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GIS TECHNOLOGIES FOR COMMUNITY PASTURE MAPPING IS AS A DIGITALIZATION TOOL

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Abstract. The use of GIS and remote sensing technologies is rapidly developing in agriculture sector of Republic Kyrgyzstan. The main objective of this research is to determine the internal boundaries and the state of pasture areas (degraded, stony, bushy, clean, etc.) that are suitable for grazing and to cultivation in eastern and southern regions of Republic Kyrgyzstan. Prior to the field work, the satellite image of Sentinel-2A and cartographic materials were prepared showing steep slopes of more than 45 degrees were determined. As a result, 3 types of thematic maps were created for all pasture committees of the investigated area: 1) The General map based on the results of community mapping of pastures of the PUU (Pasture User Units); 2) The PUU Community Pasture Mapping Tract Map, and 3) The Working map based on the results of community mapping of pastures of the PUU. Quantitative and qualitative indicators of the prepared maps allow to solve several tasks, including actions for adapting to climate change.

Keywords: Sentinel-2, Kyrgyzstan, GIS, pasture areas, SRTM, remote sensing

Currently, GIS (Geographical Information System) technologies are the main tool to determine the boundaries of actually suitable pastures for livestock grazing by using community mapping and updating geodata. In Kyrgyzstan, local communities experience difficulties such as the lack of internal boundaries of pastures on cartographic materials and the unknown quality and quantity of pastures, which have occurred due to human influence and climate change.

In community pasture mapping Sentinel-2A, SRTM, Google Earth satellite images and topographic maps, maps for establishing the pasture committee's boundaries and geodatabases were used, which include land use information, visibility, informativeness, allowing an objective assessment of the situation by determining the degree of degradation and the type of pasture use in Kyrgyzstan.

Kyrgyzstan is a mountainous country covering an area of 199,951 km^2 located in Central Asia. In the country, 90,400 km^2 (85% of the area of agricultural land) is occupied by pastures, that include summer pasture areas in the highlands (Report for 2020 year…).

Agriculture is one of the priorities of the national economy, but there is persistent land degradation and soil erosion due to unsustainable land use and lack of public investment. In the Kyrgyz Republic, the degree of land degradation has reached a critical level, and taking into account the consequences of climate change, there is practically no time left to change the situation (National Development Program…, 2021).

After the collapse of the Soviet Union, there was a reorganization of agriculture, as well as the privatization of land, which was previously controlled and managed by collective farms and state farms. The processes of reorganization of agriculture, as well as the privatization of land that was previously controlled by 195 collective farms and 275 state farms, the increase in the number of small farms and private livestock breeders, have created a number of problems related to inventory and ownership of pastures and arable lands (Borchardt et al., 2011).

Pasture management reform in Kyrgyz Republic began in 2009 with the adoption of the Pasture Law, which provided the legal basis for transferring responsibility for the management of this vast natural resource to local governments and communities. The given reform was based on three main principles:

1. Ecosystem approach; it is based on the fact that natural pastures consist of grazing systems that must remain unfragmented and managed through unified mechanisms. This approach has led to

a shift from a tenancy system, where people could acquire long-term use rights on a first-come, first-served basis, to a common ownership regime, where resource use rights are allocated to all users on an annual basis.

2. Transfer of management to the community level, i.e. from central to local government, where the management occurs at local government level that aims to improve management efficiency and provide access for local residents.

3. Incorporation of payment for the resource by means of introducing fees for the use of pastures per head of livestock (Range Management in Central Asia…, 2014).

From year to year there is an increasing degradation of pastures in the country due to an increase in the number of livestock (Report for 2020 year…; National Committee on Statistics…), severe overgrazing around settlements, soil erosion and the effects of climate change, the use of pastures for other purposes, which leads to the need for monitoring and adoption of adaptation measures for further efficient land use (fig. 1).

