LARGE-SCALE EXPLOITATION OF SATELLITE DATA IN SUPPORT OF INTERNATIONAL DEVELOPMENT

-> EO4SD – EARTH OBSERVATION FOR SUSTAINABLE DEVELOPMENT

Earth Observation for Eastern Partnership | Armenia
Cover image Sentinel 2 composites over the 2017 growing season.

Credit: GISAT for ESA/World Bank
1. INTRODUCTION

Over the past two decades, the Armenian economic growth was fueled primarily by the construction and mining industries, and foreign investments. The advent of the global financial crisis combined with reduction in external demand for metallic minerals caused a contraction in the economy and dramatic effects on rural and urban poverty. Nowadays in Armenia agriculture provides employment for about 40% of the country’s active population and over 75% of active population in rural areas. However the increase of agricultural production in the country is highly dependent on sustainable management of water resources and rural infrastructure improvement, and as such is a focus of various development projects.

Over the past years, the World Bank has been consistently supporting the government of Armenia in investing in the country’s irrigation and water rights systems in order to stimulate rural growth and to improve the lives of Armenian farmers. This included upgrading of water infrastructure and irrigation canals, establishment of Water Users Associations (WUA) to reduce energy and water losses, and expansion of farmland irrigation. Such transformation from rain fed to irrigated crops in turn allowed progressive sector diversification and cultivation of higher value crops such as vegetables, vineyards and orchards.

The Irrigation System Enhancement Project (ISEP) is focused on improving sustainability of the Armenian irrigation system reducing the amount of energy required, through the conversion from pumping to gravity system, and increasing the irrigation conveyance efficiency in targeted irrigation schemes. It created the opportunity to stimulate structural transformation and gradual market integration of the small subsistence-oriented farms and facilitated investments for the modernization of commercially-oriented farms improving the quality and capacity and reach the extension of services.

Going forward the World Bank country development strategy for Armenia is aimed to foster further improvements in agriculture sector management, and building a capacity for evidence-based policy making including generating reliable and accurate information on agricultural land use, production, and farm management practices.

The Earth Observation for Eastern Partnership (E04EP) is a project implemented as a part of the European Space Agency’s (ESA) Earth Observation for Sustainable Development initiative, which aims to achieve a step increase in the uptake of satellite-based environmental information in the development programs implemented by the Multilateral Development Banks. In case of Armenia, ESA supports the World Bank-led Armenia Irrigation System Enhancement Project (ISEP) with development of new methods for mapping of spatial distribution of crops, monitoring of plants development and early identification of anomalies. Satellite data in combination with meteorological information and calibration data from agricultural surveys (crop rotation, yields) will enable a better insight into assessment of agricultural productivity and availability of water. Resulting information, often not available from other sources, is intended to become input for more effective management of agriculture production and water resources at different levels of administration and water user associations.
2. OBJECTIVES

The WBG-financed Irrigation System Enhancement Project (ISEP) objective is to improve the irrigation efficiency in the targeted irrigation schemes (Meghri, Gegardalich, Baghramyan - Norakert and Kaghtsrashen systems). EO4EP brings two services to support ISEP:

1. Satellite monitoring of agricultural productivity,
2. Crop type classification and crop area statistics.

Target users of these services are the Armenian Ministry of Agriculture and the State Committee of Water Economy which are leading the implementation of the ISEP. The area of interest selected for the EO4EP services demonstration is the Ararat Valley.

The satellite-based crop classification and agriculture productivity monitoring will support agriculture and water management in Ararat through analysis of multi-temporal satellite data, both optical and SAR imagery, combined with national in-situ data. Both services aim to provide modern digital tools for agriculture production areas management and monitoring, as well as detection of actually and potentially irrigated areas, and actual and potential water supply sources.

