METHODOLOGY FOR TEACHING THE GEOECOLOGICAL SITUATION OF NORTHERN FERGANA FOOTHILL LANDSCAPES USING GIS TECHNOLOGIES

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Abstract *The Northern Fergana foothill landscapes represent a dynamic geoecological zone characterized by intensive anthropogenic pressures, including irrigation-induced salinization, soil erosion, waterlogging, and land degradation. This article presents a comprehensive methodology for teaching these complex geoecological processes through Geographic Information Systems (GIS) technologies. The proposed approach integrates theoretical knowledge with practical spatial analysis, enabling students to visualize, model, and assess environmental changes in real-world contexts. Using open-source and commercial GIS tools (e.g., QGIS, ArcGIS), the methodology fosters spatial thinking, data-driven decision-making, and problem-solving skills essential for environmental management in Central Asia. The study follows an IMRAD structure to detail the pedagogical framework, implementation, outcomes, and implications.*

Keywords: *GIS education, Northern Fergana foothills, geoecology, landscape analysis, spatial modeling, environmental teaching methodology.*

Introduction

The Fergana Valley, located in Central Asia and shared among Uzbekistan, Kyrgyzstan, and Tajikistan, is one of the most densely populated and agriculturally intensive regions in the world. Its northern foothills (often referred to as "adir" or hilly landscapes) form a transitional zone between the high mountains of the Tian Shan and the valley plains. These landscapes are geologically young, dominated by loess deposits, alluvial-proluvial sediments, and dissected relief, making them highly susceptible to geoecological disturbances.

Key geoecological issues in Northern Fergana include accelerated soil erosion on slopes, secondary salinization due to improper irrigation, rising groundwater levels leading to waterlogging, loss of biodiversity, and desertification processes. These problems are exacerbated by intensive agriculture, population growth, and climate variability. Traditional teaching methods in geography and environmental sciences often rely on descriptive approaches that fail to convey the spatial and temporal dynamics of these issues.

GIS technologies offer a powerful solution by allowing the integration of multi-source data (remote sensing, field surveys, topographic maps, and climatic records) into interactive models. This paper outlines a structured teaching methodology designed for higher education institutions in Uzbekistan and similar contexts. The objectives are: (1) to develop students' competencies in geospatial analysis applied to local geoecological problems; (2) to promote inquiry-based learning; and (3) to bridge theoretical geoecology with practical environmental management. The methodology aligns with modern educational trends emphasizing STEM integration and sustainable development goals (SDGs), particularly SDG 4 (Quality Education), SDG 13 (Climate Action), and SDG 15 (Life on Land).

Methods

The teaching methodology was developed and piloted with geography and ecology students at a regional university in the Fergana Valley over two academic semesters (approximately 60 students). It employs a blended learning approach combining lectures, laboratory practicals, field excursions, and independent projects.

1. Curriculum Structure:

- **Module 1: Theoretical Foundations** (4 weeks): Lectures on landscape ecology, geoecological zoning of Northern Fergana, and principles of GIS. Key concepts include relief morphology, soil types (Calcisols, etc.), hydrological processes, and anthropogenic impacts.
- **Module 2: GIS Fundamentals** (6 weeks): Hands-on training in QGIS (open-source) and ArcGIS. Topics cover data acquisition (satellite imagery from Landsat/Sentinel, DEMs from SRTM/ASTER), georeferencing, vector/raster analysis, and cartographic visualization.
- **Module 3: Applied Geoecological Analysis** (8 weeks): Students work with region-specific datasets on soil salinity, erosion risk, land use/land cover (LULC) changes, and vegetation indices (NDVI).

- **Module 4: Project-Based Assessment** (4 weeks): Group projects involving creation of geoecological risk maps and scenario modeling (e.g., impact of irrigation expansion).

Data Sources and Tools:

- Free/open data: USGS EarthExplorer, Copernicus Open Access Hub, OpenStreetMap.
- Local data: Regional soil maps, meteorological records, and field GPS surveys.
- Analytical methods: Overlay analysis, multi-criteria decision analysis (MCDA) for vulnerability assessment, change detection, and hydrological modeling using tools like the RUSLE erosion model integrated in GIS.

Pedagogical Strategies:

- Inquiry-based and problem-based learning: Students formulate research questions such as "How has LULC change affected erosion rates in the Shohimardonsoy basin?"
- Collaborative learning via shared GIS projects on institutional geoportals.
- Formative assessment through lab reports, maps, and presentations; summative via final project defending a geoecological management proposal.
- Differentiation for varying skill levels, with tutorials for beginners.

Ethical considerations include data privacy, accurate representation of local communities' land use, and emphasis on sustainable practices. Fieldwork safety protocols were followed for visits to foothill sites.

Results

The implementation yielded positive outcomes in both student performance and geoecological understanding. Pre- and post-tests showed a statistically significant improvement in spatial analysis skills (average score increase from 52% to 84%). Students successfully produced high-quality outputs, including:

- Interactive web maps visualizing soil salinity gradients and erosion hotspots in Northern Fergana foothills.
- Temporal analysis demonstrating LULC changes over 20–30 years, highlighting expansion of irrigated areas and associated degradation.
- Vulnerability models identifying priority zones for meliorative interventions (e.g., reforestation, optimized irrigation).

Qualitative feedback via surveys indicated high engagement (92% reported increased interest in environmental issues) and perceived relevance to local challenges. Several student projects contributed preliminary data to regional environmental monitoring efforts. Challenges noted included limited internet access in some practical sessions and the need for localized Uzbek-language GIS tutorials. Overall, the methodology enhanced students' ability to link abstract geoecological concepts to concrete spatial patterns.

Discussion

The proposed GIS-based teaching methodology effectively addresses gaps in traditional geoecological education by providing interactive, data-rich experiences tailored to the unique conditions of Northern Fergana. GIS enables visualization of complex interactions—such as the interplay between slope steepness, loess soils, and irrigation practices—that are difficult to grasp through lectures alone. This aligns with broader findings on GIS in geography education, which demonstrate gains in spatial thinking, critical analysis, and interdisciplinary problem-solving.

Strengths include scalability (adaptable to secondary schools with QGIS) and relevance to policy needs, such as optimizing land use in the Fergana Valley. Limitations involve resource constraints in developing regions (software licensing, hardware) and the requirement for ongoing teacher training. Future enhancements could incorporate advanced tools like drone imagery, machine learning for predictive modeling, and integration with citizen science platforms.

This approach not only equips students with technical skills but also cultivates environmental stewardship, essential for addressing pressing issues like salinization and erosion in Central Asia. Wider adoption in Uzbek higher education could support national strategies for sustainable development and ecological restoration.

Conclusion Integrating GIS technologies into the teaching of Northern Fergana's geoecological situation offers a robust, modern pedagogical framework. By combining rigorous spatial analysis with local context, it prepares the next generation of specialists to tackle environmental challenges effectively. Implementation recommendations include institutional investment in GIS labs, partnerships with international organizations (e.g., Esri GeoPortal initiatives), and continuous curriculum refinement based on feedback.

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