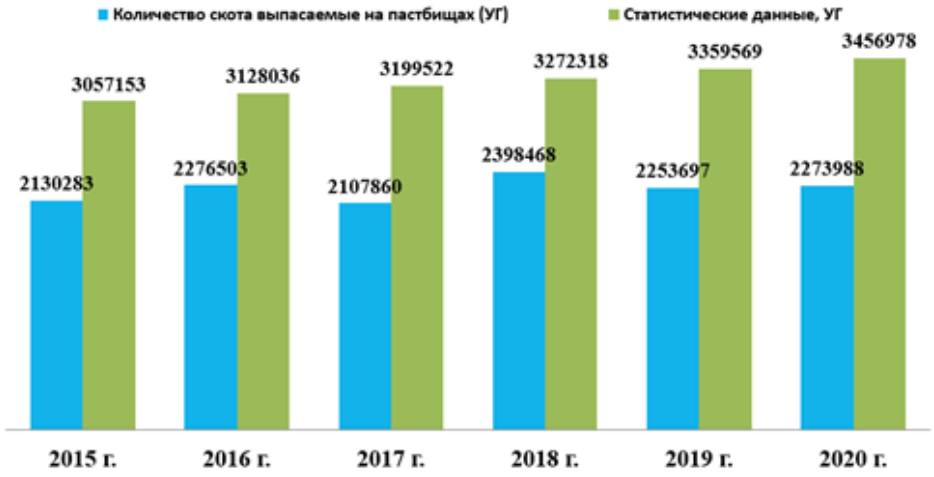

Figure 1. Number of livestock (head of cattle) for 2015-2020

In managing pasture resources, local communities deal with difficulties such as the internal boundaries of pastures and their area, state, types of pastures, season of use, etc.

Currently, the use of GIS and remote sensing technologies is developing much in agriculture sector.

The first work on digital mapping and the creation of a geodatabase was carried out within the framework of the "Agricultural Investments and Services Project" (AISP) financed by the World Bank (WB) and within the framework of the "Livestock and Market Development Project - 1.2" (LMDP-1.2) funded by the International Fund for Agricultural Development (IFAD) implemented by the Agricultural Projects Implementation Unit (APIU) under the MAWRRD KR (Chymyrov et al., 2017). The AISP and LMDP-1 projects gave opportunity to carry out work on the demarcation and delimitation of borders, the creation of geodatabases and the digitization of cartographic materials.

For the first time in Kyrgyzstan, the work on determining the boundaries of actually suitable pasture lands for livestock grazing though community mapping method was carried out within the framework of the LMDP-2 project, in the territory of Naryn, Issyk-Kul, Osh, Jalal-Abad and Batken regions.

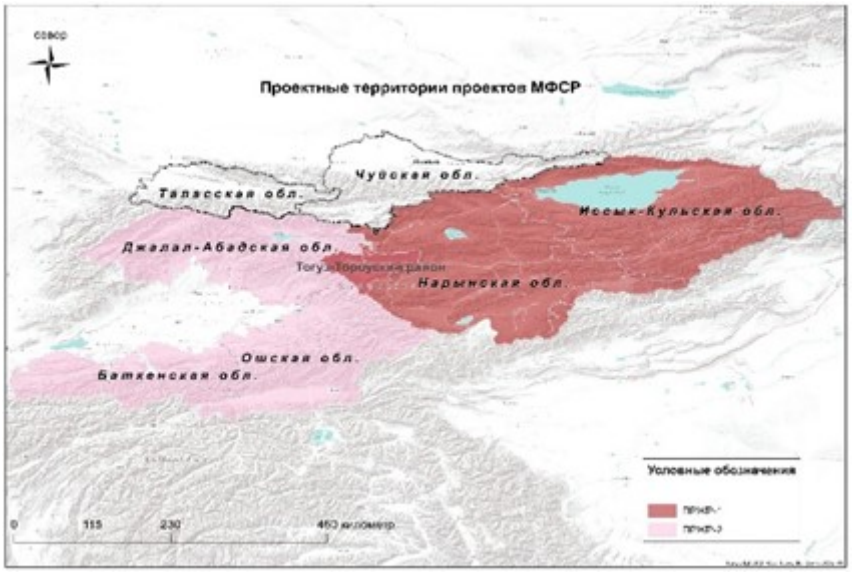

Figure 2. Project area

The main purpose of this work is to determine the internal boundaries of pasture areas, to determine the state of pasture lands (degraded, stony, bushy, clean, etc.) that are actually suitable for using, for grazing and to identify pasture lands that have allocated to be cultivated and developed.

Data and methods.

Study area

The work was carried out in the eastern and southern regions of Kyrgyzstan.

