IOP Conference Series: Earth and Environmental Science

Digital approaches in agriculture crop monitoring

To cite this article: E Barbotkina *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **937** 032098

IOP Conf. Series: Earth and Environmental Science **937** (2021) 032098 doi:10.1088/1755-1315/937/3/032098

Digital approaches in agriculture crop monitoring

E Barbotkina[1], Ie Dunaieva[1,*], V Popovych[1], V Pashtetsky[1], V Terleev[2,3,4], W Mirschel[5], and L Akimov[6]

[1]Research Institute of Agriculture of Crimea, Kievskaya street, 150, 295543, Simferopol, Russia
[2]Peter the Great St.Petersburg Polytechnic University, Polytechnicheskaya, 29, 195251, St. Petersburg, Russia
[3]St.Petersburg State Agrarian University, Peterburgskoe shosse, 2, 196601, Pushkin, Russia
[4]Agrophysical Research Institute, Grazhdansky pr., 14, 195220, St. Petersburg, Russia
[5]Leibniz-Centre for Agricultural Landscape Research, Eberswalder Straße 84, 15374, Müncheberg, Germany
[6]Politecnico di Milano, 32 Piazza Leonardo da Vinci, 20133, Milano, Italy

E-mail: dunaeva_e@niishk.ru

Abstract. Implementation of modern technologies for collecting and processing spatial information, primarily Earth remote sensing data, has made it possible to solve a wide range of tasks for specialists in the agricultural industry. The work aim is to assess the state of agricultural crops on the territory of Krymskorozovskoe rural settlement of the Belogorsky district of the Republic of Crimea using materials of Earth remote sensing and modern information technologies. The article reviews the literature on the research topic, studies the most significant works on this theme. The article presents the possibilities of digital information technologies in the framework of solving agricultural problems including creation of maps of fields and database formation, study of the territory relief and the features of its morphological characteristics, prompt identification of changes in agricultural fields, based on the calculation of vegetation indices, with the use of remote sencing; classification and identification of objects by satellite images; forecasting the potential yield of agricultural crops.

1. Introduction

Implementation of modern technologies for collecting and processing spatial information, primarily Earth remote sensing data (ERS), has made it possible to solve a wide range of tasks for specialists in the agricultural industry [1, 2].

Significant contribution to the development of agricultural satellite monitoring was made by scientists: Bartalev S.A. [3], SavinI.Yu. [4], Loupyan E.A. [5], Plotnikov D.E. [6], Strashnaya A.I. [7], Uvarov I.A. [8], Kleshchenko A.D. [9], Terekhin E.A. [10], Sidko A.F. [11], Shevyrnogov A.P. [12], Muratova N.R. [13], Terekhov A.G. [14], Sultangazin U.M. [15], Zhurkin I.G. [16], Leontiev A.A. [17], etc.

Remote assessment of crops state of is based on the influence of their biophysical characteristics on spectral-reflective properties of vegetation [18, 19] and on intensive change in spectral parameters in time in the optical range, which is a consequence of the seasonal development of crops [6, 20].

Crops state analysis during the growing season is largely based on the use of a series of time slices of their spectral characteristics, for example, the values of vegetation indices (VI) [8, 12].

Improving the accuracy of the estimates can be achieved using satellite data that allows analyzing the state of crops within specific cultivated fields [19].

Based on the study of long-term dynamics of VI, it seems possible to solve problems, associated with modeling and forecasting productivity [21, 22], as well as crop yields [23], complex analysis of the dynamics of vegetation changes [24-26]. In the works of Boken V.K. [27], Loupyan E.A. [5], Terekhin E.A. [28] and many others, the study of the peculiarities of agricultural crops development during the growing season, including for relatively long-term periods (over ten years), is carried out using the analysis of dynamics of indirect indicators of the level of plant biomass development.

To obtain a qualitative result of assessing the state of agricultural crops, a number of requirements are imposed on modern ERS materials, such as spatial resolution, spectral resolution, scanning bandwidth, temporal resolution [29].

