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## VERY HIGH RESOLUTION SATELLITE DATA FOR CADASTRAL MAPPING

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*В статье рассмотрены мероприятия и результаты проекта в Таджикистане,  
финансируемого Европейским Союзом*

*Activities and results achieved of the European Union financed project in Tajikistan is discussed*

**Introduction.** The urgent need nowadays is to establish and develop a modern cadastral system for former Soviet Union collective farms which don't have any of these kind of maps. The target group are individual farmers whose security of ownership could be increased significantly by accurate mapping and demarcation of their land use rights. For this reason, European Union has launched two projects in Tajikistan in the years 2007–2011.

Critical for such development is the availability of actual cadastral maps in scale 1:5000. Effective tools to create such maps are the modern, very high resolution satellite images, the digital photogrammetric methods, the orthorectification of raw data, based on the ground control points (GCPs) measured by GPS techniques and well prepared and on-the-job trained specialists in all of these technical fields.

The overall objective of the projects were to support the implementation of a more transparent and efficient land reform process in Tajikistan through capacity building and assisting the Agency of Land Management, Geodesy and Cartography (ALMGC) in preparation of geodesists, photogrammetrists and cartographers to use modern satellite photogrammetric data for cadastral mapping of agricultural land. The specific objective was to support and strengthen the professional capacity of the "Fazo" Institute in the field of satellite geodesy, satellite digital photogrammetry, advanced digital satellite image processing and digital cartography. The project activity included also cooperation and providing expertise with ongoing that time World Bank project: "Land Registration and Cadastre System for Sustainable Agriculture".

The new map projection was chosen and the new unclassified geodetic network for cadastral mapping has been established in which all agricultural parcel boundaries are being mapped.

The necessary high resolution panchromatic satellite imagery IKONOS, QuickBird, GeoEye, WorldView-1 and hardware with sophisticated software have been provided by the World Bank project. Know-how, technology transfer and on-the-job training have been done in the frame of the EU project.

The main activity in the project is listed bellow:

- Lectures and on-the-job training for the staff of the Institute "Fazo" and ALMGC in satellite geodesy with GPS techniques, digital photogrammetry, digital cartography and the use of very high resolution satellite data for cadastral mapping of agricultural land;
- Development and implementation of the technologies for digital mapping in the scale of 1:5000 with the use of IKONOS and QuickBird data with the use of corrected DEM from raw SRTM data;
- Providing technical expertise and assisting "Fazo" in the establishment and measurement of the new unclassified geodetic network;

- Providing technical expertise and assisting “Fazo” with the identification, GCPs measurement with GPS techniques and the use of GCPs for orthorectification of very high resolution satellite images;
- Preparation of technologies, technical manuals and Standard Operational Procedures;
- Elaboration and implementation of a Quality Control System for all steps to produced in the end digital cartographic data;
- Assisting Institute “Fazo” in orientation, georeferencing and orthorectification of the satellite images;
- Providing technical expertise to the World Bank project and leading trainings courses for the personnel of their new established seven Regional Land Cadastre Centers in Tajikistan;
- Organization of study tours to private and governmental institutions in Europe and CIS countries;
- Transferring of know-how in all subjects including cadastral mapping;
- Organization of English lessons for the technical personnel.

Project has been running by the FM-International Oy FINNMAP and Human Dynamics AG Austria in two phases each lasting 2 years. As the results of the project Institute “Fazo” was granted first prize on the International Conference in Moscow in April 2010 for the project “Technology for Digital Cadastral Mapping in Tajikistan with the use of HRSD”.

**1. Geodesy.** The new geodetic network ITRF2005 and UTM in 6° zones has been chosen as the coordinate system and projection for digital cadastral mapping. The 1<sup>st</sup> class network covers all of the territory of Tajikistan with 21 stations spaced at 100 km and 2<sup>nd</sup> class network with 2 km spacing between stations covered all agricultural regions. That network provides the necessary reference for digital orthophotomap production, DEM correction and field surveying by geodetic and GPS methods of the parcel boundaries not recorded with the satellite images.

In the framework of the World Bank project “Land Registration and Cadastre System for Sustainable Agriculture” new seven Regional Land Cadastre Centers have been established. The staff has been trained in GPS techniques and now is able to measure newly created farms, prepare land inventory, shareholder lists and land files containing all necessary documents in order to issue land use rights certificates.

**2. Photogrammetry and satellite image processing.** Leica Photogrammetric Suite with ERDAS Imagine workstations have been purchased, installed and staff has been trained for orthorectification of Very High Resolution Satellite Data: IKONOS, QuickBird, WorldView-1 and GeoEye on the basis of elaborated in the project technology.

Example of the GCP is shown on Fig.1 and measured it with GPS in the field is shown on Fig.2.

Mean value of RMS x, y errors for space triangulation calculated on the Independent Check Points was  $\pm 0.6\text{m}$ . This accuracy is equal to one pixel of QuickBird panchromatic data and less for IKONOS images. Accuracy mostly depends from the identification of natural GCPs in very complicated agricultural areas.

