Assessment of arable lands use in the VEGA satellite monitoring services on the example of Primorsky Krai, Russia

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Abstract. The paper considers the possibility of arable lands use assessing by the facilities of satellite monitoring services VEGA. The services provide access to archived and operational satellite data of various spectral bands, spatial resolution and time ranges. They also implement various tools for interactive and automated processing of this data. These include comparative visual analysis of multi-temporal satellite imagery, visual analysis of multi-temporal color composites and graphs of vegetation indices dynamics, pixel-based and object-based classification. The main features of cultivated and abandoned arable lands are considered on the example of Primorsky Krai, Russia. It is shown that the object-based classification tool implemented in the services allows user to classify cultivated and abandoned arable lands with an accuracy above 90%.

1. Introduction
Since 2018, the program “Export of agricultural products” has been implementing in the Russian Federation within the national project “International Cooperation and Exports”. The main purpose of the program is to increase exports of agricultural products to 45 billion dollars by 2024, that requires an increase in its production. One of the main ways to increase the volume of agricultural production is the expansion of sown areas, which is possible due to the cultivation of abandoned arable land. In this regard, it is important to have information about the location and condition of such lands. Moreover, the government in Russia provides the support for agricultural producers who re-cultivate abandoned lands. This is followed by the issue of controlling the use of subsidies for their intended purpose.

Objective information about the location, area and the state of agricultural lands, including abandoned, can be provided by remote sensing data. Successful solutions to such problems using satellite data of different resolution, spectral bands and time ranges can be found, for example, in [1-4]. The paper [5] provides an overview of more than 70 articles published in the period 1992-2019 on remote detection and research of abandoned agricultural lands, which confirms the value of satellite observations for solving this problem.

Russia is very elongated from North to South and from West to East, so in order to obtain objective information about abandoned agricultural lands throughout the country, it is important to have a work environment that allows to work with big sets of remote sensing data. One of such environments is a
group of satellite biosphere monitoring services “VEGA-Constellation” (VEGA-Science (http://sci-vega.ru/), VEGA PRO (http://pro-vega.ru/), and etc. (http://sozvezdie-vega.ru/), developed by the Space Research Institute of Russian Academy of Sciences [6].

2. Materials and methods
VEGA services provide receiving, storing and processing of satellite data of various spectral bands, spatial resolution and time ranges. All the user's work with the data is performed in the web-browser via the map interface. Table 1 shows the main sources of satellite data provided by the services that are appropriate for assessing the use of agricultural lands.

Table 1. The main satellite data for assessing the use of agricultural land, stored in the "VEGA" services.

| Satellite  | Imaging system | Spectral bands | Pixel spacing, m | Temporal coverage       |
|------------|----------------|----------------|------------------|-------------------------|
| Terra Aqua | MODIS          | Visible, NIR   | 250              | 2000–present            |
|            |                |                |                  | 2011–present            |
| Meteor-M №1 | KMSS          | Visible, NIR   | 60               | 2011–2014               |
| Meteor-M №2 |                |                |                  | 2014–present            |
| Meteor-M №2-2 |              |                |                  | 2019–present            |
| Landsat-4  | TM             | Visible, NIR, SWIR | 30 | 1987–1993 |
| Landsat-5  |                |                |                  | 1984–2012               |
| Landsat-7  | ETM+           | Visible, NIR, SWIR/Pan | 30/15 | 1999–present |
| Landsat-8  | OLI            | Visible, NIR, SWIR/Pan | 30/15 | 2013–present |
| Sentinel-2A | MSI            | Visible, NIR/ SWIR | 10/20 | 2015–present |
| Sentinel-2B |                |                |                  | 2017–present            |
| Sentinel-1A | C-band SAR     | Microwave      | 10               | 2014–present            |
| Sentinel-1B |                |                |                  | 2016–present            |

The use of agricultural lands in VEGA services is evaluated within the vector contours of fields. This information can be either imported into the system or created in it based on actual and archived (since 1984) satellite data.

Assessment of the use of fields in the selected season can be performed using the following features of the services [7]:

– Comparative visual analysis of multi-temporal satellite images series;
– Visual analysis of multi-temporal color composites;
– Analysis of vegetation indices dynamics graphs;
– Pixel-based satellite imagery (including a series of multi-temporal images) classification;
– Object-based classification of satellite data time series.