Currently, when solving problems of vegetation monitoring, satellite data of low and medium spatial resolution (from 1 km to 100 m) are used, such as NOAA-AVHRR, SPOT-VEGETATION, Terra/Aqua-MODIS, Envisat-MERIS, NPP-VIIRS, Proba -V. Open access to high spatial resolution data Landsat-TM/ETM +/OLI and Sentinel-2, having a spatial resolution of 10-30 m, has significantly expanded the potential of satellite mapping of vegetation cover [3].

Unique scientific development of the Space Research Institute of the Russian Academy of Sciences (SRI RAS) is VEGA satellite monitoring service [30]. Based on the service, VEGA-Science system was created, the main purpose of which is to solve the problems of studying the vegetation cover in the framework of various scientific projects [30].

When decoding green vegetation and separating its image from other objects, primarily from soil cover and water surface, vegetation indexes (VI)are used [31]. VIs are based on the ratios of brightness values in spectral zones, the most informative for the characteristics of vegetation - red and near infrared. The denser and healthier vegetation is characterized by a greater value of the difference in light reflection in red and infrared ranges of spectrum; therefore, a higher VI value will be for such vegetation compared to VI value of suppressed vegetation [31].

Currently, there are more than 160 varieties of VI, among which the most common for solving problems of quantitative assessment of photosynthetically active biomass is the normalized difference VI — Normalized Difference Vegetation Index (NDVI) [32]. It was first described in 1973 in work [33] by Dr. J.W. Rouse, director of The Remote Sensing Center of Texas A&M University, and the concept of this vegetation index was first presented in the work of F.J.Kriegler et al. [34].

Strashnaya A.I. [7] notes that the state of vegetation, assessed through the NDVI, changes significantly in the process of vegetative development of plants. So, from the moment of the growing season beginning, agricultural plants accumulate green biomass and, therefore, the value index increases. After the biomass reaches its maximum values, in the process of crop formation and harvesting, biomass decrease and NDVI values decrease are noted. NDVI decrease during the active growing season (before the milk ripeness phase onset) indicates the stress state of crops. It can be caused by plant diseases or pests, lack of moisture [35], or be the result of natural phenomena (hail, rainfall, drought, fires) [36].

High values of the vegetation index NDVI act as an indicator of healthy development and active growth of vegetation. An increase in NDVI values in fallow fields is an indicator that such fields have weeds. If the value of VI NDVI in fallow fields reaches values of 0.37 and higher, agrotechnical weed control activities should be taken. Currently, space information technologies are widely used, such as remote sensing, satellite navigation (GLONASS/GPS systems). They provide not only the data necessary to assess the state of agricultural land (crops, soil, heat and moisture supply and other indicators), but also the coordinates of the location of processing units and areas of fields requiring special processing, which creates the basis for the application of precision farming methods, including the use of a physically grounded mathematical model of soil hydrophysical properties, taking into account the phenomenon of hysteresis [37-42].

The aim of the work is to assess the state of agricultural crops, based on remote sensing data and technology of geographic information systems (GIS) using.

2. Materials and Methods

Krymskorozovskoerural settlement is part of the Belogorsky municipal district of the Republic of Crimea and includes two settlements – v.Crimean Rose and v. Vishnevoye. In the north it borders Tsvetochnensky rural settlement, in the west -Zuisky rural settlement, in the east and south -Aromatnovsky rural settlement. The area of Krymskorozovskoe rural settlement is 2150 hectares, which is 1,1% of the territory of the Belogorsky municipal district.

The terrain is represented by the northern foothills of the Inner ridge of the Crimean Mountains (Figure 1), the height of the v. Crimean Rose and v. Vishnevoye center above sea level - 294 and 292 m, respectively. Elevation marks of the territory vary in the range from 245 m to 365 m.

