4);

3. The NDVI for every polygon for a several-year vegetation period has been calculated; the results of calculation have been included in the database;

4. The graphs of the NDVI variance during the vegetation period have been made (figure 5);

5. The data on yield for several years has been compared to the graphs of the NDVI variance.

Selecting and downloading the medium resolution data from satellites Sentinel – 2andLandsat – 7, 8. The data from satellites Landsat 7 and 8 and Sentinel-2 have been used in the experiment. For over 40 years, Landsat program has continuously collected spectral information from the Earth surface. This unique archival data give scientists the opportunity to assess the changes in the Earth's landscape over long periods of time. The Landsat program was created specifically for natural resource monitoring.

The ETM + survey instruments (advanced thematic cartographer) installed on Landsat-7 satellite provides survey of the Earth surface in six channels with Spatial Resolution (SR) 30 m, and panchromatic survey with SR 15 m in the thermal IRchannel with SR 60. The swath width is 185 km in all channels. The surveyinterval is 16 days; theRadiometric Resolution (RR) is 8 bits [6].

The Landsat 8has two Earth-observing sensors: the multispectral scanner OLI created by Ball Aerospace & Technologies Corporation, and the thermal-imaging infrared sensor (TIRS) created by NASD Goddard Space Flight Center (GSFC). Both sensors are more advanced than the previous Landsat instruments. The Landsat 8 observatory consists of the spacecraft bus and its payload of two Earth-observing sensors. The OLI sensor collects image data for nine short wave spectral channels in a 190-kilometer swath; the SR for all channels is 30 m, except for the 15-meter panchromatic channel [7-9].

Sentinel-2 is a high resolution European multicurrency and multispectral mission which delivers optical images from 13 spectral ranges: four 10-meter wide swaths, six 20-meter wide swaths, three swaths with SR 60 m. The width of the orbital swath is 290 km. Each of the Sentinel-2 satellites weighs approximately 1.2 ton. Both satellites were launched with the European VEGA launcher. The service life of the satellite is 7.25 years, including 3 months of in-orbit commissioning. Batteries and propellants are provided for 12 years of operation, including decommissioning at the end of the service life. Two identical satellites operate simultaneously; they are installed at an angle of 180° to each other, at an average altitude of 786 km in the sun-synchronous orbit [6].

An extensive work with ArcGIS software has been executed to create the vector polygon (figures 3, 4). More than 60,000 vector fields have been created; each of them contains information on geolocation, the field area and calculated indices (figures 3, 4). The database can be expanded significantly; the data on the level of groundwater and its mineralization can be included in the future, as well as the indices describing the water content and soil salinization [10-12].