As a result of applying any of these tools, a vector field can be assigned the “used”, “partially used”, or “not used” class in each season.

Experimental work on assessing the use of agricultural lands in VEGA services was carried out on the example of one of the far Eastern regions of Russia: Primorsky Krai. As of 01.01.2019, the total area of arable land here was 706.9 thousand hectares, and 87.2 thousand hectares (i.e. 12.3% of them) were abandoned [8].

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3. Results and discussion

The main features of cultivated and abandoned arable lands are considered below.

The distinctive feature of the used arable land at a series of multi-temporal satellite imagery is the presence of periods when both open soil (before sowing and after harvesting) and vegetation (between sowing and harvesting) are observed on the field. As a rule open soil is not typical for abandoned fields (figure 1).

![Figure 1. Used (A) and abandoned (B) arable land in Sentinel-2 satellite images (color synthesis: R - red, G – near infrared, B - green).](image)

Besides, the used and abandoned arable areas are often characterized by different image texture. For example, in figure 1, lanes can be seen that are caused by the movement of agricultural machinery on the cultivated field “A”. At the same time the abandoned field “B” has a patchy texture.

It is also possible to separate used and abandoned arable lands effectively by color synthesis of multi-temporal images obtained during the growing season. In such composites abandoned arable lands usually have different shades of gray, while the cultivated areas have different colors (red, green, and etc.) depending on the selected imagery acquisition dates and the phenological stages of vegetation development observed on these dates. Comparing the results of multi-temporal color synthesis over different years is a way to clearly display the changes in sown area (figure 2).

![Figure 2. Multi-temporal color composites (2008 and 2019) of MODIS weekly NDVI images.](image)
According to the last 20 years statistics (https://fedstat.ru), the minimum (305.84 thousand hectares) and maximum (484.7 thousand hectares) sown area was registered in Primorsky Krai in 2008 and 2019 respectively. A significant increase in the area of arable land used in the Prikhankai Lowland is proved by a noticeable increase in the number of green-blue pixels in the right part of figure 2.

It is also possible to distinguish used and abandoned arable lands based on the dynamics of vegetation indices. VEGA services provide the weekly calculation of NDVI (Normalized Difference Vegetation Index) values based on MODIS sensor data, averaged within the vector contours of fields. Figure 3 shows the dynamics of NDVI for one abandoned field as well as for several fields where crops typical for Primorsky Krai (early cereals, soy, corn) were grown in 2019.

![Figure 3. NDVI dynamics of four test fields in 2019.](image)

Figure 3 clearly shows the difference between NDVI of cultivated and abandoned fields. Unused agricultural field is characterized by the significant growth of NDVI roughly from late April to early June, then its values stabilization until September and subsequent decline until November. For areas where crops are grown, the maximum of NDVI is more distinct, and there is also a smaller width of the graph between the beginning of vegetation index growth and the end of its decline.

These approaches allowed experts to determine the use of a number of fields in the Oktyabrsky district of Primorsky Krai in 2019. As a result, 1289 fields with a total area of 33.9 thousand hectares were assigned to the “used” class, and 270 fields with an area of 4.4 thousand hectares were assigned to the “not used” class (figure 4).

![Figure 4. The use of arable lands of Oktyabrsky District, Primorsky Krai in 2019.](image)
Further this information was applied for testing the tool for automated land use assessment which implies an object-based classification of fields according to NDVI dynamics. While working with the tool, the status of a certain number of fields must be determined by an expert, that is necessary for training and accuracy assessment purposes. A series of experiments, in which different number of fields was set as training and control samples showed that the tool allows to separate cultivated and abandoned agricultural fields with a steady confidence greater than 90%.

4. Conclusion
The capabilities of agricultural lands use assessment in VEGA satellite monitoring services are shown on the example of Primorsky Krai. Various tools for interactive and automated satellite data processing allows to implement such assessment both for separate fields and for large groups of fields within the boundaries of administrative districts or even subjects. It is shown that the object-based classification tool implemented in the services allows to discriminate cultivated and abandoned arable fields with an accuracy above 90%. Generally, the availability of such an instrument allows to reduce significantly the time spent on the creation and updating the arable lands use maps.

The VEGA-Science system which is the part of the Center for collective use “IKI-Monitoring” [9] was used for the analysis of satellite data. The special tools allowing the experts to assess the use of agricultural lands were developed within the system according to the program “Monitoring” (state registration № 01.20.0.2.00164).

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