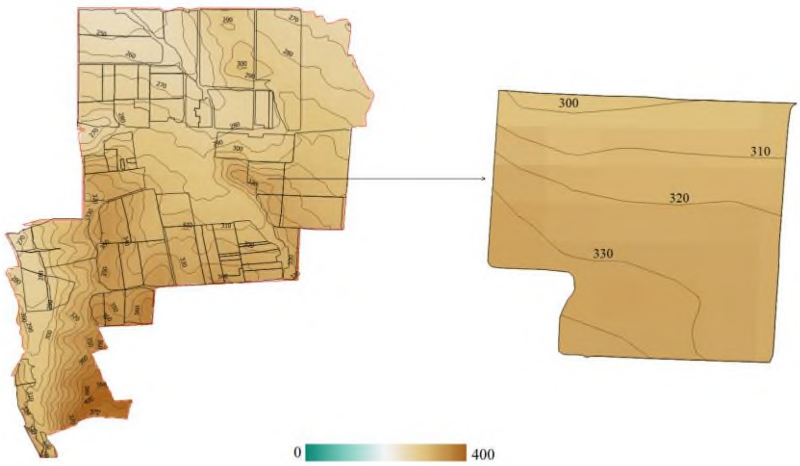

Figure 1. Relief of Krymskorozovskoe rural settlement territory.

Climatically, the territory of Krymskorozovskoe rural settlement belongs to the steppe, foothill and mountain regions. Crimean mountainous relief has a great influence on the climate. The climate is arid, most often with mild winters. The average annual air temperature is 10 °C. The warm period lasts from 300 to 315 days a year [43]. In terms of natural moisture, the region under study belongs to the insufficient moisture zone, the average annual precipitation is 528 mm.

The largest area is occupied by piedmont chernozems leached on different rocks – 107,00 hectares (47%), piedmont carbonate chernozems on eluvium and deluvium of dense carbonate rocks – 78,00 hectares (34%), 23,30 hectares (10%) and 15,00 ha (7%) is occupied by soddy soils on the eluvium of non-carbonate rocks and meadow-chernozemic calcareous soils, respectively. As the primary information on the structure of cultivated areas of Krymskorozovskoe rural settlement for 2017-2020, data of the production unit of the Research Institute of Agriculture of Crimea were used. Manual vectorization of field boundaries was carried out on their basis and schematic map of agricultural crops location in the territory of Krymskorozovskoe rural settlement was compiled.

Processing, analysis, and storage of spatial data was carried out using open source geoinformation software - Quantum GIS v. 2.18.23 (QGIS) in geographic coordinate system EPSG: 32636 - WGS 84 / UTM zone 36N.

To identify winter and spring crops, trained (controlled) classification of Sentinel-2A multichannel satellite images (MSI scanner), provided by VEGA-Science operational satellite monitoring service in the form of archival documents, and was carried out. Classification with training was chosen, because it is necessary to select a relatively small number of classes that are well distinguishable on digital image, as well as the fact that crops location in the fields is known.

Detection of agricultural crops in QGIS was carried out using algorithm of trained classification of satellite image. For this purpose, the Semi-Automatic Classification Plugin was used. Classification was made according to the maximum likelihood rule. As identification mask, the vector layer of agricultural crops borders was used. In the «ROI creation» tab, the following information was entered: serial number and information about macroclass and class.

To carry out semi-automatic classification on the «ROI creation» tab, one macro class was selected – «agro». It includes 2 classes - winter crops and spring crops. For semi-automatic classification of satellite images, training samples, so-called reference polygons, were created.

Satellite images were selected, based on information on onset timing of phenological phases of agricultural crops, prevailing on the territory of Krymskorozovskoerural settlement.

Normalized differential VI of vegetation NDVI was used as agricultural crops state indicator, to obtain the values of which, according to the data from SA of Sentinel-2 family, 4 and 8 spectral bands are used with spatial resolution of 10 m/pixel.

To study the relationship of NDVI index on agricultural crops with physical and geographical conditions of Krymskorozovskoe rural settlement, the area relief was analyzed and main relief morphometric indicators were determined. SRTM (Shuttle Radar Topography Mission) data were used as the initial materials for relief study.

