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Preparing and Evaluating the LULC Map of the Kosonsoy River Basin Using GIS Technologies

Tursunov Yunusali, Mirzahmedov Ismoiljon

Departament of Geography and environmental protection, Namangan State University, Namangan, 160107, Uzbekistan
E-mail: ismoil_landsat@mail.ru

Abstract. This paper addresses the development and analysis of Land Use/Land Cover (LULC) maps of the Kosonsoy River basin using Geographic Information System (GIS) technologies. In the course of the study, LULC maps for 2017 and 2024 were produced in the ArcMap environment based on Sentinel-2 satellite imagery, including image preprocessing, classification, and accuracy assessment stages. Using the watershed delineation method, the hydrological boundaries of the Kosonsoy River basin were defined, enabling an integrated assessment of the natural and anthropogenic characteristics of the area in conjunction with the LULC maps. The results highlight the effectiveness of GIS-based approaches for land cover mapping, spatial analysis, and monitoring of land use changes, as well as their practical significance for territorial planning, environmental monitoring, and sustainable land resource management.

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1. Introduction

Rational use of land resources, preservation of their ecological condition, and scientifically grounded assessment of spatial changes are currently among the most pressing issues in the fields of geography and ecology. Population growth, increasing demand for agricultural land, rapid urbanization processes, and intensified anthropogenic pressure on natural landscapes are leading to significant changes in land cover and land use patterns [1].

Land Cover refers to the physical and biological surface of the Earth, including natural and human-made elements, whereas Land Use reflects the functional utilization of land shaped by human activities. These two concepts are closely interrelated, and their integrated analysis is conducted through Land Use/Land Cover (LULC) studies. LULC maps play an important scientific and practical role in assessing the current state of a territory, identifying the dynamics of changes, and developing future land development scenarios. In recent years, Land Use and Land Cover mapping has been significantly improved through the application of remote sensing technologies and Geographic Information Systems (GIS). High spatial and spectral resolution satellite imagery enables accurate discrimination of land cover types, assessment of their spatial distribution, and monitoring of temporal changes over time.

In recent years, the development of Geographic Information Systems (GIS), remote sensing, and cartography has been identified as one of the priority directions in the Republic of Uzbekistan. There is widespread recognition of the need to extensively implement modern GIS technologies in territorial analysis, rational use of land and water resources, improvement of environmental monitoring, and spatial planning processes [3]. In this regard, a number of regulatory and legal documents have been adopted in Uzbekistan to establish and develop the National Spatial Data Infrastructure (NSDI), which serves as an important institutional foundation. This infrastructure is aimed at collecting, storing, and sharing spatial data related to geodesy, cartography, land resources, ecology, and other sectors based on unified standards, and it plays a significant role in integrating GIS technologies into scientific research and practical management processes [4]. In addition, projects are being implemented in Uzbekistan in cooperation with international financial institutions, including the World Bank, to develop spatial data infrastructures, create digital maps, and introduce geo-information platforms. These initiatives expand opportunities for conducting scientifically grounded Land Use and Land Cover (LULC) monitoring, accurately assessing spatial changes, and effectively utilizing modern software tools such as ArcGIS Pro / ArcMap (Esri), MapInfo Professional (Pitney Bowes), GeoMedia (Hexagon Geospatial), Manifold GIS, Smallworld GIS (GE Digital), QGIS, GRASS GIS, ILWIS (Integrated Land and Water Information System), ArcGIS Online, Google Earth Engine (GEE), and IDRISI [2].

The Fergana Valley, particularly the Kosonsoy River Basin, is characterized by complex natural and climatic conditions, high population density, and well-developed agriculture. In this area, processes such as the expansion of irrigated lands, reduction of natural vegetation cover, and degradation of pastures have been observed. Therefore, the preparation of LULC maps of the Kosonsoy River Basin and the analysis of their temporal changes are of great importance for assessing the ecological condition of the region and for drawing scientifically grounded conclusions on the sustainable use of land resources.

