



MULTI-CRITERION GEOPHYSICAL ASSESSMENT OF EARTH RESOURCES AND FORMATION OF AN INTEGRAL INDEX

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Abstract

This article develops the scientific and methodological foundations of multi -criteria assessment of the geospatial state of land resources, combining ecological, soil-ameliorative, hydrological, geomorphological and anthropogenic indicators of various nature into a single analytical system, and forming an integrated geospatial index. The relevance of the study is determined by the need for a comprehensive assessment of territorial differences arising in the process of land resource use, soil degradation, salinization, erosion, water supply imbalance, land cover change, and increasing anthropogenic pressure. The research methodology is based on the integration of geographic information systems (GIS), remote sensing (RS), multi- criteria decision-making (MCDA), Analytical Hierarchy Process (AHP), entropy-based weighting and weighted aggregation methods. In the proposed approach, the stages of reducing the initial indicators to a single dimensionless scale, determining their significance, integrating spatial layers, and dividing the results into territorial classes are consistently carried out. Also, the issues of assessing the reliability of the integral index, checking its sensitivity to weight coefficients, and validating it based on field observations are discussed. The proposed methodological approach serves to rationally use land resources, identify areas at high risk of degradation, improve territorial land development projects, and organize ecological monitoring on a scientific basis.

Keywords: Land resources, geospatial analysis, integral index, multi- criteria assessment, GIS, remote sensing, AHP, entropy method, soil degradation, land monitoring, NDVI, salinity, spatial modeling, sustainable land management.

Introduction

are strategic natural and economic capital that determines the economic development of society, food security, environmental sustainability and the formation of territorial infrastructure. The productive potential, ecological functions and socio-economic value of land are determined not only by its area, but also by soil properties, relief conditions, water supply, vegetation cover, land reclamation status, intensity of use and the level of anthropogenic impact. Therefore, the transition from an assessment based solely on individual indicators to a comprehensive, multi-criteria and geospatial approach to land resource management is an important scientific and practical task. In traditional land assessment systems, soil quality, economic value of lands, salinity level or land cover status are often studied separately. Although such an approach allows us to determine the state of a particular factor, it does not fully reveal the joint manifestation of various factors in one

area, the spatial relationship between them and the mechanisms of interaction. For example, a high vegetation index value may indicate good crop development, but this is not sufficient to draw definitive conclusions about soil salinity, groundwater levels, or soil organic carbon stocks.

In solving this problem, the integration of geographic information systems and remote sensing data with multi-criteria analysis methods is of particular importance. GIS allows combining data from different sources into a single coordinate system, performing spatial operations, and identifying territorial patterns. Remote sensing, in turn, provides a wide range of opportunities for systematic monitoring of land cover dynamics, vegetation status, moisture conditions, and anthropogenic changes. Indicator 15.3.1 of the UN Sustainable Development Goals uses land cover change, land fertility dynamics, and soil organic carbon stocks as key indicators for assessing land degradation. This approach is one of the internationally recognized scientific foundations of a comprehensive assessment of the state of the land [1–2]. However, identifying land degradation and assessing the overall functional state of land resources are not the same task. In identifying degradation, some negative changes themselves can be an important signal. In assessing the complex state of land resources, it is necessary to take into account soil quality, water supply, ecological stability, relief hazards and anthropogenic pressure. Therefore, in this article, the formation of an integral index is considered as a separate methodological task. The main idea of the study is to bring indicators with different units of measurement, data sources and spatial resolution into a single geospatial assessment system through scientifically based normalization, weighting and integration processes [3–5].

2. Purpose and objectives of the study

is to develop a scientific and methodological model for the formation of an integrated geospatial index based on the integration of indicators characterizing the ecological, soil-ameliorative, hydrological, geomorphological and anthropogenic state of land resources.