3. Results and Discussions

Knowledge of the field gradients is necessary for correct field distribution in crop rotation and for selecting the direction of main cultivation (see Fig. 2). Any crops can be cultivated on slopes up to 3°. On flat lands with steepness from 0 to 1°, there are no restrictions on sowing technology and soil cultivation selecting. On sloping lands with a steepness of 1 to 3°, it is necessary to observe sowing and cultivation across or at permissible angle to the slope. Lands with a slope of 3-5° are used in field crop rotations with exclusion of row crops and implementation of anti-erosion agricultural complex. Lands with a slope of 5-7° are used in soil-protective crop rotations and perennial grasses. Figure 2 shows the processed data of the territory gradients and the slopes exposure of Krymskorozovskoe rural settlement.

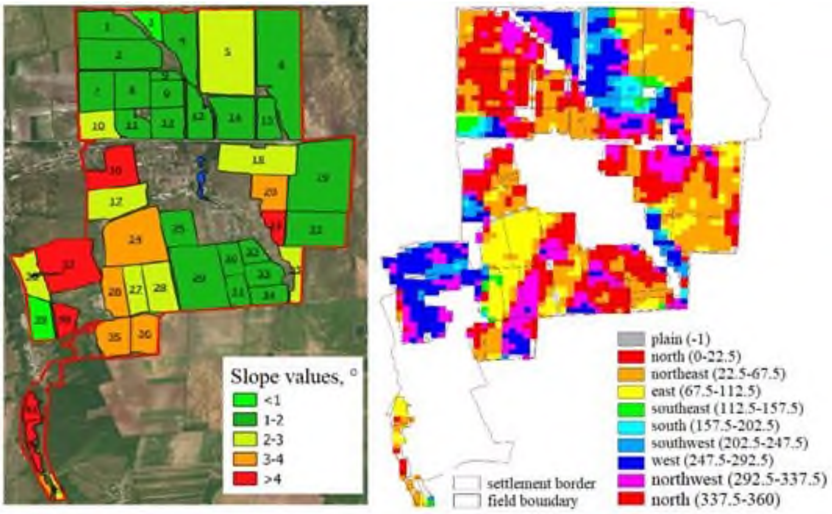

Figure 2. Map of slopes and exposition of agricultural fields of Krymskorozovskoerural settlement.

Slope exposure has a significant impact on the microclimatic conditions and the intensity of soil washout, the distribution and properties of biogeocenoses. For example, the slopes, located to the north, are predominantly colder and more humid, the soil on them is thicker, and the southern slopes are usually dry and warm and are characterized by a less thick soil cover.

Based on the classification of satellite images, the fields, where winter and spring crops are cultivated, have been identified. Figure 3shows the result of this classification.

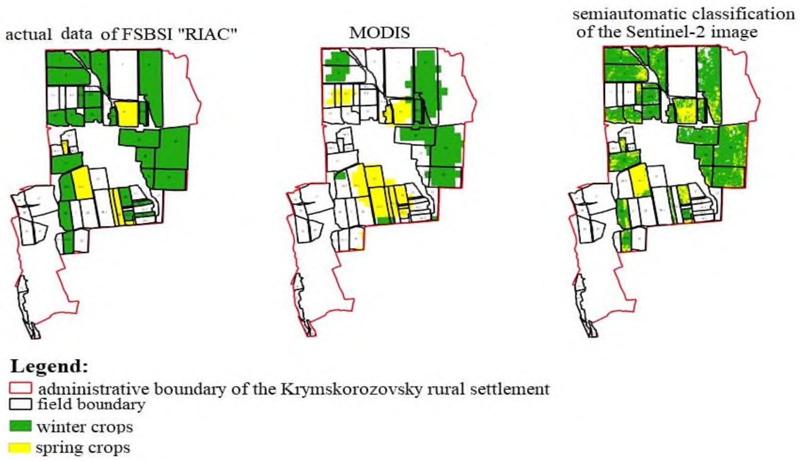

Figure 3. Result of identification of agricultural crops sowings.

Errors in agricultural crops detection are associated with small contour of some fields, which made the classification process difficult. The accuracy of crop identification, based on Sentinel-2 images, was 87%, which indicates sufficiently high reliability of the obtained classification map. Identification of winter and spring crops using high spatial resolution data (Sentinel-2) made it possible to clarify the location of crops in the fields. Compared to the map of winter and spring crops, detected on the basis of MODIS low spatial resolution data, presented on the VEGA-Science operational satellite monitoring service, identification, using high spatial resolution data (Sentinel-2), is more accurate.