2. Material and Methods

The Kosonsoy River Basin in the Fergana Valley was selected as the object of this study. This area is distinguished by its natural and climatic conditions, relief characteristics, increasing anthropogenic pressure, and well-developed agriculture. The region includes agricultural lands, pastures, forested areas, water bodies, and urbanized zones, whose spatial and temporal changes are of significant scientific importance for sustainable land resource management and environmental monitoring. The Kosonsoy River is the largest river originating from the southern slopes of the Qurama and Chatkal mountain ranges. It begins from the Angren Plateau, near the source of the Govasoy River. The river is formed by the confluence of the Childiksoy and Chapchamasoy streams and has several tributaries within its drainage basin, including Ishtamberdi, Terek, Uryukti, Olabuqa, and Qorasuv. Unlike many other rivers, the Kosonsoy flows eastward and southeastward until it exits the mountainous area. Near the city of Kosonsoy, the river emerges from between foothills into a basin, where a large portion of its water is diverted into canals and irrigation ditches for agricultural purposes [6].

The mountains surrounding the Kosonsoy Basin are of moderate elevation, generally ranging between 3,200 and 3,500 meters, reaching up to 4,300 meters only in the upper reaches of the Terek River. Within the basin of the Olabuka River, a tributary of the Kosonsoy, there is a single lake known as Okboltirgon. The lake is approximately 500 m long and 200 m wide, with a water surface area of 0.1 km², and is located at an elevation of 1,962 m above sea level. The lake collects water from a catchment area of 12.5 km². Water does not flow out of the lake through an open channel; instead, it emerges underground at a distance of about 1.3 km.

The average long-term discharge of the Kosonsoy River at Baymoq village is 13 m³/s. The maximum recorded discharge was observed on June 1, 1969, reaching 88.5 m³/s, while the minimum discharge during the observation period was measured in winter and amounted to 0.9 m³/s. The average annual runoff depth generated within the basin is 220 mm. The high-water period lasts for approximately 165 days, typically from March 30 to September 8, during which about 80% of the annual river flow occurs. The river water is relatively clear, with the highest average monthly suspended sediment load reaching 29 kg/s. The average annual sediment load does not exceed 4.8 kg/s, and the total annual sediment yield has not exceeded 150 thousand tons, usually ranging between 40-50 thousand tons. The mineralization level of the river water is higher compared to that of the Govasoy River [6, 7].

In this study, Remote Sensing (RS) and Geographic Information System (GIS) methods were applied to identify Land Use and Land Cover (LULC) changes. Multitemporal satellite images from Landsat and Sentinel missions were analyzed, and datasets with low cloud cover were selected. Relevant data for the study area were collected through the Living Atlas platform (https://livingatlas.arcgis.com/landcover/) and analyzed using ArcGIS 10.8.2 software (Figure 1). Prior to analysis, the satellite images underwent preliminary radiometric and geometric corrections to improve their spectral and spatial accuracy.

