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REMOTE SENSING APPLICATIONS FOR PREDICTING CROP YIELDS (ON EXAMPLE OF THE MUNICIPAL DISTRICT OF THE REPUBLIC OF TATARSTAN)

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Abstract

Result of developed methodology is a forecasting of yield of grain crops on the basis of space monitoring and modeling of bioproductivity. To perform this task, it is recommended to use space scanner images of medium resolution data and daily defined weather stations. Based on space images processing site observations of Earth's natural resources by Glovis parameters of plants such as biomass, leaf area index, monitoring the condition of crops from planting to harvesting is carried out, an advanced estimation of the yield and determination of optimum time of harvesting of grain crops is given.

Keywords: Remote sensing, satellite Images, Software, satellite system, biomass, Yield, Crop, Spring wheat.

1. Introduction

By the land use area and acreage of crops Russian Federation occupies a leading position in the World, and on total gathering of grain yield precession to the US, China and India. One of the reasons of low yields is the lack of timely forecasting of state of cultivated crops sowing and taking forward measures to address negative effects (treatment of crops against pests and diseases, timely fertilization, etc.).

On the other hand, forecasting the yield of grain and leguminous crops allows to establish a "fair" price of grown products realization, volume of deliveries of grain to the state coffers, harvesting grain forage for livestock feed and seed, which ultimately reflected in the cost of bread, meat, milk and other food products in the retail trade [Gouache, Bouchon, Jouanneau, Le Bris 2015, Zhang, Xu, Sun, Xiong, Huang, Wu 2016]. In this context, the aim of research is to develop methods of effective use of materials of Earth remote sensing for rapid estimation of crop conditions and spring wheat yield forecasting on the example of the Nurlatsky municipal district of Tatarstan Republic.

2. Materials and methods

Research on the prediction of yield was carried out in the Nurlatsky municipal district of Tatarstan, which is located in the southern part of the republic. District administratively borders on the west with Alkeyevsky district, on the north with Alekseevsky district, on the east with Aksubaevsky and Cheremshansky districts of RT, on the south boundary of the region coincides with the boundary of the Republic of Tatarstan with the Samara region.

The region is located within the two major Permian age tectonic structures: Melekess depression (on the west) and Soksko-Sheshminsky-shaft (on the east). One of the major rivers is affluent Cheremshan. On the district territory Cheremshan has a length of 465 km.

The study area is located in the zone of moderate continental climate. The average annual temperature is 3.2 degrees, the average temperature of the warmest month (July) is 22 degrees, and the coldest (January) is 19 degrees. The sum of positive temperatures (above 10 degrees) is 2270 degrees. Temperature conditions of the area are considered the warmest in the range of Tatarstan municipal districts.

Nurlatsky municipal district in recent years has become a leader not only in the Republic of Tatarstan, but in the Russian Federation on grain production. It is over 112 thousand hectares of agricultural land, including 88,400 hectares of arable land in the district. The district has 20 agricultural enterprises and 20 farms, stably developing livestock breeding, bred cattle, pigs, sheep and horses.

Satellite data and mathematical models play growing role in evaluation of the seasonal dynamics of crop yield [Pis'man, Botvich, Sid'ko 2015, Ignatiev, Murynin 2015, Bolton, Friedl 2013, Budka, Łacka, Gaj, Jajor, Korbas 2015 etc.]. For this reasonfirst-hand research materials set of Landsatsatellite data in two spectral ranges are available after free registration at: https://earthexplorer.usgs.gov/register/ were used. After entering latitude and longitude in the public domain, one can get a map of region of interest, in this case Nurlatsky municipal district of the Republic of Tatarstan and using SAGA software processing of results of forecasting of spring wheat yield for a number of years are conducted. The validity of using satellite imagery is compared with the actual yield obtained in the years of 2004-2013.