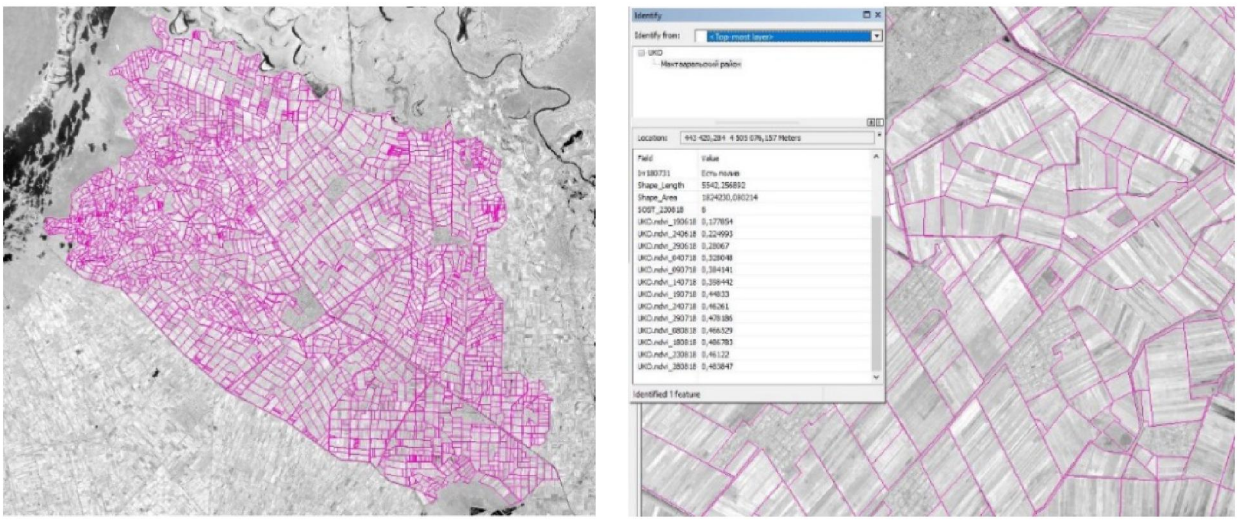
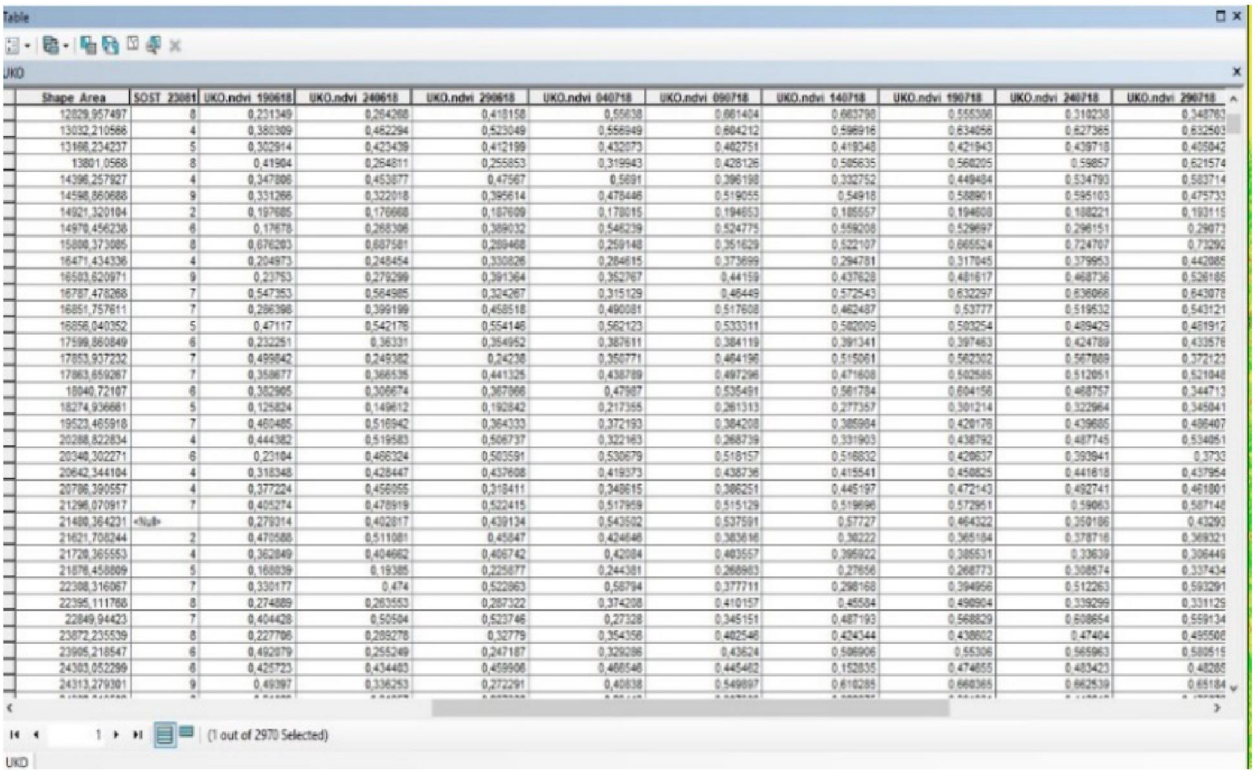