State of agricultural crops in the context of the fields of Krymskorozovskoe rural settlement of the Belogorsky district of the Republic of Crimea is shown in Figure 4.

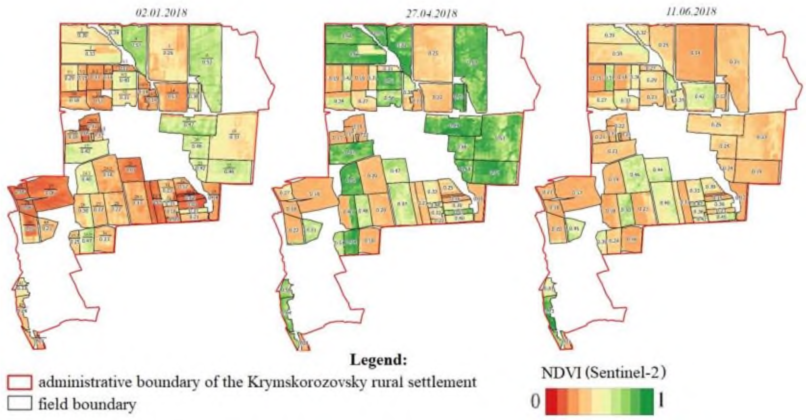

Figure 4. Cartogram ofagricultural crops state.

The result of the quality crops assessing is the Integrated classification of agricultural crops state (see Figure 5). The combination of two types of classifications of crops state (qualitative state of crops and deviation from the norm) makes it possible to assess the state of crops in a more comprehensive way. Based on these data, it is possible to conclude about the qualitative state of agricultural crops. The state of agricultural crops was also determined taking into account their deviation from the average long-term norm (according to the VEGA-Science service): <(25%); (25%) - (-15%); (-15%) - (-5%); (-5%) - 5%; 5% - 15%; 15% - 25%; > 25%.

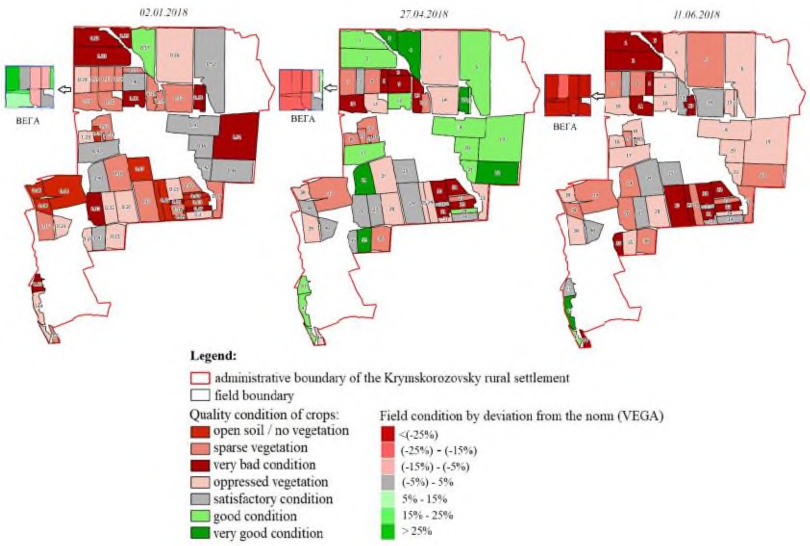

Figure 5. Integrated classification of agricultural crops state.

Based on the substitution of the NDVI index maximum values into the regression equation, the yield value for 2019 was predicted for each field of winter wheat (Table 1).

Table 1. The results of forecasting the yield of winter wheat for 2019.