Digital orthophoto images in 16-bits data have been generated with the use of corrected DEM of the raw SRTM data. Accuracy in Z coordinate of this DEM for agricultural regions was calculated from profiles recorded in the field with GPS techniques. It was achieved  $\text{RMS}_z = \pm 4\text{m}$ . Accuracy of digital orthophoto maps was  $\text{RMS}_{xy} = \pm 1\text{m}$ .

**3. Cartography.** Digital orthophotomaps in GeoTIFF format in 8-bit data were used for production of cadastral maps in Cartographic Department with the use of ArcMap software. The digital cadastral maps are used then by the seven Regional Land Cadastral Centres for elaboration of “Cadastral certificate” and for additional measurement of parcels in the field with the use of GPS and Total Stations equipments.

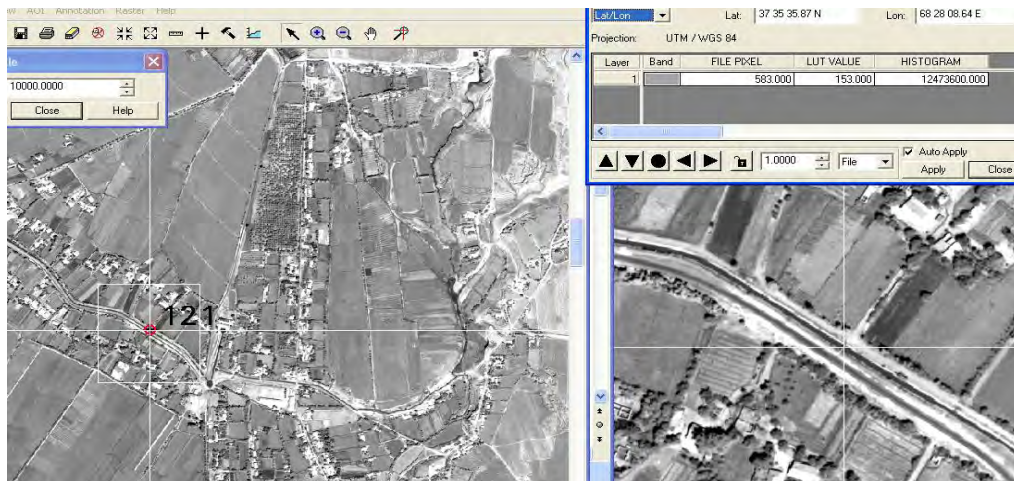


Fig. 1. GCP with approximately measured coordinates: Lat, Lon is used in the field work by geodesists with GPS instruments



Fig. 2. Measurement of GCP in the field by GPS technique

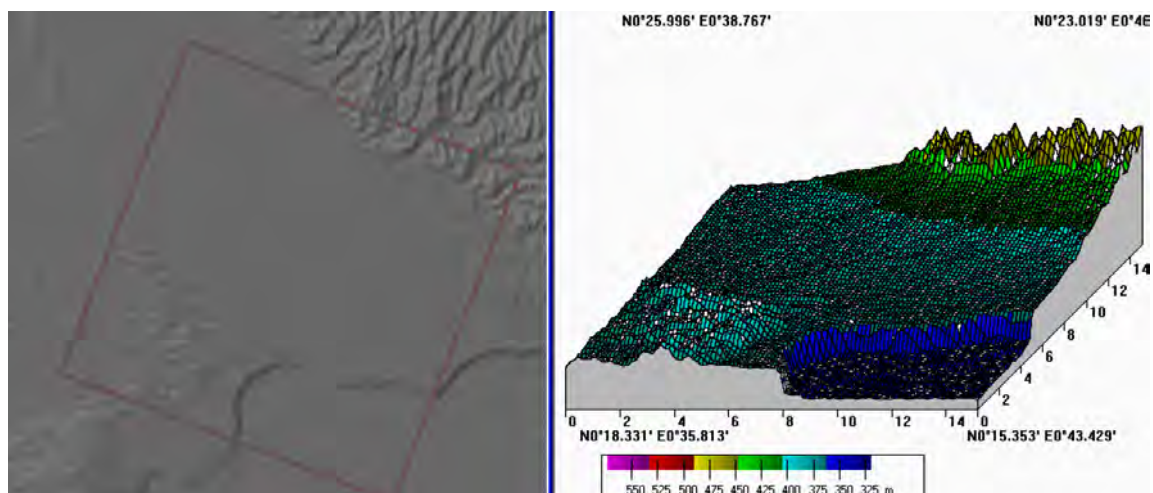


Fig. 3. Corrected DEM from SRTM data and oblique view of agricultural region close to the high mountains