Figure 3 – Vector polygons of irrigated fields



Shape Area	SOST 23081	UKO.ndvi 190618	UKO.ndvi 240618	UKO.ndvi 290618	UKO.ndvi 040718	UKO.ndvi 090718	UKO.ndvi 140718	UKO.ndvi 190718	UKO.ndvi 240718	UKO.ndvi 290718
12829,957497	8	0,231349	0,264268	0,418158	0,55638	0,661404	0,663798	0,555386	0,310238	0,348763
13032,210566	4	0,380309	0,462294	0,523049	0,556949	0,604212	0,596916	0,634056	0,627365	0,632503
13166,234237	5	0,302914	0,423439	0,412199	0,432073	0,402751	0,419348	0,421943	0,439718	0,405042
13801,0568	8	0,41904	0,264811	0,255853	0,319943	0,428126	0,585635	0,568205	0,59857	0,621574
14396,257927	4	0,347806	0,453877	0,47567	0,5691	0,396198	0,332752	0,449484	0,534793	0,583714
14598,860688	9	0,331266	0,322018	0,395614	0,478446	0,519055	0,54918	0,588901	0,595103	0,475733
14921,320104	2	0,197685	0,176668	0,187609	0,178015	0,194653	0,185557	0,194608	0,188221	0,193115
14970,456238	6	0,17678	0,268306	0,389032	0,546239	0,524775	0,559208	0,529697	0,296151	0,29073
15808,373085	8	0,676283	0,687581	0,289468	0,259148	0,351629	0,522107	0,665524	0,724707	0,73292
16471,434336	4	0,204973	0,248454	0,330826	0,284615	0,373699	0,294781	0,317045	0,379953	0,442085
16503,620971	9	0,23753	0,279299	0,391364	0,352767	0,44159	0,437628	0,481617	0,468736	0,526185
16787,478268	7	0,547353	0,564985	0,324267	0,315129	0,46449	0,572543	0,632297	0,636066	0,643078
16851,757611	7	0,286398	0,399199	0,458518	0,490081	0,517608	0,462487	0,53777	0,519532	0,543121
16856,040352	5	0,47117	0,542176	0,554146	0,562123	0,533311	0,582009	0,503254	0,489429	0,481912
17599,860849	6	0,232251	0,36331	0,354952	0,387611	0,384119	0,391341	0,397463	0,424789	0,433576
17853,937232	7	0,499842	0,249382	0,24238	0,350771	0,464196	0,515061	0,562302	0,567889	0,372123
17863,659267	7	0,358677	0,366535	0,441325	0,438789	0,497296	0,471608	0,502585	0,512051	0,521048
18040,72107	6	0,382965	0,306674	0,367966	0,47987	0,535491	0,561784	0,604156	0,468757	0,344713
18274,936681	5	0,125824	0,149612	0,192842	0,217355	0,261313	0,277357	0,301214	0,322964	0,345041
19523,465918	7	0,460485	0,516942	0,364333	0,372193	0,384208	0,385984	0,420176	0,439685	0,496407
20288,822834	4	0,444382	0,519583	0,506737	0,322163	0,268739	0,331903	0,438792	0,487745	0,534051
20348,302271	6	0,23104	0,466324	0,503591	0,530679	0,518157	0,516832	0,428637	0,393941	0,3733
20642,344104	4	0,318348	0,428447	0,437608	0,419373	0,438736	0,415541	0,450825	0,441618	0,437954
20786,390557	4	0,377224	0,456055	0,318411	0,348615	0,386251	0,445197	0,472143	0,492741	0,461801
21296,070917	7	0,405274	0,478919	0,522415	0,517959	0,515129	0,519696	0,572951	0,59063	0,587148
21488,364231	<Null>	0,279314	0,402817	0,439134	0,543502	0,537591	0,57727	0,464322	0,350186	0,43293
21621,708244	2	0,470588	0,511081	0,45847	0,424646	0,383616	0,38222	0,365184	0,378716	0,369321
21728,365553	4	0,362849	0,404662	0,406742	0,42084	0,403557	0,395922	0,385531	0,33639	0,306449
21876,458809	5	0,168039	0,19385	0,225877	0,244381	0,268983	0,27656	0,268773	0,308574	0,337434
22308,316067	7	0,330177	0,474	0,522863	0,58794	0,377711	0,298168	0,394956	0,512263	0,593291
22395,111768	8	0,274889	0,263553	0,287322	0,374208	0,410157	0,45584	0,490904	0,339299	0,331129
22849,94423	7	0,404428	0,50504	0,523746	0,27328	0,345151	0,487193	0,568829	0,608654	0,559134
23872,235539	8	0,227706	0,289278	0,32779	0,354356	0,402546	0,424344	0,438602	0,47404	0,495508
23905,218547	6	0,492079	0,255249	0,247187	0,329286	0,43624	0,506906	0,55306	0,565963	0,580519
24303,052299	6	0,425723	0,434483	0,459906	0,466546	0,445462	0,152835	0,474655	0,483423	0,48285
24313,279301	9	0,49397	0,336253	0,272291	0,40838	0,549897	0,610285	0,660365	0,662539	0,65184