Field No.	Predicted yield, c/ha	Actual yield, c/ha	Deviation, +/- c/ha
7	20.6	23.0	+2.4
23	22.8	21.6	-1.2
24	18.5	25.4	+6.9
28	22.8	31.1	+8.3
33	18.5	18.4	-0.1
36	23.8	21.9	-2.1
37	27.0	28.3	+1.3

The analysis of table 1 show that the obtained values of yield can change because of the influence of certain factors (temperature, amount of precipitation, etc.). At the same time, when determining the predicted yield, it is important to use maximum values of crop development index NDVI (from the flowering phase to the achievement of milky-wax ripeness). A rather large deviation of the forecasted yield of winter wheat for fields № 24 and № 28 is associated with their location on elevated territory [45].

4. Conclusion

Availability of up-to-date data on agricultural crops location together with data from monitoring their state and meteorological conditions makes it possible to predict crop yields by districts and region as a whole, to obtain estimates of the possible profitability of a significant agribusiness sector for various water supply conditions, and to optimize the structure of cultivated areas. Based on the classification of satellite images, it seems possible to monitor crops and assess their state not only at the farm level, but also at the regional level.

Acknowledgements

The reported study was funded by theme #0834-2015-0015 (AAAA-A16-116022610123-9).

The researchwas carried out, using the infrastructure of the IKI center for collective use of satellite data archiving, processing and analysing systems, aimed at solving the problems of environmental study and monitoring [46].

References

[1] Dunaieva Ie *et al.* 2019 GIS Services for Agriculture Monitoring and Forecasting: Development Concept *Advances in Intelligent Systems and Computing* **983** pp 236-246
[2] Poluektov R A, Oparina I V and Terleev V V 2003 Three methods for calculating soil water dynamics *Russian Meteorology and Hydrology* **11** pp 61-67
[3] Bartalev S A and Loupian E A 2013 R&D on methods for satellite monitoring of vegetation by the Russian Academy of Sciences' Space Research Institute *Current problems in remote sensing of the Earth from space* **10(1)** pp 197-214
[4] Savin I Yu, Loupian E A and Balthev S A 2011 Operational satellite monitoring of agricultural crops in Russia *Geomatics* **2** 69-76
[5] Loupian E A, Bartalev S A and Krasheninnikova Yu S 2016 Observing an abnormally early development of crops in the southern regions of Russia in spring 2016 using remote monitoring data *Current problems in remote sensing of the Earth from space* **13(2)** pp 240-243
[6] Plotnikov D E, Bartalev S A, Zharko V O, Mikhailov V V and Prosyannikova O I 2011 An experimental assessment of crop types recognisability using time-series of intra-seasonal spectral reflectance measurements by satellite sensor *Current problems in remote sensing of the Earth from space* **8(1)** pp 199-208
[7] Strashnaya A I, Bartalev S A, Maksimenkova T A, Chub O V, Tolpin V A, Plotnikov D E and Bogomolov N A 2014 Agrometeorological assessment of winter grain crops condition during the growing season termination using ground and satellite data through the example of the Privolzhskiy Federal District *HMC Works* **351** pp 85-107
[8] Bartalev S A, Egorov V A, Ershov D V, Isaev A S, Loupian E A, Plotnikov D E and Uvarov I A. 2011 Mapping of Russia's vegetation cover using MODIS satellite spectroradiometer data *Current problems in remote sensing of the Earth from space* **8(4)** pp 285-302
[9] Kleschenko A D and Savitskaya O V 2011 Technology of decade estimation of grain crops yield onsatellite and ground-basedagrometeorological information *Current problems in remote sensing of the Earth from space* **8(1)** pp 178-182
[10] Terekhin E A and Marinina O A 2016 Investigation of winter cereal crops development based on their spectral reflectance properties *Current problems in remote sensing of the Earth from space* **13(5)** pp 202-213
[11] Sid'ko A F, Pugacheva Y I and Shevyrnogov A P 2009 Investigation of the Spectral Brightness Dynamics of Agricultural Crops during Vegetation Period at the Krasnoyarsk Territory *Journal of Siberian Federal University. Engineering and Technology* **2(1)** pp 100-111
[12] Shevyrnogov A P, Zorkina T M, Zhukova V M, Zhukova E Yu and Zhidkaya M V 2007 Study of seasonal dynamics of agricultural crops in the territory of Khakassia by Terra MODIS images *Siberian Bull. of Agric. Sci*. **5** pp 29-35
[13] Muratova N R and Terekhov A G 2007 Experience of five-year operational monitoring of agricultural lands of Northern Kazakhstan using satellite data *Current problems in remote sensing of the Earth from space* **4(2)** pp 277-283
[14] Terekhov A G, Vitkovskaya I S, Batirbayeva M J and Spivak L F 2010 Principles of agrolandscape zoning of arable land of the Northern Kazakhstan with using of LANDSAT and MODIS *Current problems in remote sensing of the Earth from space* **7(3)** pp 292-304
[15] Sultangazin U M, Muratova N R and Terekhov A G 2004 The use of space monitoring in planning and forecasting the parameters of grain production *Current problems in remote sensing of the Earth from space: Physical principles, methods and technologies for monitoring the environment, potentially dangerous objects and* **1(1)** pp 291-297
[16] Zhurkin I G, Karpukhin S S, Karpukhina O A and Nikishin J A 2011 Strategy, processing of hyperspectral images in the task of monitoring the cultivation of crops *Geodesy and cartography* **1** pp 37-42
[17] Leontiev A A 2013 System of satellite monitoring of fields state and yield forecasting