The eastern regions include: Naryn, Issyk-Kul regions and Toguz-Toroi region of Jalal-Abad oblast. The population of the two main regions, about 154,000 households, of which 71 percent live in rural areas, are mainly livestock breeders that belong to 125 pasture committees. Pasture committees are the executive body of pasture users who represent the interests of all households that have used pastures. On average, one association of pasture users includes 900 households or about 4600 people (Project Completion Report, 2020).

The southern regions include the pasture committees of Osh, Jalal-Abad and Batken oblasts. In three regions, there are 189 pasture committees, which make about 51% of the country's population (Livestock and Market Development Programme II).

Data

The territory of Kyrgyz Republic is 90 percent mountainous and the elevation varies from 500 meters above sea level to 7,000 meters, leading to steep slopes in many mountain pastures. In this regard, based on the Digital Relief Model (DEM), SRTM data were used, steep slopes above 45 degrees were determined for all pasture plots of pasture committees that are not used for grazing. Prior to the field work, cartographic materials were prepared showing steep slopes of more than 45 degrees marked in red and their areas were determined.

Satellite images play an important role in solving issues related to the environment, land use and its condition, etc. The space images of Sentinel-2A were used in the work. This is a European Space Agency (ESA) satellite launched in June 2015 as part of the Copernicus program. The spatial resolution of the imaging system varies from 10 to 60 m, depending on the spectral range.

Vector data formats were used for geodatabases of the Department of Pastures with the main layers of a digital map (outer boundaries of pastures, administrative boundaries, hydrography, roads, infrastructure, settlements, etc.) and attribute data in the UTM projection with uniform symbols and scales on maps (Chymyrov et al., 2017). Additional layers were added to the geodatabases: tracts, pasture areas, which are extract the types of pastures.

Table 1.

All of the above data has a WGS_1984_UTM_Zone_42N map projection system.

	Simple resolution	Characteristics	Compile-time	Yield (Data frame)
Sentinel2	10x10 meters	Number of channels - 10 Full size - 101,35 GB File format - TIFF Pxl type - full number, no symbols Depth of file format - 16 bit	2019-2020	Public resources. https://sentinels.copernicus.eu/web/sentinel/sentinel-data-access https://sentinels.copernicus.eu/documents/247904/1848117/Sentinel-2_Data_Products_and_Access
SRTM	30x30 meters	Number of channels - 1 Full size - 101,35 GB File format - BPT Pxl type - with floating point Depth of file format -32 bit	-	Public resources: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-digital-elevation-shuttle-radar-topography-mission-srtm-1-arc?qt-science_center_objects=0#qt-science_center_objects https://earthexplorer.usgs.gov/

Spacial image, ESRI	Zoom 18	Mosaics of spacial image for a country territory	2018-2020	Public resources. App - SASPlanet
Topographic map	Scale1:100 000	Mosaics of topographic maps for a country territory		

Methodology

The work was carried out within the following stages: preparatory, field and cameral. At the stage of preparatory work, there carried out works of collecting geodatabases and checking them for georeferencing accuracy and study planning and cartographic materials of established boundaries, determining the state of biomass (NDVI) using multispectral satellite images Sentinel, Google Earth, ESRI, topographic cartographic materials on a scale of 1:100000 m.