2.1 Crop type classification and crop area statistics

The aim of the crop type classification and crop area statistics service is to provide a crop types map identifying specific crops (or groups of crops) and deliver related statistics (distribution, structure) aggregated to a defined unit. It is produced during or at the end of the crop growing season depending on the availability of input satellite data and user requirements. Its production relies on multi-temporal satellite imagery combined with national in-situ data, by integration of two complementary classification results independently derived from dense time series of optical imagery (Sentinel-2, Landsat-7 & 8) and SAR imagery (Sentinel-1).

Growing cycles of the crops are depending on climatic specifics and local crop calendar. The generation of satellite composites for winter and spring crops facilitate detection of crops based on spectral and temporal differences of their specific management cycles, which differ over the growing season: sowing, germination, ripening and harvesting. If sufficient amount of (cloud- and snow-free) data are collected in sub-season, the following data composites and data products will be generated for the pilot areas in Kakheti region:

• early spring to detect winter crops such as winter wheat and barley,
• late spring-early summer to detect spring crops as spring wheat and barley, and cereals,
• late summer to detect other (later) crops such as maize or potatoes,
• high value crops such as orchards and vineyards,
• grasslands,
• other arable land.

The list of crops is adaptable and can be customized depending on local conditions and in-situ training data availability. The service is envisaged to allow the following uses:

• identification of major crop types and calculation of area under cultivation,
• distribution of specific crops,
• aggregative statistics of crop shares,
• spatial and temporal description of cropping patterns (cycles),
• comparison of cropping pattern with previous season(s).
The mapping product will provide baseline for various supplementary analytical products by integration with available statistical and agriculture productivity data. This will further enable:

- monitoring of specific crops conditions (water stress),
- detection of irrigated crops,
- monitoring of cropping patterns, e.g. intra- or inter-annual development of crops (e.g. rotation).
2.2 Satellite monitoring of agricultural productivity

Satellite monitoring of agricultural productivity allows to improve irrigation system efficiency. The online crop monitoring service is based on the analysis of time series of multi-temporal EO data as well as meteorological data (if available through online access).

The service enables several use cases:

- an ongoing assessment of the state of crops, e.g. current development stage characterised across space and time,
- detection of anomalies compared to previous seasons or regions,
- an up-to-date assessment of soil water deficit,
- evaluation of the impact of investments of ISEP project,
- deriving a baseline for evaluation and monitoring the effects of implementation of crop management measures.

Automated alarms linked to sudden changes in vegetation state along the irrigation canals will be implemented within the area of interest in the Ararat Valley. Such vegetation anomalies often indicate irregularities in water passage through the canals. Monitored areas, located on both sides of canals each represent an area between 5 and 25 ha. Thanks to the use of multi-temporal satellite imagery it will be possible to observe the history of vegetation state in each area and provide supporting numerical and statistical analysis. In addition, this service will permit to visualize monitored area with regularly updated fine-resolution images from Sentinel-2 satellite (pixel 10 m) linking images to the corresponding graphs and alarms, in order to enable efficient navigation from the alarm alert to the image.

![Image](image-url)

Figure 3. Agriculture monitoring preliminary service presenting irrigation/leakage alarms.
Credit: GISAi for ESA/World Bank.
Figure 4a: Agriculture monitoring preliminary service presenting overall productivity and water stress in Kakheti.
Credit: GeoPulse for ESA/World Bank

Figure 4b: Overall productivity and water stress
Credit: GeoPulse for ESA/World Bank
3. IMPLEMENTATION PLAN

Currently for the management of irrigation schemes, the Water User Associations (WUA) are equipped with a **GIS-based water management software**, which monitors i.a. cultivated lands, crop types, water sources, intake of irrigation water, water delivery, electricity consumption and so on, typically using data collected via in situ surveys. As satellite technology allows to monitor crop productivity from space in an on-line and automated manner over large geographical areas the specific aim of the EO4EP is to:

- facilitate inclusion of these additional sources of data to the existing WUA’s GIS platform, and
- to generate information of the actually and potentially irrigated areas, actual and potential water sources, crop patterns and their rotation.