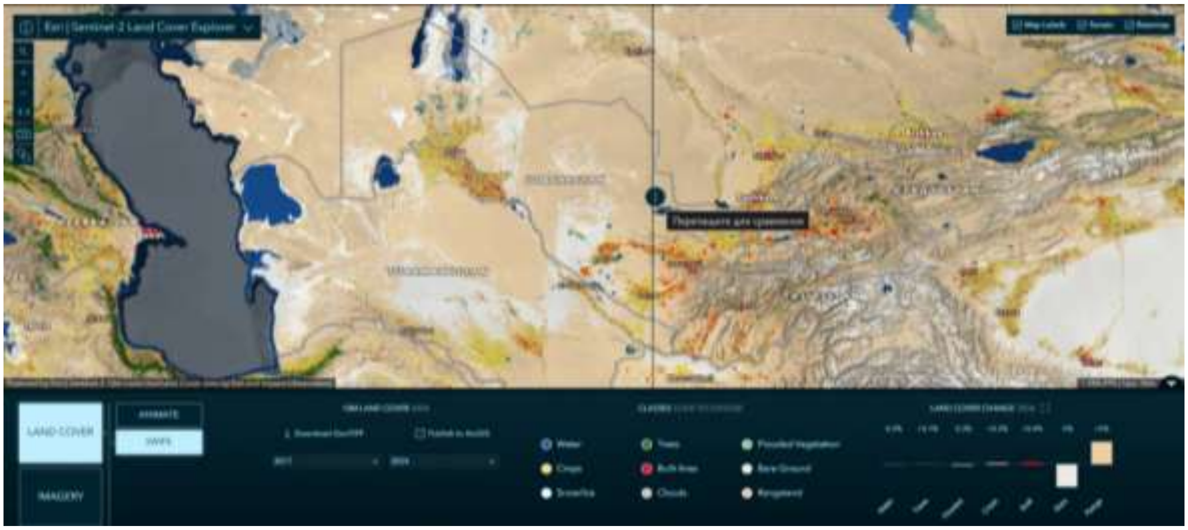

Figure 1. Living Atlas working interface (Source: https://livingatlas.arcgis.com/landcover/).

During the analysis, the boundaries of the study area were defined, and a watershed delineation map of all river basins within the Fergana Valley was also created. In addition, foreign and domestic dissertations, research studies, scientific articles, and textbooks were reviewed, and the author's perspectives were formulated based on the analysis and synthesis of their findings.

3. Results

The Land Use/Land Cover (LULC) map for the Kosonsoy River Basin was prepared using the ArcMap software. The process consisted of several stages. First, Sentinel satellite images for the years 2017 and 2024, along with LULC datasets obtained from NASDA, USGS, and the ArcGIS Living Atlas, were downloaded and integrated into the analysis [8]. To identify the geomorphological structure and relief characteristics of the study area, Digital Elevation Model (DEM) data and basin shapefiles were prepared. Based on these datasets, a watershed delineation map was generated and analyzed, as presented in Figure 2.

Watershed delineation is the process of identifying the catchment areas that encompass rivers and their tributaries. This process is carried out using Geographic Information Systems (GIS) and Digital Elevation Models (DEM). A watershed delineation map allows the determination of hydrological boundaries, identification of flow directions, and hydrological analysis of river basins [11]. The map preparation process typically involves several steps: first, DEM data of the study area are imported into the GIS software. Next, flow direction and flow accumulation algorithms are applied to identify natural water flow paths. Based on this, catchment polygons bounded by rivers and their tributaries are generated [12]. The watershed delineation map visually demonstrates how various geomorphological elements—such as mountains, valleys, and foothills—influence the water collection process.

Conceptually, a watershed delineation map provides information on where water resources flow within a region, the direction of water movement, the structure of catchment areas, and how natural and geographical features affect flow patterns. These data are widely used in environmental monitoring, water resource management, agriculture, hydrological modeling, and natural hazard assessment [13]. In the context of the Fergana Valley, watershed delineation maps are of great practical importance. They enable effective hydrological management in water-scarce areas, optimization of irrigation systems, and informed decision-making in spatial planning. When combined with LULC maps, they allow a detailed analysis of agricultural lands, denuded areas, and flood-affected vegetation, as well as the assessment of ecological conditions and changes in landscape elements.

