Possibilities of “Vega” satellite monitoring services for arable land use assessment on the example of Smolensk region, Russia

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Abstract. The paper shows the practical use possibilities of satellite services “Vega” for arable land use determining. The services provide access to satellite data and different tools for its processing for solving this problem. The article shows examples of agricultural land use types interpretation using different approaches such as multi-temporal RGB composites analysis and NDVI vegetation index dynamics analysis. The results of object-based classification of arable land use assessment are demonstrated in the paper on the example of Safonovsky District (Smolensk region, Russia). It is shown that the reliability of the proposed approach reaches more than 90%.

1. Introduction

According to the project of the State program for effective increasing the area of agricultural land and the development of the reclamation complex of the Russian Federation, it is planned to increase the cultivation area of agricultural land at least on 12 million hectares by the end of 2030. To solve this problem and monitor the effectiveness of its implementation, it is important to have information about the location and use of agricultural land, as well as the state of unused land.

One of the sources of such information can be remote sensing data, which have shown its effectiveness in agricultural land monitoring, including the arable and unused land detection [1-5].

The task of increasing the cultivation area has a national scale, so it is necessary to obtain spatial data on agricultural land throughout the country. Consider this, it is important to have both remote sensing data for all areas of interest and a software that provides the ability to work with it. In this paper, a group of information services for biosphere satellite monitoring “VEGA-Constellation” (Vega-Science, Vega-PRO and others, hereinafter referred to as “Vega” services), developed at the Space Research Institute of the Russian Academy of Sciences are considered as such a software [6].

2. Materials and methods

“Vega” services provide the ability to work with archive and operational data of various remote sensing satellite systems, as well as with various image products obtained on their basis. Visualization, processing and analysis of data is performed by the services user in a web browser via the map interface. Table 1 shows the main available satellite data that are appropriate for assessing the use of agricultural land.
Table 1. The main satellite data for assessing the use of agricultural land, stored in the “Vega” services.

| Satellite System | Imaging System | Spectral bands | Pixel spacing, m | Temporal coverage |
|------------------|----------------|----------------|------------------|------------------|
| Terra Aqua       | MODIS          | Visible, NIR   | 250              | 2000–present     |
|                  |                |                |                  | 2002–present     |
| Meteor-M No1     | KMSS           | Visible, NIR   | 60               | 2011–2014        |
| Meteor-M No2     |                |                |                  | 2014–present     |
| Meteor-M No2-2   |                |                |                  | 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         | Microwave      | 10               | 2014–present     |
| Sentinel-1B      | SAR            |                |                  | 2016–present     |

The effectiveness of solving many agricultural problems based on satellite data, such as agricultural land use determining, depends on the presence of vector field boundaries. In the “Vega” services, it is possible to import vector data. Also, it is an option to create field boundaries directly in the system using satellite data or imported earlier custom maps and images.

Agricultural land use determining can be performed in the services using the following tools and approaches [7]:

- Visual analysis of multi-temporal satellite images series;
- Visual analysis of multi-temporal RGB-composites;
- Analysis of the dynamics of vegetation indices averaged within the vector fields boundaries;
- Pixel-based classification of single satellite imagery or a series of multi-temporal imagery;
- Object-based classification of satellite data time series.

As a result, the analyzed fields can be assigned one of the classes: "used", "not used" or "partially used".

3. Results

The possibilities of determining the use of agricultural land by data and tools of the “Vega” services are demonstrated below on the example of Smolensk Oblast territory. The area of arable land under cultivation in this region has decreased by approximately 1 million hectares during the last 30 years (figure 1). That means that this region can be characterized by a high potential for increasing the cultivation area of agricultural land.

It is necessary to consider the main features on which it is possible to divide agricultural land in accordance with its use.

The main distinctive feature of the used agricultural land at a series of multi-temporal satellite imagery is a periodic and dramatic change in its color, due to the implementation of agrotechnical activity and changes in the state of cultural vegetation. Abandoned land, as a natural vegetation, tend to have a gradual change of color during the season.
It is possible to consider tree and shrub vegetation overgrowth as another feature of abandoned arable land. An example of overgrown fields is shown in figure 2 on the right. At the same time, it is possible to verify that the selected contours actually correspond to agricultural land using archived satellite data (data from 1984 is available in the “Vega” services, (table 1)). Thus, figure 2 shows that in 1990 there were traces of plowing within the same fields.