Geomatics **2** pp 77-79
[18] Kramarov S O and Mitasova O Yu 2015 *Development and research tools to assess the information in the monitoring of agricultural facilities from space (Proceed. of IV Int. forum "Intellectual resources regional development")* (Rostov-on-Don) pp 23-31
[19] Yan L and Roy D P 2014 Automated crop field extraction from multi-temporal Web Enabled Landsat Data *Remote Sensing of Environment* **144** pp 42-64
[20] Miklashevich T S and Bartalev S A 2016 Method for estimating vegetation cover phenological characteristics from satellite data time series *Current problems in remote sensing of the Earth from space* **13(1)** p 13
[21] Bryskin V M 2007 Application of the adapted model of bioproductivity EPIC and MODIS satellite images for grain yield forecasting in the territory of Western Siberia *Vestnik NSU. Series: Information Technologies* **5(2)** pp 20-26
[22] Terekhov A G 2009 Estimation of accuracy of satellite definition of cropland in framework of method with using of different resolution data *Current problems in remote sensing of the Earth from space* **6(2)** p 459
[23] Kiryukhina E V 2017 Modern methods of remote sensing in predicting crop yields and assessing the condition of crops *Sci. almanac* **4-3(30)** pp 365-368
[24] Gunin P D, Zolotokrylin A I, Vinogradov V V and Baza S N 2004 Dynamics of the vegetation of the South of Mongolia according to NDVI *Arid ecosystems* **10** pp 24-25, 29-35
[25] Sakharov E Y, Sladkigh L A and Kulik E N 2015 *Satellite monitoring of crops with the use of vegetation index, Interexpo GEO-Siberia-2015 (XI Int. sci. Congr.: Intern. sci. Conf. "Remote methods of Earth sensing and photogrammetry, environmental monitoring, geoecology")* 1 pp 47–52
[26] Tulokhonov A K,Tsydypov B Z, Voloshin L A, Batueva J D and Chimeddorj C 2014 Spatial-temporal characteristics of vegetation cover of arid and semiarid climatic zones in Mongolia on the base of the vegetation index NDVI *Arid ecosystems* **20(2)** pp 19-29
[27] Boken V K 2000 Forecasting spring wheat yield using time series analysis: a case study for the Canadian Prairies *Agronomy Journal* **92(6)** pp 1047-1053
[28] Terekhin E A 2015 Analysis of vegetation index long-term dynamics for crop areas *Current problems in remote sensing of the Earth from space* **12(6)** pp 48-58
[29] Pesacov G I, Shevchenko G G, Gura D A and Gribkova I S 2016 Application of remote sensing data for the purpose of rational use of lands in the Russian Federation *Sci. works KubSAU* **10** pp 24-38
[30] Loupian E A, Savin I Yu, Bartalev S A, Tolpin V A, Balashov I V and Plotnikov D E 2011 Satellite service for vegetation monitoring VEGA *Current problems in remote sensing of the Earth from space* **8(1)** pp 190-198
[31] Labutina I A and Baldina E 2011 The Use of remote sensing data in monitoring ecosystems of protected areas *UNDP/GEF/MKI "Biodiversity Conservation in the Russian part of the Altai-Sayan Ecoregion"* (Moscow)
[32] Huete A, Justice C and Van Leeuwen W 1999 Modis vegetation index (MOD13) *Algorithm theoretical basis document* 3 p 120
[33] Rouse J W, Haas R H, Schell J A and Deering D W 1973 *Monitoring vegetation systems in the great plains with ERTS (Third ERTS Symposium, NASA SP-351)* 1 pp 309-317
[34] Kriegler F J, Malila W A, Nalepka R F and Richardson W 1969 *Preprocessing transformations and their effects on multispectral recognition (Proceedings of the Sixth International Symposium on Remote Sensing of Environment)* pp 97−131
[35] Terleev V *et al.* 2019 Improved Hydrophysical Functions of the Soil and Their Comparison with Analogues by the Williams-Kloot Test *Advances in Intelligent Systems and Computing* **983** pp 449-461
[36] Antonov V N and Sladkigh L A 2009 Monitoring of crop state and crop yield forecasting of spring wheat, according to remote sensing data *Geomatics* **4** pp 50-53