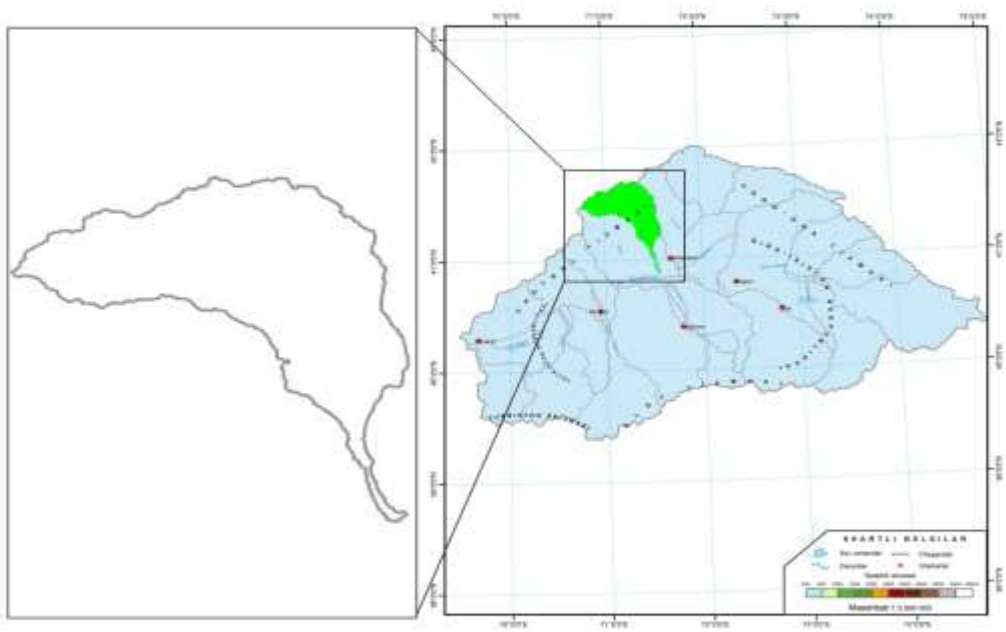

Figure 2. Location of the Kosonsoy River Basin within the Fergana Valley

The imported satellite images were preprocessed, including cloud removal and radiometric and geometric corrections. Using the Clip function, only the required area corresponding to the Kosonsoy Basin boundaries was extracted, ensuring accurate and reliable map analysis and LULC classification [9]. In the next stage, LULC classes were identified. For the years 2017 and 2024, the main classes selected were: pastures and natural grasslands, denuded land, agricultural crop areas, flooded vegetation, forests and trees, snow and glaciers, landslide-prone areas, and water bodies. Supervised Classification was applied to determine the classes, and the Maximum Likelihood algorithm was used to optimize the results [10].

Globally, Sentinel-2 10 m Land Use/Land Cover Time Series data divides landscapes into 11 classes [14]. In our study area, eight of these landscape classes were present (Figure 3), as follows:

The LULC map for the Kosonsoy River Basin was prepared for 2017 and 2024 to analyze spatial and temporal changes. Eight primary landscape classes were identified:

Water – areas with permanent water presence throughout the year, including rivers, lakes, reservoirs, and inundated salt flats. Vegetation is almost absent, and anthropogenic objects (e.g., docks, ports) are not considered. Water resources in these areas are strategically important for irrigation, agriculture, and ecosystem functioning.

Trees/Forest – densely vegetated areas with trees approximately 2–3 meters or taller, including natural forests, plantations, and waterlogged vegetation (e.g., mangroves). Forested areas serve as carbon sinks and play a critical role in biodiversity conservation.

Flooded Vegetation – regions partially or completely covered by water during certain periods of the year, such as rice paddies, wetlands, flooded forests, and irrigated lands. These areas are essential for hydrological balance and agricultural sustainability.

Crops – agricultural lands planted with cereals, vegetables, and industrial crops (e.g., cotton, wheat, maize, soy). Crops shorter than tree height fall into this category, reflecting the agrarian potential of the basin.

Built-up Areas – human-made infrastructure, including residential zones, factories, cities, villages, roads, and paved surfaces. This class serves as an indicator of the degree of urbanization.

Bare Ground – sparsely vegetated or unvegetated areas, such as deserts, sandy soils, salt flats, dry lake beds, quarries, and mines. This class is important for analyzing soil erosion, salinization, and desertification processes.

Rangeland/Pastures – areas predominantly covered by natural grasses and shrubs, sparsely populated by trees. Examples include open savanna-type grasslands, natural pastures, and livestock grazing areas. This class is significant for livestock management and ecological resource planning.

Snow/Ice – areas with perennial snow and glaciers, generally located at the highest elevations of mountainous regions.