Used and abandoned arable lands are also effectively separated by multi-temporal RGB composites. The used fields are usually depicted in such composites in different colors (green, blue, etc. depending on the sensing dates and the phases of plant development observed on these dates) while abandoned ones are grayscale. Figure 3 shows two RGB composites compiled from satellite data obtained in 1988-1990 and 2020 covering a part of Safonovsky district in the vicinity of Levkovo village. These images clearly show the change in the area of cultivated arable land over a 30-year period. In 2020 within the allocated area, crops were grown only in the western part (blue-coloured fields), while 30 years ago a significantly large area was occupied by crops [8].
Figure 3. Multi-temporal color composites: Landsat-5/TM, 770-900 nm, R – 06.06.1988, G – 29.06.1990, B – 07.08.1990 (left); Sentinel-2/MSI, 785-900 nm, R – 11.06.2020, G – 11.07.2020, B – 27.09.2020 (right).

It is also possible to distinguish used and abandoned arable lands based on the course of vegetation indices seasonal dynamics. The “Vega” services provide weekly calculation of NDVI (Normalized Difference Vegetation Index) values averaged within the fields boundaries based on MODIS data. Figure 4 shows several examples of graphs of NDVI dynamics for used and abandoned fields located in the Safonovsky District (Smolensk Oblast).

Figure 4. Typical NDVI dynamics of agricultural fields in Smolensk Oblast (Safonovsky District): upper left – winter crops, upper right – spring crops, bottom left – perennial grass, bottom right – unused field (fallow).

Figure 4 clearly shows the difference in the NDVI dynamics of the used and abandoned land. Fields occupied by winter crops are usually characterized by increasing NDVI values in autumn of the
previous year and a well-defined summer peak in the analyzed year. Spring crops are characterized by one peak of NDVI values in summer. Graphs of the vegetation index of perennial grasses are characterized by several peaks during the season, which can explained by periodic mowing and subsequent growth of biomass. Abandoned fields are characterized by increasing of NDVI values in spring, its reaching a plateau in summer and then decline in autumn.

The described approaches were applied in expert analysis on a group of agricultural fields (more than 500) located in the western part of Safonovsky District. It was estimated whether the fields were used in 2020. The fields were divided into two classes: "used" and "unused". The obtained information was used to conduct a series of experiments on automated land use determination, which is based on object-oriented classification of fields. This classification was based on the NDVI values averaged within the fields boundaries and its seasonal changes. A generalized flowchart of the corresponding tool implemented in the “Vega” services is shown in figure 5, and an example of its operation is shown in figure 6.

Figure 5. Flowchart of object-based classification of agricultural fields use realized in the “Vega” services.

Figure 6. Smolensk Oblast, Safonovsky District: result of object-based classification of agricultural fields use (green fields – arable, violet – unused).

As can be seen from the error matrix (upper left part of Figure 6), the classification accuracy in the given example is more than 90%. The accuracy value was obtained for 583 fields with known classes defined by an expert. The total number of classified fields was 1664 and the training data set was just
28 fields. At the same time, similar confidence values were obtained when a different number of fields in different parts of the study area were set as a training sample.

4. Conclusion
The examples given in this paper show that the “Vega” satellite monitoring services provide the possibility of expert and automated determination of the arable land use for both individual fields and groups of fields. The automated fields use assessment tool based on the NDVI index time series and the object-oriented approach implemented in the service. It allows to separate used and abandoned fields with a confidence of more than 90%. Generally it allows to reduce significantly the time spent on creating and updating agricultural land use maps at districts and even subjects scale.

It should be noted that the demonstrated possibilities of the agricultural land use determining are relevant not only for assessing the potential of subjects to return agricultural fields in use. For instance, it is planned to conduct an Agricultural micro-census in Russia in 2021. The data set to be collected during the census will include also the types of agricultural land use. Meanwhile, the main source of this information will be land users. This fact indicates the need of assessing the reliability of the information provided by them. Remote sensing data and products based on it can be used as data sources for such an assessment.

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