DEVELOPMENT OF SMART GIS TECHNOLOGIES FOR SUSTAINABLE LAND AND WATER RESOURCE MANAGEMENT IN UZBEKISTAN

Matkarimov Mansur
Associate Professor of Mamun University matkarimov_mansur1@mamunedu.uz

Abstract: *This article explores the development and application of smart Geographic Information System (GIS) technologies for sustainable land and water resource management in Uzbekistan's agriculture. The study highlights the growing importance of digital geospatial solutions in addressing environmental challenges, optimizing agricultural productivity and improving water resources distribution efficiency. Modern GIS tools, remote sensing data, and spatial analysis methods are discussed as key components for monitoring natural resources and supporting data-driven decision-making.*

Keywords: *Geographic Information System (GIS), land and water resource management, digital geospatial solutions, optimizing agricultural productivity, water distribution efficiency, GIS tools, remote sensing data, spatial analysis methods, monitoring natural resources.*

Analysis and discussion of results: Nowadays, the effective use and sustainable management of land and water resources is one of the pressing global issues. Climate change, water scarcity and environmental problems require the introduction of modern approaches to natural resource management. In this context, digital technologies such as GIS (Geographic Information System), remote sensing, drones, IoT and artificial intelligence are widely used as effective tools for monitoring, analyzing and managing land and water resources.

This article analyzes the potential of GIS and other digital technologies in land and water resource management, their practical significance and their role in the rational use of resources in agriculture.

GIS (Geographic Information System) has become a very important technology in monitoring agricultural lands in Uzbekistan. With the help of GIS, land resource management, cropland analysis, water resource monitoring, and yield forecasting are effectively implemented.

GIS is a digital system designed to collect, store, analyze, and map geographic data. GIS works in integration with satellite, drone, GPS, and meteorological data. Water resource monitoring is very relevant for Uzbekistan. With the help of GIS, irrigation networks, water distribution, and moisture maps are created. This is especially important in the Amu Darya and Syrdarya basins.

Table 1

Main components of GIS[37]

Component	**Tasks**
GPS	Location determination
Satellite images	Large area monitoring
Drons	High-precision tracking
GIS software	Analysis and mapping
Database	Information storage

The most popular GIS programs used in Uzbekistan are mainly "ArcGIS", QGIS, Google Earth Engine, etc.

Table 2

Comparative analysis of ArcGIS, QGIS and Google Earth Engine programs[38]

Criterion	**ArcGIS**	**QGIS**	**Google Earth Engine (GEE)**
Manufacturer	Esri	Open-source community	Google
License	Paid	Paid	Free (for science/education)
Platform	Desktop + Cloud	Desktop	Cloud platform
Operating system	Windows	Windows, Linux, macOS	Browser based
Main direction	Professional GIS	Universal GIS	Satellite and Big Data Analysis
Interfeys	Very professional	Simple and flexible	Based on code
Programming requirement	Less	Low/Medium	High
Python support	High	High	Very high
Satellite data	Integration available	Via plugin	Ready inside
Dron data	Very good	Good	Limited
GIS analysis	Very high	High	Very high

[37] The table was prepared by the author based on data from "Google Earth Engine Team. (2022). Earth Engine Data Catalog and Remote Sensing Applications Documentation".

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Remote sensing	Professional	High	Very high
3D analysis	High	Medium	Limited
Real-time monitoring	Existent	Limited	High
Artificial Intelligence/Machine Learning	ArcGIS AI tools	Via Plugin	TensorFlow integration
Working with Big data	High	Medium	Very high
Internet requirement	Medium	Little	High
Offline working	Yes	Yes	No
Plugin ecosystem	High	Very high	Via API
Learning complexity	Medium	Easy/medium	Complex
Price	High	Free	Free
The most suitable field	Public and professional GIS	Education and scientific work	Large-scale satellite monitoring

Each of the programs analyzed in this article has its strengths and weaknesses. For example, the strengths of the ArcGIS program are professional mapping, spatial analysis, GIS for farms, 3D and Internet GIS, drone integration, etc. The disadvantages are that the license is very expensive, and it requires a powerful computer.

The strengths of the QGIS program are free, open data, many plugins, and it is convenient for agriculture. The disadvantages are that some professional farms have limited functions, and sometimes work slowly with large data.

The strengths of the Google Earth Engine program are trillions of satellite data, Sentinel and Landsat satellite data, artificial intelligence integration, and fast analysis of large areas. The disadvantages are that it requires an Internet connection, requires coding, and is complex for new users.

Table 3

Recommended GIS programs for agriculture in Uzbekistan[39]

Task	**The most suitable program**
Land cadastre	ArcGIS

[39] The table was prepared by the author based on data from "Google Earth Engine Team. (2022). Earth Engine Data Catalog and Remote Sensing Applications Documentation".

Task	The most suitable program
Free GIS jobs	QGIS
Satellite monitoring	Google Earth Engine
Drone data	ArcGIS + QGIS
NDVI monitoring	GEE + QGIS
Scientific research	QGIS + GEE
Precision agriculture	ArcGIS + GEE
Large area monitoring	GEE

In the agricultural practice of Uzbekistan, the following combination is often used:

- GEE program - for receiving and processing satellite data
- QGIS program - for mapping and visualization
- ArcGIS program - for professional enterprise GIS and reports

This combination is one of the most effective approaches for Uzbek agro-monitoring systems.

Remote Sensing technologies are important in monitoring agricultural lands of Uzbekistan. This method allows you to observe and analyze the earth's surface using satellites, drones, aircraft, sensors without directly touching it.

Remote sensing is especially effective for water scarcity, salinity, yield monitoring, and precision agriculture. Remote sensing is a technology for obtaining information about objects through electromagnetic radiation. In the process, the sensor receives light reflected from the earth's surface, the data is converted into a digital image and analyzed using GIS and AI.

Remote sensing uses satellites and drones as the main sources of information. The main applications of remote sensing in agriculture are as follows:

1. Vegetation monitoring. NDVI is widely used to assess plant health. NDVI is used to detect plant stress, water shortage, disease, and biomass.

2. Irrigation monitoring. Remote sensing is very important in Uzbekistan due to the limited water resources. This includes monitoring soil moisture, irrigation efficiency, and water losses.

3. Salinity and degradation detection. Remote sensing is used to monitor salinity, erosion, desertification, and land reclamation. This allows for rapid identification of problem areas.

4. Yield forecast. Based on vegetation and meteorological data, yield, crop development, and agrotechnical condition are forecasted. This reduces costs and increases productivity.

IoT (Internet of Things) technologies are one of the main directions of "smart agriculture" in monitoring agricultural lands in Uzbekistan. With the help of IoT, devices in fields and farms are interconnected via the Internet and exchange information in real time.

IoT is a system for collecting and transmitting data through sensors, devices and applications. IoT in agriculture includes sensors, drones, smart irrigation systems, weather stations, GPS devices, cloud platforms.

IoT technologies determine when to water and how much fertilizer to apply. Water conservation is one of the most important issues for Uzbekistan. The IoT system monitors soil moisture, controls automatic irrigation, and reduces water waste.

CONCLUSION

GIS and other digital technologies play a key role in the effective management of land and water resources. The use of remote sensing, drones, IoT, and artificial intelligence technologies can improve monitoring accuracy, ensure rational use of resources, and ensure environmental sustainability. The widespread implementation of these technologies will contribute to increasing agricultural productivity and developing digital management systems.

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