To achieve this goal, the following tasks were set:

1. and indicators characterizing the geospatial state of land resources.
2. remote sensing, cadastral, soil maps, hydrological observations, and field research data into a single geodatabase.
3. Develop methods for converting indicators with different units of measurement into a comparable dimensionless scale.
4. of indicators in an integrated assessment based on expert assessment and statistical information.
5. Proposing an algorithm for calculating an integral geospatial index and creating its cartographic model.
6. the reliability of assessment results using sensitivity analysis, field tests, and independent data.
7. the results obtained in land management, cadastre, environmental monitoring and territorial planning.



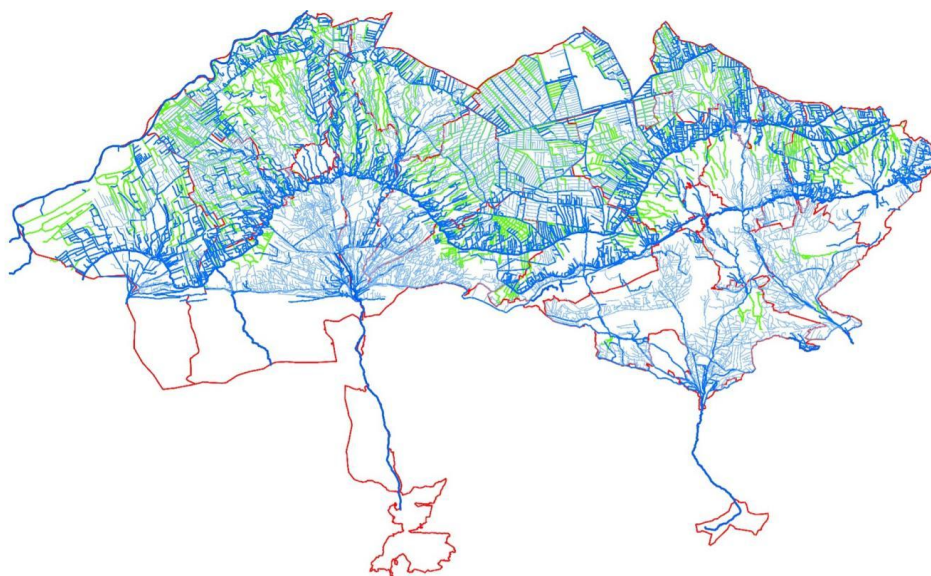


Figure 1. Research object : Land resources and their geospatial status in the Fergana region.

The object of research is land resources in a specific area and their geospatial situation, which is formed under the influence of natural and anthropogenic factors.

of indicators characterizing the state of land resources , their correlation, weight coefficients, and the laws of combining them into a single integral index.

3. Theoretical and methodological foundations of the study

3.1. The concept of geospatial status of land resources

is interpreted as a set of geographical locations, changes, and interactions of indicators that characterize the quality, ecological stability, production potential , and conditions of use of land in a particular area.

This concept encompasses three interrelated components:

The status component is soil quality, salinity, moisture, vegetation, erosion , and other current indicators.

The dynamic component is land cover change, vegetation trends, degradation processes , and recovery rates.

The pressure component is irrigation intensity, population and infrastructure density, land use changes, and natural hazards.

A combined analysis of these components helps to determine not only the current state of land resources, but also their likely directions of change.

3.2. The essence of multi-criteria geospatial assessment

Multi- criteria geospatial assessment is the process of standardizing spatial data obtained according to several criteria, determining their relative importance, and generating a single decision or index. The theoretical foundations of this approach are rooted in multi- criteria decision-making, systems analysis, spatial statistics, and cartographic modeling. The integration of GIS and MCDA is widely used in the assessment of land suitability, environmental risks, and resource use priorities [3]. The main problem in multi-criteria assessment is not the simple collection of indicators, but rather their

meaningful orientation, interdependence, and decision-making significance. For example, an increase in the amount of soil organic carbon, *ceteris paribus*, often indicates a positive state, while an increase in salinity indicates a negative state. Therefore, it is necessary to bring all indicators into a form that can be interpreted in the same direction [6-8].

In addition, it should be clearly defined in advance what content a high value of the integral index represents. This article proposes to distinguish between two types of indices:

1. Comprehensive Land Resource Condition Index (CLCI) — a high value indicates that the assessed condition of the land is relatively favorable.