Figure 4 – Tables of the geodatabase on polygons

At the next stage, the NDVI for each polygon during the several-year vegetation period has been calculated; the results of the calculation have been included in the database. The NDVI is a simple quantitative index of the amount of photosynthetically active biomass which shows the density of vegetation on the given surface area.It is one of the most commonly used solution indices with quantitative estimates of vegetation.

In formula (1), NIR Reflection in the near infrared region of the spectrum (0.7–1.0 μm); RED is reflected in the visible region of the spectrum (0.4–0.7 μm), NDVI is the index of the spectral reflectivity of plants. According to (1), the vegetation density (NDVI) at the remote point of the satellite image is equal to the difference of the intensities of the reflected light in the visible and infrared ranges divided by the sum of their intensities.

$$NDVI = \frac{NIR-RED}{NIR+RED} \qquad (1)$$

The calculation of the NDVI is based on the two most stable (independent of other factors) parts of the spectral curve of the reflection of plants. In the visible region of the spectrum (0.4–0.7 μm) lies the absorption maximum of solar radiation by chlorophyll of the culture, and in the infrared region (0.7–1.0 μm) there is the region of maximum reflection of the cellular structures of the leaf, that is, high photosynthetic activity (associated, as a rule, with dense vegetation) leads to less reflection in the visible spectrum and more in the infrared. The relationship of these indicators to each other allows you to clearly separate and analyze vegetation from other natural objects, moreover, if you have performed a sub-satellite experiment, you can perform vegetation type recognition. The use of not a simple relationship, but a normalized difference between the minimum and maximum reflections increases the measurement accuracy, reduces the effects of such phenomena as differences in the light of a picture, clouds, haze, radiation absorption by the atmosphere, etc. A standardized continuous gradient or discrete scale is used to display the NDVI index showing values in the range - 1,..., 0, 0.1, ... 1 in% [13-20].

Results. Figure 5 show the development of the NDVI for Cotton field 1 during the vegetation period of 2018. The peak of the vegetation period of Cotton field 1 is the third decade of August and the first decade of September; the NDVI is 0.49. The NDVI is calculated for every field; the highest values during the vegetation period 2013-2018 are detected. The data on cotton yield in Maktaaraldistrict during the vegetation period 2013-2018 is collected from EGOV (statistics section). The statistic information is compared to the NDVI, as it is shown on the graph (figure 7). The graph shows the direct correlation between cotton yield and the NDVI.