[37] Terleev V, Nikonorov A, Togo I, Volkova Yu, Garmanov V, Shishov D, Pavlova V, Semenova N and Mirschel W 2016 Modelling the Hysteretic Water Retention Capacity of Soil for Reclamation Research as a Part of Underground Development *Procedia Engineering* **165** pp 1776-1783

[38] Terleev V, Nikonorov A, Togo I, Volkova Yu, Ginevsky R, Lazarev V, Khamzin E, Garmanov V, Mirschel W and Akimov L 2017 Hysteretic water-retention capacity of sandy soil. *Magazine of Civil Engineering* **2** pp 84-92

[39] Terleev V, Ginevsky R, Lazarev V, Nikonorov A, Togo I, Topaj A, Moiseev K, Abakumov E, Melnichuk A and Dunaieva Ie 2017 Predicting the scanning branches of hysteretic soil water-retention capacity with use of the method of mathematical modeling *IOP Conference Series: Earth and Environmental Science* **90** 012105

[40] Terleev V *et al.* 2018 Hysteresis of the soil water-retention capacity: estimating the scanning branches *Magazine of Civil Engineering* **1** pp 141-148

[41] Terleev V *et al.* 2018 Five models of hysteretic water-retention capacity and their comparison for sandy soil *MATEC Web of Conferences* **193** 02036

[42] Terleev V *et al.* 2019 Models of Hysteresis Water Retention Capacity and Their Comparative Analysis on the Example of Sandy Soil *Advances in Intelligent Systems and Computing* **983** pp 462-471

[43] Zolotilov V A, Zolotilova O M and Skipor O B 2017 New variety of rose essential oil with a high collection of concrete *Sci. and tech. Bull. of the Russian research Institute of oil crops* **3(171)** pp 36-40

[44] Vecherkov V V, Golovastova E S, Dunaeva E A, Melnychuk A J, Korostylev A A and Terleev V V 2018 *Assessment of agrolandscape organization of the territory with using of geoinformation technologies, Legal, economic and environmental aspects of sustainable use of land resources (Proc. of the III Int. Sci. and practical conf.)* pp 79-84

[45] Popovich V F 2018 *Analysis of the online service Cropmap for the territory of Crimea. Current state, problems and prospects for the development of agricultural science (Materials of the III Int. Sci. Conf. Sci. ed. V.S. Pashtetskiy)* pp 239-240

[46] Loupian E A *et al.* 2015 IKI center for collective use of satellite data archiving, processing and analysis systems aimed at solving the problems of environmental study and monitoring *Current problems in remote sensing of the Earth from space* **12(5)** pp 263–284