2. Land Degradation and Pressure Index (LDPI) — a high value indicates increased negative processes or degradation pressure.

Using these indices interchangeably can lead to methodological errors. Therefore, their purpose, indicators, and interpretation rules are defined separately.

4. Research materials and methods

4.1. Database creation

To form an integrated geospatial index, it is necessary to bring data from various sources into a single system. Data sources are divided into the following groups:

1. Remote sensing data. Sentinel-2 and Landsat satellite images can be used to classify land cover, identify vegetation indices, open ground surfaces, and detect regional changes. Radar data, including Sentinel-1, can support analyses related to moisture and surface deformation under certain conditions. However, the determination of soil moisture or other properties from the radar signal depends on local conditions and calibration.

2. Digital terrain model. Parameters such as terrain elevation, slope angle, exposure, and water flow direction are used to assess erosion risk, water storage, and land use potential.

3. Soil and land reclamation data. Soil type, mechanical composition, humus content, salinity as characterized by electrical conductivity, soil fertility, groundwater depth, and drainage conditions are taken into account.

4. Hydrological and climatic data. Precipitation, temperature, evaporation, water availability, irrigation potential, and drought indicators serve to explain the natural functional state of the land.

5. Cadastral and anthropogenic data. Land parcel boundaries, land use types, settlements, roads, industrial facilities, irrigation networks, and land use changes are taken into account.

6. Field observations. Soil samples, salinity measurements, groundwater levels, vegetation status and GPS/GNSS-based control points are used to verify and calibrate remote sensing results.





Figure 2. Analysis of remote sensing data

All data are transferred to a single coordinate system and are coordinated in terms of spatial resolution and time interval. Raster layers are scaled to a common pixel size, but are not considered to have a resolution higher than the original data resolution. Data gaps, cloudiness, measurement errors, and time differences between observations are separately recorded.

4.2. Formation of a system of indicators

The study proposes to divide the indicators into five main groups. Table 1

Indicator group	Main indicators	Role in assessment
Soil quality	Bonitet score, humus, organic carbon, mechanical composition	Assessment of natural soil fertility and quality
Reclamation situation	Salinity, groundwater depth, drainage condition	Determining the reclamation risk of irrigated lands
Ecological and biological situation	NDVI/EVI, vegetation trend, land cover change	Describe vegetation cover and ecosystem functions
Geomorphological-hydrological situation	Slope, erosion risk, water supply, drought	Determining the impact of natural hazards and the water factor
Anthropogenic pressure	Land use intensity, construction pressure, proximity to infrastructure	Assessment of changes related to human activities

The indicators in the table are not intended as a universal and fixed list, but as a set of initial indicators that can be adjusted to the natural and geographical conditions of the area, the type of land use and available information. For example, in irrigated farming areas, salinity, groundwater depth and drainage conditions are important, while in foothill areas, slope, erosion risk and rain runoff may be of priority.