3. Results and discussion.

As it is known reflection of vegetation cover in the red and near-infrared regions of the electromagnetic spectrum is closely linked with its green phytomass. Taking this into consideration, we use vegetation index NDVI to assess the state of the vegetation[Sharma, Bu, Denton 2015, Islam, Garcia, Henry 2011, Ren, Chen, Zhou, Tang 2008]. NDVI calculation is based on the two most stable [not dependent on other factors) sections of the spectral reflectance curve of vascular plants. In the red spectral region (0.6-0.7 mm) is the maximum absorption of solar radiation by chlorophyll of higher vascular plants, and in the infrared (0.7-1.0 microns) is the region of maximum reflection of cellular structures of the sheet (Fig. 1).

That is, the high photosynthetic activity (associated usually with dense vegetation) leads to less reflection in the red region of spectrum and more in the infrared[Zhang, Wu, Liu 2003]. The ratio of these indicators together allows separate clearly and analyze vegetation from other natural objects. Using normalized difference between the minimum and maximum reflection it is possible to increase measurement accuracy that can reduce the impact of such phenomena as difference in the image illumination, clouds, haze, radiation, atmospheric absorption and so on[Gonzalez-Dugo, Hernandez, Solis, Zarco-Tejada 2015].

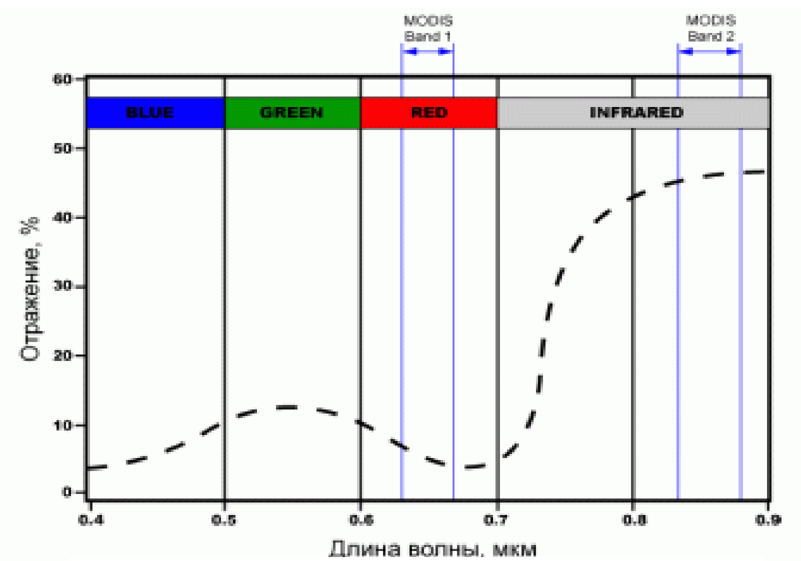

Fig. 1. Characteristic curve segments of vegetation reflection (average) used to calculate NDVI.

To display an NDVI index standardized continuous gradient or discrete chart is used (Fig. 2), which shows values ranging from -1 ... 1% or so-called scalechart in ranging from 0 to 255 (used to display in certain packages for processing ERS, correspondsto number of gray levels), or in the range of 0 ... 200 (-100 ... 100), which is more convenient because every unit corresponds to 1% change in the index.

For green vegetation reflection in red area is always smaller than in the near infrared due to light absorption by chlorophyll, so NDVI values for vegetation cannot be less than 0.

Thus, reflection of vegetation in red and near-infrared regions of electromagnetic spectrum is closely related to the

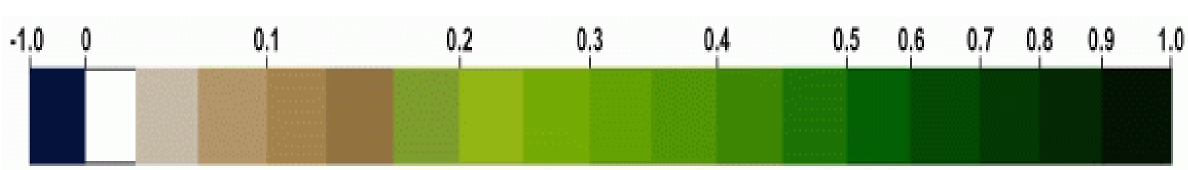

Fig. 2. NDVI discrete scale.

content of chlorophyll in a green mass of plants. High photosynthetic activity in crops with dense vegetation causes less reflection in the red region of the spectrum and Vice versa.