Main source of data consists in optical images from the Sentinel-2, Landsat 8 and MODIS, and radar images from the Sentinel-1 satellites. This data will be combined with meteorological data from regional stations accessible online via World Meteorological Organisation. The cooperation with the appropriate local agencies will be establish to facilitate the access to locally operated weather stations. Service delivery will involve satellite and meteorological data preprocessing using platform capabilities (Google Earth Engine and European Space Agency Innovation Platform Testbed (IPT) infrastructures). They will be integrated with ancillary data such as: extents of arable lands and focus areas, outlines of individual field plots, crop calendar, and maps of irrigation canals and irrigated areas (depending on the availability of the national statistical information).

All the services will be fully operational in the first quarter of 2018. In the same time EO4EP will continue stakeholder engagement to deliver other additional prototype products, created on demand, annually or seasonally based on user consultations.

The proposed products and services are also designed to be scaled up to other areas of interest in the country, and to include other input data using higher resolution imagery as well as new Sentinel-family satellites (specifically Sentinel-3) in order to improve and expand the scope of information content.

<table>
<thead>
<tr>
<th>Product/service level</th>
<th>Data</th>
<th>Spatial coverage</th>
<th>Temporal coverage</th>
<th>Spatial resolution</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>Crop type classification</td>
<td>Ararat Valley</td>
<td>Seasonally, annually, 2017</td>
<td>10-30m</td>
<td>Crop types map identifying specific crops (or groups of crops) and delivery of related statistics (distribution, structure) aggregated for defined unit.</td>
</tr>
<tr>
<td>Agricultural productivity</td>
<td></td>
<td>Ararat Valley</td>
<td>Depending on input data</td>
<td>10-30m</td>
<td>Timely information on agricultural productivity: an ongoing assessment of the state of crops, detection of anomalies compared to previous seasons or regions, daily assessment of soil water deficit, deriving a baseline for evaluation and monitoring the effects of implementation of crop management measures.</td>
</tr>
<tr>
<td>Water supply monitoring</td>
<td></td>
<td>Kakheti Region</td>
<td>Depending on input data (seasonally, annually)</td>
<td>10-30m</td>
<td>Satellite monitoring of the irrigation infrastructure connected to an alarm system.</td>
</tr>
</tbody>
</table>
4. CAPACITY BUILDING

The EO4EP Capacity Building is responding to the specific needs and expectations of the main stakeholders of the EO4EP project. The aim of these activities is to increase engagement and awareness of significance of Earth Observation (EO) information for efficient management among staff working for Multilateral Development Banks (MDBs), their client countries and the various governmental, and non-governmental user organisations interested in innovative technologies and more efficient implementation and management of development projects.

Capacity building will focus on:

- Organisation of capacity building workshops;
- Creation of Capacity Building Support Package (CBSP) and Communications Package.

Workshops

Capacity building workshops will be organized in collaboration with the MDBs and involve participants consisting of local users from national entities interested in using EO products. The capacity building requirements will be defined with partner institutions along with technical implementation arrangements that correspond to their readiness level.

The workshops will be thematically oriented and focused on land management, water management, agriculture and irrigation systems management. During the three-day workshop users will learn about general issues related to EO technology, explore technical aspects of data processing and become familiar with the methodology for generating products and requirements for the specific products and services listed in the portfolio (see Figure 5). Workshop in Armenia will take place in October/November 2017 in Yerevan.

Support Package

Capacity Building Support Package will be a main source of sharing knowledge and systematizing learning during the workshops. It will contain example of use cases, characteristics of EO-based information products and services and their comparison against alternative sources of information, description of benefits, impact and utility of geospatial data analytics as well as practical exercises accessible on the project website (eo4sd.esa.int/easterneurope).
Partners of the Eastern European Region Cluster

For more information, please contact:

ESA Technical Officer: Anna Burzykowska - Anna.Burzykowska@esa.int
Project Lead: Jakub Ryzenko - eo.developmentaid@cbk.waw.pl

www.eo4sd.esa.int/easterneurope