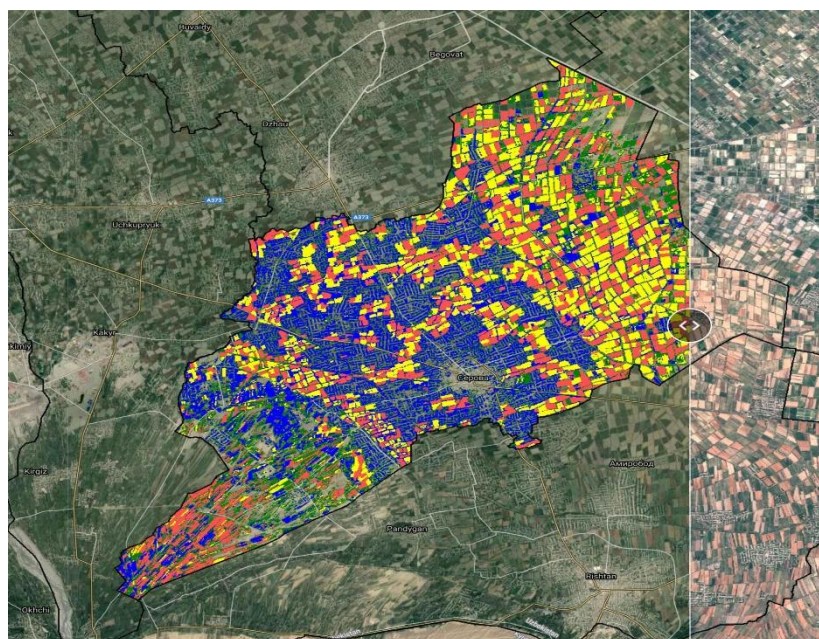


Figure 3: Satellite image of Fergana region

4.3. Calculation of remote sensing indicators

commonly used indicators to describe the state of vegetation is NDVI - the normalized difference vegetation index:

$$[NDVI = \frac{NIR - RED}{NIR + RED}]$$

Here:

(NIR) — reflected radiation in the near infrared range;

(RED) — reflected radiation in the red range.

range from -1 to $+1$. While positive and higher values are often associated with active green vegetation, their significance depends on plant species, phenological stage, moisture, soil background, and imaging conditions. A low NDVI value is not in itself evidence of land degradation. Such conditions can also be associated with harvested fields, seasonal drying of natural vegetation, or bare soil. Therefore, vegetation indices should be analyzed in conjunction with the same seasonal cross-section, multi-year time series, and land use types. Moisture-sensitive indices such as the NDMI can be used to assess soil surface moisture properties. However, these indices should not be equated with direct soil moisture measurements, but should be verified by field measurements or an appropriate model. Land cover change, on the other hand, is determined by comparing raster layers classified in different years. In this case, the reduction of forest or natural vegetation cover, the conversion of agricultural land into construction areas, and other changes are assessed in separate classes. The main advantage of remote sensing data is the ability to repeatedly observe large areas based on the same methodology. At the same time, limitations related to cloudiness, seasonal variation, and spectral interference in optical images, and to physical surface properties in radar images, must be taken into account.

4.4. Spatial Computing and Mapping

for each raster pixel or a defined spatial unit - a land plot, contour, neighborhood, massif or administrative territory. The raster approach allows for the identification of continuous spatial differences. Calculation based on cadastral plots or other polygons directly links the index to land management and planning processes. If the calculation is performed on a raster basis, the spatial resolution, pixel size and timeliness of the initial layers affect the reliability of the final result. In the aggregation by polygons, statistics such as area fraction, mean value, median value or fraction of dangerous pixels should be selected appropriately. The calculation algorithm in a GIS environment is organized in the following sequence:

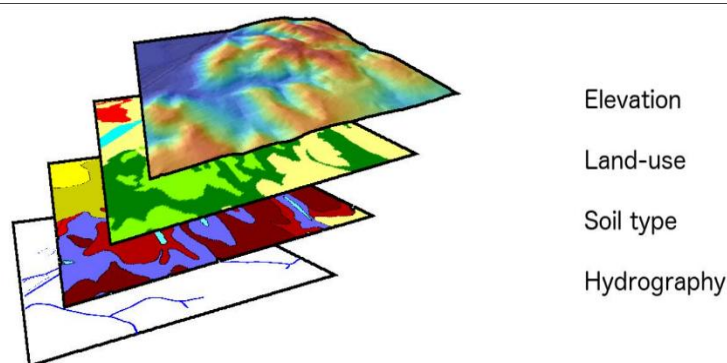


Figure 4. GIS layers

1. Initial spatial data collection and quality control.
2. Coordinate systems, spatial resolution, and observation periods.
3. Calculation of indicators and normalization in the same direction.
4. Determining weight coefficients and checking their consistency.
5. Calculating the integral index on rasters or polygons.
6. Classify the results and create thematic maps.
7. Perform validation and uncertainty analysis based on independent observations.

5. Classification of integral index results

Dividing continuous index values into manageable classes is important for regional decision-making.