Based on this phenomenon NDVI index was calculated by the following formula:

NDVI = NIR-RED / NIR + RED

where

NIR - reflection in near infrared spectrum;

RED - reflected in red region of a spectrum.

According to the NDVI index one can draw conclusions about provision of plants with nutrients and moisture, set the state of crops and to determine reasons for sparse grass formation (Table 1).

Table 1. NDVI index value depending on crops condition.

Object type	Reflection in red region of spectrum	The reflection in infrared region of spectrum	NDVI index value
Densevegetation	0,1	0,5	0,7
Sparse vegetation	0,1	0,3	0,5
Open soil	0,25	0,3	0,025
Clouds	0,25	0,25	0
Snow and ice	0,375	0,35	-0,05
Water	0,02	0,1	-0,025
Artificial materials (concrete, asphalt etc.)	0,3	0,1	-0,5

Based on the NDVI we can predict yield of the object of our research. However, you need an average curve and depending on it, forecast of this year yield will be given. Such an average curve can be obtained by data smoothing for several years (Fig. 3, Table 2). The graph shows that maximum accumulation of biomass of spring wheat is in the middle of July. As for the agro-meteorological conditions of a particular year, it is clear the growth and development of spring crops in 2010 was going very poorly, because of the absolute droughtof vegetation period.

Table 2. Standard deviation of curves from the mean curve.

Year	AQD
2004	0,089
2005	0,011
2007	0,166
2008	0,023
2009	0,016
2010	0,218

2011	0,170
2012	0,065
2013	0,132

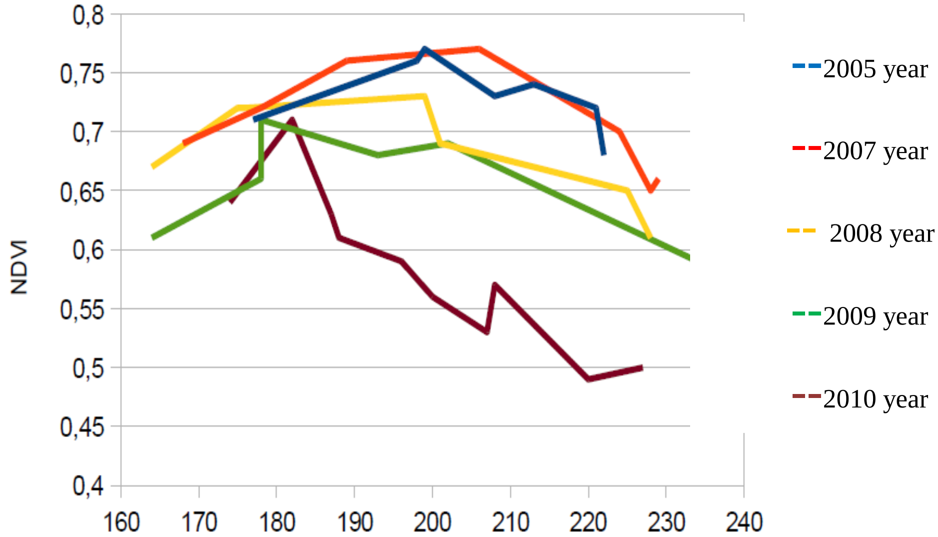

Fig. 3. Time course of the vegetation index of spring wheat in Nurlat y municipal district of the Republic of Tatarstan

Since the research purpose was to determine the biomass of spring wheat with the help of remote sensing data, the obtained results can predict future yields. For the forecast it is necessary to have a certain average curve (year-to-analog), which will be analyzed with respect to the curve of vegetation for the current period. Such average curve can be obtained by averaging the vegetation curves for several years, and the vegetation curves on any particular single year are based on the average values of the vegetation index over the region.For example, on the reference date 15.05.2013 this NDVI average vegetation index in the region will be equal to 0.21 (Fig. 4). With a few key dates we get growth curve diagram, which istime-averaged across the region.