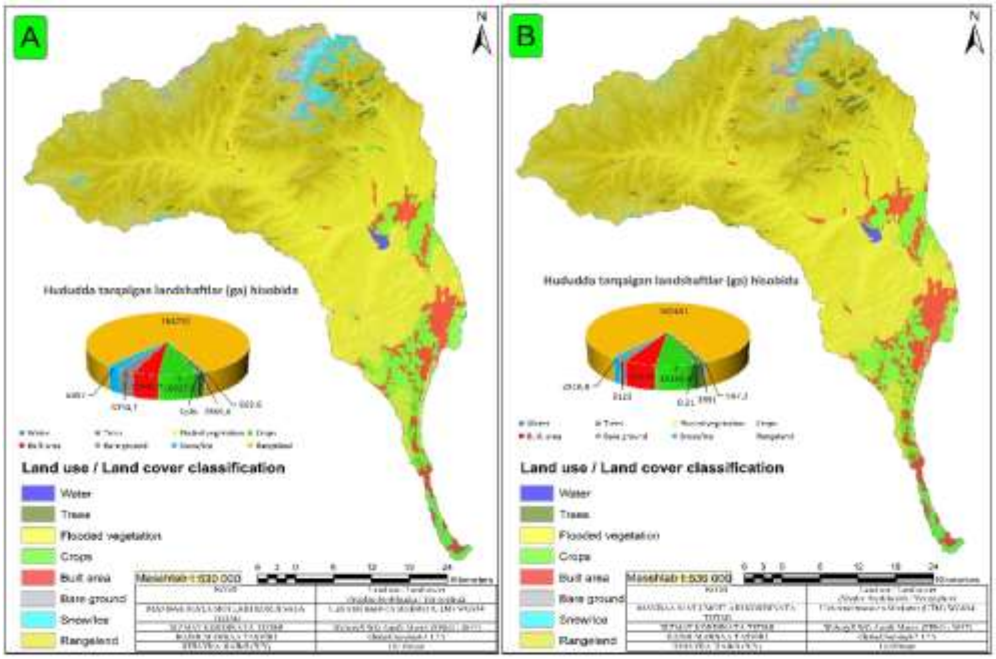

Figure 3. Land Use/Land Cover (LULC) map of the Kosonsoy River Basin (A = 2017; B = 2024)

The 2017 situation, marked A on the map, shows that the landscape structure in the Kosonsoy basin is relatively stable. Most of the territory is covered by pastures and natural grasslands, which are mainly distributed as continuous areas in the foothill and foothill zones (Figure 3). Denuded lands are mainly located on slopes and in areas with strong water erosion, which is associated with the complexity of the relief and natural geomorphological processes. Agricultural arable land is concentrated in the lower part of the basin, in the river valley and irrigated plains, which were formed in close connection with irrigation systems [2].

The 2024 LULC map, marked B, shows that significant spatial changes have occurred in the region. The expansion of pastures and natural grasslands indicates a relative decrease in anthropogenic pressure in some areas and a partial restoration of natural vegetation cover. At the same time, the reduction in the area of denuded lands is explained by the measures taken to protect the land and stabilize natural processes in the region [15].

The compiled LULC maps made it possible to assess the exact area of landscape types occupying the territory, their relative share, and trends in change over time. The main part of the territory is pastures and natural meadows. This landscape type initially occupied 184,726 hectares, which corresponds to the main share of the total area of the basin. In the subsequent period, the area of pastures and natural meadows reached 187,451 hectares, an increase of 2,725 hectares or about 1.5%. This is explained by the decrease in economic pressure in some areas and the restoration of natural vegetation cover. Although the increase in pasture area is a positive factor for livestock, if environmental standards are not followed in their management, degradation processes may increase in the future.