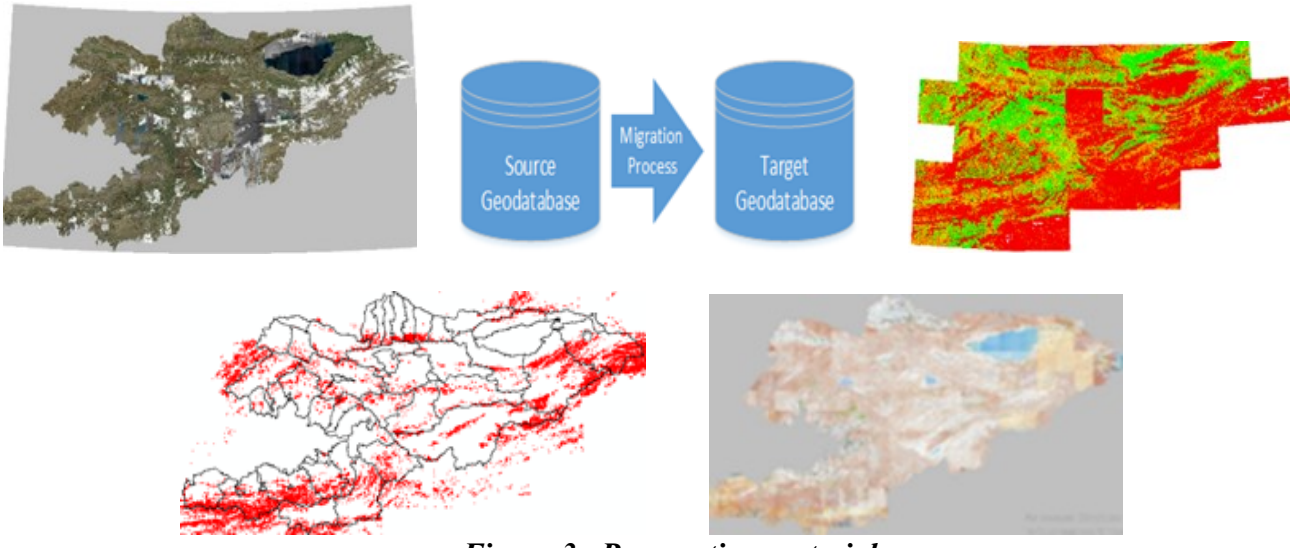

Figure 3. Preparation materials

During the field work in all aiyl aimaks (local communities), the consortium specialists organized meetings with representatives of the aiyl aimaks, pasture user units (PUU), as well as with other meeting participants (livestock owners, shepherds, persons who know or are related to pastures, pasture infrastructure, etc.). At the meetings, they carried out works to determine the internal boundaries of pasture plots used for other purposes, for example, pastures developed for gardens,

quarries, new buildings, hayfields, arable land etc. In the process of follow up meetings paper cartographic materials were used: remote sensing data, vegetation maps with NDVI, and SRTM data, as well as software such as Google Earth Pro and Arc GIS.

During in-office work, works of updating the geodatabase, entering attributive data and creating cartographic materials were carried out. As a result of the work, 3 types of maps were created, which were distributed to all pasture committees of the project area.

1) The first map is the **General map based on the results of community mapping of pastures of the PUU**, the map that reflects all existing layers, except for the tracts.

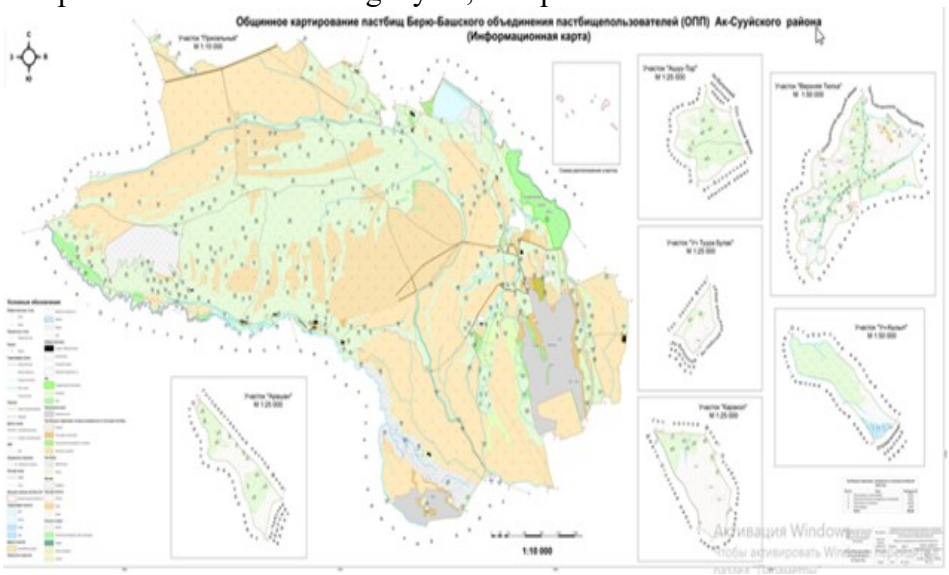

Figure 4. General Map

The second map is th**e PUU Community Pasture Mapping Tract Map,** the map that reflects all existing layers except Grasslands.

An inscription was made of point like a spring, pasture infrastructures, linear (rivers), and polygonal contours and areas of pastures, pasture infrastructures, cattle track, lakes, land cover, etc. And also the inscription of the layer of Tracts is performed: name and yield/capacity.