Fig. 4. Agricultural region in high mountains area

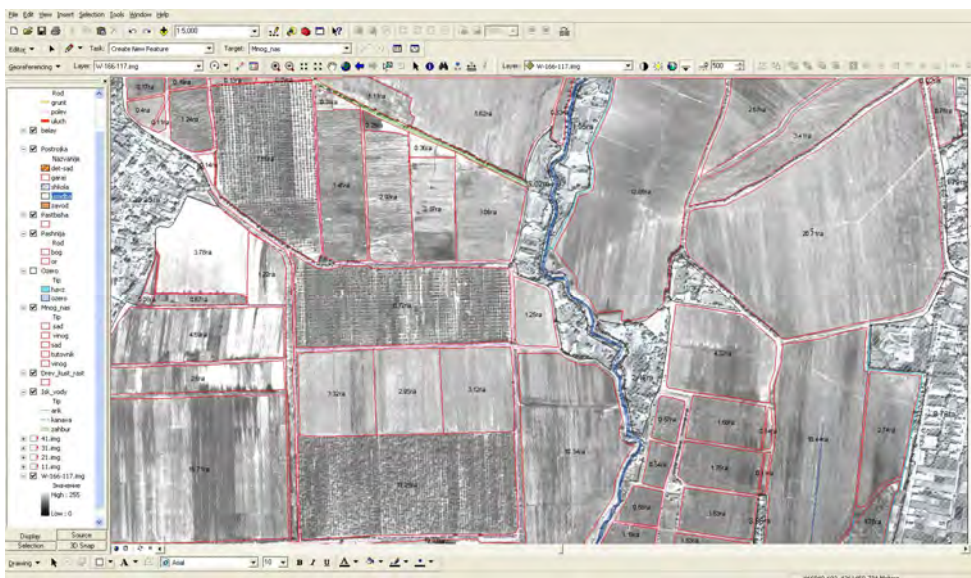


Fig. 5. Orthophoto with overlaid cadastral layer in ArcMap

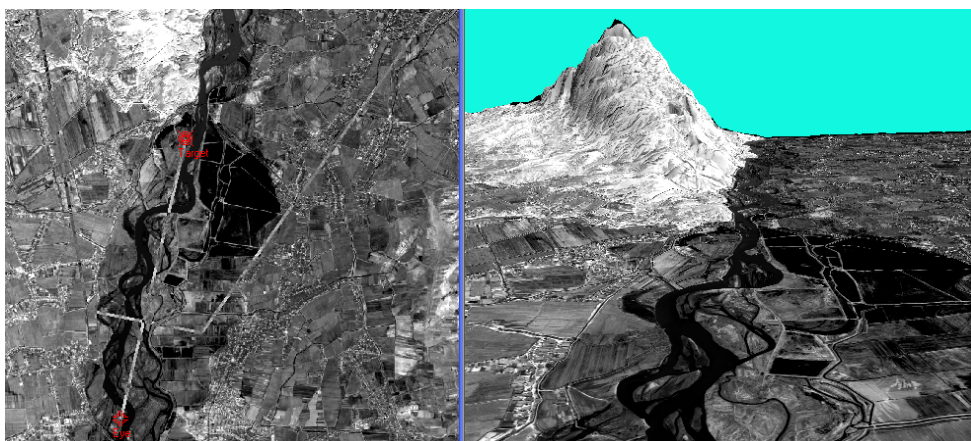


Fig. 6. Perspective view of the agricultural areas as seen in the Erdas Imagine

**5. Results.** Transferred know-how and technologies for: establishment of open geodetic networks for cadastral mapping; measurement of ground control points for orthorectification using GPS method; producing of digital orthophoto maps from very high resolution satellite images; production of digital cadastre maps was done successfully for the staff of “Fazo” Institute.

Technical personnel of the Institute “Fazo” and other organizations of ALMGC have been trained successfully and now are able to carry out their respective tasks in the field of modern geodesy, digital photogrammetry, processing of high-resolution satellite images and digital cadastre map compilation.

Technical Manuals, Standard Operational Procedures and instructions have been elaborated and implemented in Tajikistan. On the basis of elaborated technology and methodology in the framework of the European Commission financed project thousands of digital orthophoto map sheets in the scale of 1:5000 with pixel size 0.5m have been produced by the “Fazo” Institute. Accuracy of digital orthophoto maps is  $RMSE_{xy}=1$  m, which is equivalent to two pixels of raw QuickBird panchromatic data. On the basis of generated digital orthophoto maps, agricultural borders are being elaborated in “Fazo” Institute and by the staff of the Regional Cadastre Centers with the use of ArcGIS software.

1. Kaczynski R.: *Cadastral mapping in Tajikistan*. *GIM International*, 2009, Issue 10, Vol. 23.
2. Kaczynski R., Yatimov A.: *Progress in Cadastral Mapping in Tajikistan*. *INSPIRE Conference in June 2010, Krakow, Poland*.
3. Kaczynski R., Kotzev V.: *Project completion report*. Dushanbe 2011.
4. Note: Agency of Land Management, Geodesy and Cartography (ALMGC) has now the new name: State Committee for Land Management and Geodesy of the Republic of Tajikistan