The area of denuded lands initially amounted to 6,354.7 hectares, but later decreased to 3,122.7 hectares. This is a decrease of 3,232 hectares, which is about a 50 percent decrease. Such a sharp decrease is associated with a slowdown in soil erosion processes, the re-formation of vegetation cover on some slopes, and a relatively regularization of water flow. As a result, the risk of landslides and mudflows has decreased, and the stability of agricultural lands located in the lower regions has increased. Agricultural arable land has remained relatively stable in the basin. Initially, their area was 16,027.3 hectares, but in the subsequent period it reached 16,146.6 hectares. This represents an increase of 119.3 hectares, or about 0.7 percent. This change indicates the efficient use of irrigated land, but should be considered in conjunction with the increasing pressure on water resources.

Although the flooded vegetation cover occupies a very small area, its change is important for hydrological processes. This landscape type has expanded from 0.06 hectares to 0.21 hectares, which is almost a threefold increase. This indicates an increase in irrigation systems and temporary water storage processes. The area of forests and groves has increased from 2,869.9 hectares to 3,991 hectares. As a result, the green cover has expanded by 1,121.1 hectares, or about 39 percent. This change is environmentally positive, contributing to the slowdown of erosion processes, the softening of the microclimate, and the stabilization of the water regime.

The area of snow and glaciers has decreased significantly. Their area has decreased from 5,897 hectares to 2,918.8 hectares, a loss of 2,978 hectares or about 51 percent. This process indicates an increase in climatic factors in high mountain zones, which may negatively affect the seasonal distribution of river flows. The area of seliteb territories has expanded from 10,566.7 hectares to 12,834 hectares, an increase of 2,267.3 hectares or about 21 percent. This is associated with increased anthropogenic activity, the expansion of settlements and infrastructure, which leads to a reduction in natural landscapes.

The area of wetlands has decreased from 603.5 hectares to 587.2 hectares, a decrease of 16.3 hectares. This indicates an increase in the intensity of water resource use and pressure on natural water bodies. In general, the LULC changes identified in the Kosonsoy basin directly affect the ecological stability of the region, the state of water resources and the land use system. These results serve as an important scientific basis for the development of regional planning, environmental monitoring and sustainable development strategies.

4. Discussions

The analysis allowed us to assess the expansion of pastures and natural meadows and the reduction of denuded lands as a positive ecological situation for the region. These processes indicate a decrease in the risk of soil erosion, the natural restoration of some landscape elements, and a relatively increase in ecological stability in the basin. At the same time, the increase in the area of forests and groves serves as an important factor in mitigating the microclimate in the basin, regulating the water regime, and strengthening landscape stability.

However, the expansion of the area of selibet regions and a significant reduction in the area of snow and glaciers indicate the intensification of anthropogenic pressure and climatic factors in the region. This situation may lead to an increase in the seasonal distribution of water resources, an increase in the risk of floods and flooding, and an increase in environmental threats to agriculture and settlements. The reduction in the area of wetlands indicates the need to reconsider the efficiency of water resource use. The use of watershed delineation maps in conjunction with LULC analyses made it possible to determine the relationship between land cover changes and water catchment processes in the basin. This approach creates a reliable scientific basis for hydrological modeling, environmental monitoring, and territorial planning processes. The results of the study confirm the importance of GIS technologies in land resource management and ensuring ecological safety in the Kosonsoy basin.

Based on the results obtained, the following practical suggestions can be made. First of all, it is necessary to introduce sustainable management mechanisms in the use of pastures and natural meadows, and protect them from overgrazing. It is recommended to strengthen soil consolidation and vegetation restoration measures in areas prone to denudation. In areas where the salinity zone is expanding, it is advisable to conduct territorial planning and construction work based on LULC and watershed maps. In water resource management, it is necessary to apply a basin approach, implement measures aimed at efficient use of water in irrigation systems, and reduce water losses. In general, the results of this study are of significant scientific and practical importance in assessing land use and ecological status, regional planning, and developing sustainable development strategies in the Kosonsoy basin, and serve as a reliable methodological and information base for future research.

Author: Tursunov Y.
Geography and environmental protection
Namangan State University, Namangan,
E-mail: ismoil_landsat@mail.ru

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