The experiment carried out within the framework of BioWat project has shown the importance and big potential of the ERS data for analyzing the crop yield.The graph of correlation between the calculated NDVI and the actual data on harvest is linear; its error is 0.1-0.3 t/ha, that confirms a high probability of yield forecast.The obtained results prove that the ERS data can be successfully used not only for monitoring cotton fields, but also for the agriculture in general.

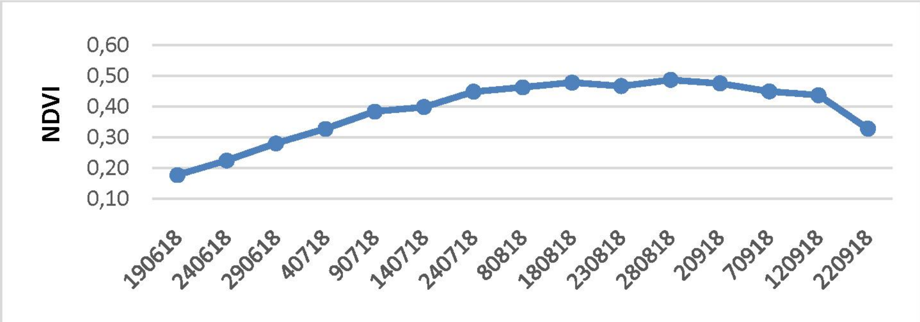


Figure 5 – Graph of the NDVI development for Cotton field 1 during 2018

Figure 6 – Graph of cotton yield and NDVI for Cotton field 1during the period 2013-2018

Moreover, the ERS data can be efficiently used for quick detection and response in case of problems in the irrigated fields.This experiment is important and relevant as this method to monitor the agricultural production can significantly facilitate people’s work and contribute to improvement and increase of yield.

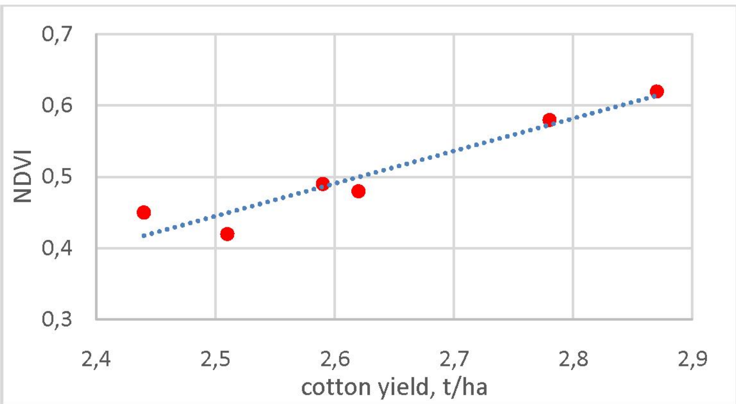


Figure 7 – Graph of correlation between the NDVI of Cotton field 1 and cotton yield

Acknowledgments. This research was financially supported by the GermanFederal Ministry of Education and Research (BMBF) in frame of the BioWat project. The results of the research and can be used in management at different levels of agriculture and can help to improve the condition of agricultural lands. The scope of use of the results of this project is very wide; they can be used by the governments at regional and national levels. The methods used in this project,as well as adequate managerial measures can significantly improve the condition of agricultural lands of the Republic of Kazakhstan and the living conditions of population of Maktaaraldistrict.The results of the researchwere discussed at the final meeting of the participants of the BioWat project.