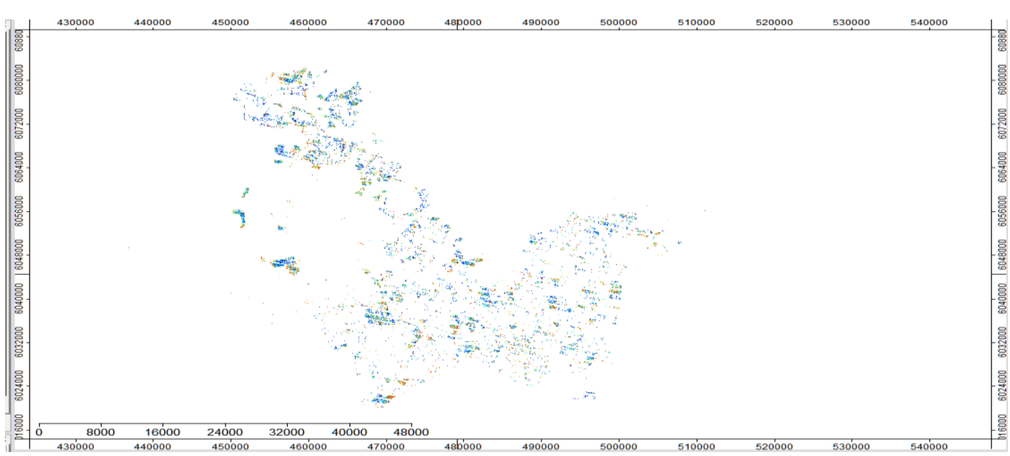

Fig. 4. NDVI indexmap for spring crops fields (on 15.05.2013).

A more detailed analysis of the time course of vegetation index of spring wheat shows minimum deviation from mean value in 2005. Therefore, we recommend to use values of 2005 in the future as the year-analogue, which is confirmed by the results of forecasting the yield of spring wheat in 2013 (Table 3, Fig. 5).

Table 3. Time course ofvegetation index of spring wheat.

Date / Ordinal day of the year	Average NDVI values	
	Year-analog	2013 year
01.06.2013/152	0,50	0,47
10.06.2013/161	0,61	0,56
21.06.2013/172	0,68	0,63
05.07.2013/187	0,73	0,71
18.07.2013/199	0,77	0,58
24.07.2013/205	0,73	0,57
12.08.2013/224	0,64	0,52

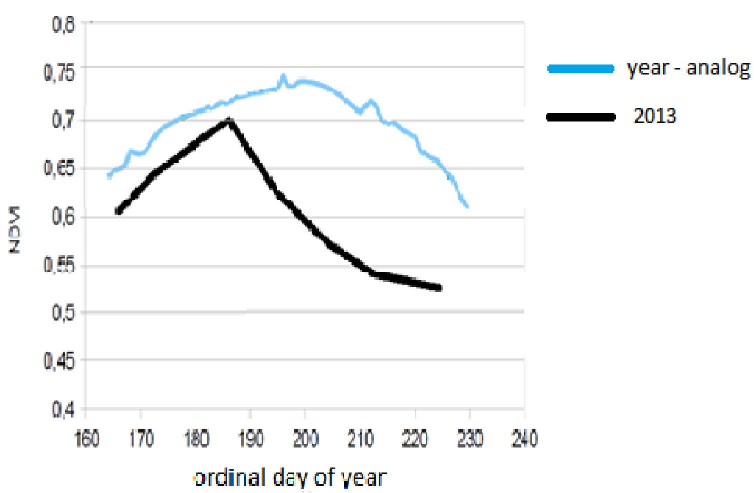

Fig. 5. Course of mean curve of spring wheat growing season in 2013

The dynamics of biomass accumulation of spring wheat in the middle of the summer of 2013 cede ground to amean value of the year-analog, and our forecast is confirmed by official data the yield of spring wheat in Nurlatsky municipal district of the republic (yield per unit is on 8 dt/ha lower than in 2005).

4. Conclusions.

Environmental, economic and social importance of agriculture of the Russian Federation, including the Republic of Tatarstan, determines the priority to use entirely new methods, such as Earth remote sensing and GIS analysis, for rapid estimation of crop conditions assessment and yield forecasting of agricultural crops.

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