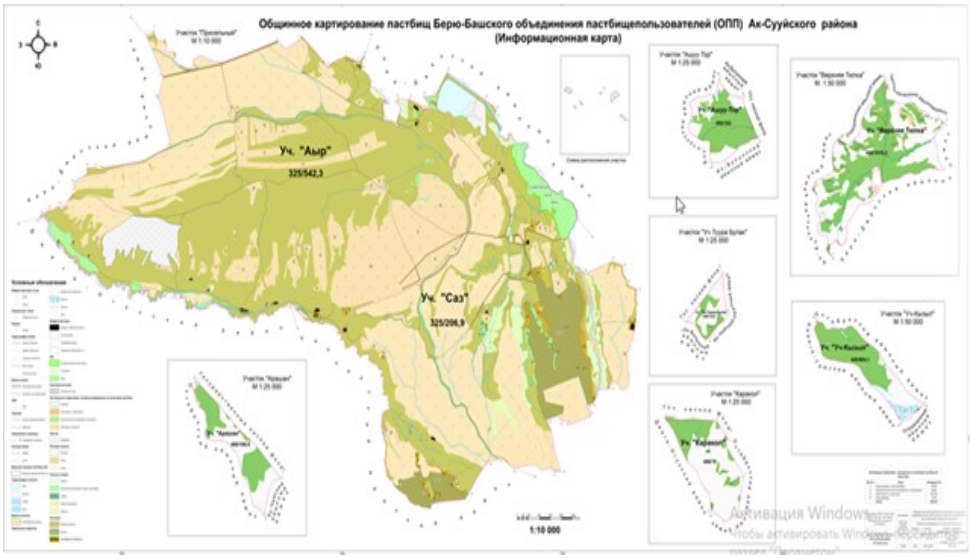

Figure 4. Map of tracts.

The third map is **the Working map based on the results of community mapping of pastures of the PUU**, this map reflects the layers: Turning points, direction of allied areas, external border of AA, settlements, tracts.

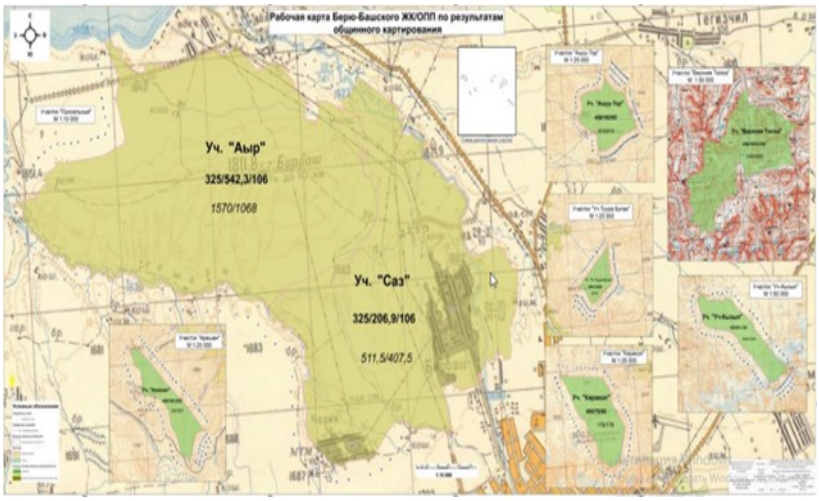

Figure 5. Working map

Conclusion

Cartographic materials of the work of determining the boundaries actually suitable pasture land for grazing by community mapping is a very important resource for pasture user associations, local governments, the Department of Pastures and Livestock Breeding of the Ministry of Agriculture, Water Resources and Regional Development of the Kyrgyz Republic to monitor work and effectively manage pasture areas.

Quantitative and qualitative indicators of work using cartographic materials allow us to solve the following tasks and are used for:

1) Rational distribution of livestock according to pasture capacity;

2) Know the places of degraded pastures, for further improvement activities;

3) Accounting for land for proper use and regarding its intended purpose;

4) State authorized bodies should have information on the quantitative and qualitative indicators of pasture lands in aiyl aimak sections.

5) At the local and state levels, use materials to resolve disputes between the pasture user unit and related pasture committees.

6) Determination of the real area of a good pasture land used for grazing for the taxation of land of this category.

7) Accounting and control of pasture lands when issued for other use, as unproductive. State bodies have to conduct monitoring at the level of every Pasture committee.

8) Taking action and adapting to climate change.

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