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ЖҚЗ-НЫҢ ОҢТҮСТІК ҚАЗАҚСТАН СУАРМАЛЫ МАССИВТЕРІНІҢ ӨНІМДІЛІГІН САРАПТАУ ҮШІН ҚОЛДАНЫЛУЫ

Аннотация. Бүгінгі таңда ауыл шаруашылық саласына Қазақстанның ауыл шаруашылық өнімдерін экспорттаудағы жетекші мемлекеттердің қатарына кіруін қамтамасыз ету жөнінде мақсат қойылған. Отандық шаруалардың сыртқы нарықтағы бәсекеге қабілеттілігін сақтау және азық-түлік қауіпсіздігін қамтамасыз ету барысында, ҚР Ауыл шаруашылық Министрлігінің ауыл шаруашылық өнімдерін өндіру туралы объективті ақпаратқа мұқтаждығы туындайды. Сондықтан ауыл шаруашылық өндірісін жерсеріктік ақпараттар арқылы қадағалау әдістерін дамытудың Қазақстан үшін маңызы зор.

Мақалада Қазақстан Республикасы, Түркістан облысы, Мақтаарал ауданының суармалы массивтеріндегі мақта өрістерінің өнімділігін, жерді қашықтықтан зондылау деректерінің көмегімен жасалған сараптаманың нәтижелері көрсетілген. Зерттеу жұмыстары екі этапта жүргізілді. Бірінші этапта суармалы массивтердің далалық зерттемелері жүргізілді. Мақта алаңдарының жағдайы мен орналасу ерекшеліктері тексерілді және бағаланды. Екінші этап зертханада жүргізілді, оның ішінде Мақтаарал ауданының суармалы массивтерінің ГИС моделі құрастырылды. Мақтаарал ауданының территориясының 2013–2018 жылдар аралығында вегетация периодының NDVI – normalized difference vegetation index есептелініп NDVI өзгеріс графигі тұрғызылды. Мақтаарал ауданының мақта өнімділігі туралы ақпарат жиналды. NDVI және өнімділіктің байланыс графигі тұрғызылды.

Зерттеу жұмыстарының нәтижелері суармалы егін шаруашылығының мониторингінде ЖҚЗ-ның жоғарғы тиімділігін, және де өнімділікті 0,1–0,3 т/га дәлдікпен болжамдауға болатындығын көрсетті.

Түйін сөздер: мақтаарал ауданы, мақта, суармалы массивтер, NDVI, ЖҚЗ, өнімділік, ГАЖ, мәліметтер базасы, LandSat, Sentinel-2.

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ПРИМЕНЕНИЕ ДЗЗ ДЛЯ АНАЛИЗА УРОЖАЙНОСТИ ОРОШАЕМЫХ МАССИВОВ ЮЖНОГО КАЗАХСТАНА

Аннотация. В настоящее время перед сельскохозяйственной отраслью поставлена задача – обеспечить вхождение Казахстана в число стран – Лидеров по экспорту сельхоз культур. В связи с необходимостью обеспечения продовольственной безопасности страны и сохранности конкурентоспособности отечественных земледельцев, на внешних рынках увеличатся потребности Министерства сельского хозяйства РК в объективной информации об объемах производства сельхоз культур. Поэтому развитие методов контроля над сельскохозяйственным производством с помощью спутниковой информации представляет большой интерес для Казахстана.

В настоящей статье показаны результаты работ по анализу урожайности хлопковых полей орошаемых массивов Мактааральского района Туркестанской области Республики Казахстан, выполненных с применением данных дистанционного зондирования Земли.

Работа проводилась в два этапа. На первом этапе, проведены полевые обследования орошаемых массивов, оценено состояние хлопковых полей. На втором этапе, построена ГИС-модель орошаемых массивов Мактааральского района, вычислены NDVI (NormalizedDifferenceVegetationIndex) в течение вегетационного периода за период времени с 2013 по 2018 годов, построены графики изменения NDVI, собраны данные по урожайности хлопка, построен график зависимости NDVI от урожайности.

Результаты исследовании показали высокую эффективность применения методов дистанционного зондирования Земли (далее, ДЗЗ) в мониторинге орошаемого земледелья, в анализе и в прогнозе урожайности с точностью в 0,1–0,3 т/га.

Ключевые слова: Мактааральский район, хлопок, орошаемые массивы, NDVI, ДЗЗ, урожайность, ГИС, база данных.

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