The following classification can be used as an initial methodological model: Table 2

Integral index value	Status class	Content
0.00–0.20	Very uncomfortable	Serious adverse events may be observed across multiple criteria
0.20–0.40	Uncomfortable	The state of land resources is relatively poor.
0.40–0.60	Average	The condition is of mixed or intermediate nature.
0.60–0.80	Convenient	Relatively positive situation by most criteria
0.80–1.00	Very convenient	High comprehensive score on selected criteria

Important methodological note: the boundaries in the table are presented as indicative and preliminary classifications. They are not universal ecological norms or results confirmed by field studies. In practical research, class boundaries should be determined in accordance with normative criteria, data distribution, local conditions and independent validation results. The method of equal intervals, quantiles, natural breaks (Jenks) or ecological boundaries can be used for classification. Since these methods can give different results, the classification rules should be clearly stated in the article. Also, the index's comfort classes are not exactly the same as the official classification of the state of degradation. For example, the complex index is high. There may also be significant salinity or erosion in a small area within the area. Therefore, the integrated map is interpreted in conjunction with indicator maps and critical hazard layers.

6. Discussion

The main scientific advantage of the proposed methodology is the ability to assess various structural features of land resources in a single geospatial system. While individual indicator maps serve to identify a specific problem, the integrated index helps to identify general differences between regions and determine priority areas for monitoring. However, three important methodological issues require special attention when forming an integrated index.

First, **the interrelationship of indicators**. For example, NDVI, EVI, and indicators related to vegetation productivity may provide close information to each other. Adding all of them as independent criteria with a high weight artificially increases the share of the vegetation component in the overall index. In this case, it is appropriate to conduct correlation analysis, grouping indicators, or separate aggregation within each component.

Second, **spatial and temporal consistency**. The observed differences in the integration of soil, cadastral and satellite data obtained in different years may not be due to real environmental change, but to the difference in the data period. Therefore, the assessment period for all indicators should be clearly defined and, as far as possible, aligned to the same time frame.

Third, **the problem of compensation**. In a weighted linear index, several positive indicators can reduce the impact of a single critical negative event. Such aggregation is useful if the goal is to compare the overall state of the land. If the goal is to identify serious cases of degradation, critical thresholds and specific degradation indicators should be shown separately. The UNCCD methodology uses the principle of "if one is negative, it counts in the overall assessment" to combine degradation indicators in terms of land cover change, productivity and soil organic carbon [1–2].

Therefore, in addition to a single integrated index for land resource management, it is necessary to present its component components and separate risk maps. Such an approach turns the index into a scientific tool that supports decision-making, rather than just a rating indicator.

7. Scientific novelty and practical significance

The claim to novelty of the scientific and methodological approach proposed in this article is expressed in the following aspects:

1. A concept is proposed to integrate the soil-ameliorative, ecological-biological, geomorphological-hydrological and anthropogenic state of land resources into a single multi-criteria geospatial assessment system.





2. A hybrid weighting model is based on combining weighting based on expert knowledge and statistical information.
3. By distinguishing the complex condition index from indicators of degradation and anthropogenic pressure, the methodological accuracy of the index interpretation is enhanced.
4. A basis is created for the development of a repeatable computational algorithm that includes the stages of indicator normalization, weighting, integration, and cartographic classification.
5. the reliability of the index through field validation, sensitivity analysis, and spatial statistics will be incorporated into a single methodological system.

These aspects are currently considered methodological solutions proposed in the article. To confirm them as an empirical scientific innovation, it is necessary to calculate them in a specific area, compare them with existing methods, and present validation results. In practice, the methodology can be used to improve land cadastre data, monitor the condition of agricultural lands, regional planning of land reclamation measures, identify the risk of land degradation, and justify land development projects. When applying this approach in irrigated agricultural areas of Uzbekistan, priority can be given to salinity, groundwater, drainage, soil quality, and vegetation dynamics. However, the composition and weights of the indicators should be justified individually in accordance with the natural conditions of each region, data quality, and land use goals.

8. Conclusion

Multi- criteria geospatial assessment of land resources and the formation of an integral index are one of the promising areas of systematic analysis of natural, ecological and anthropogenic properties of the land fund. This approach allows combining spatial data from different sources on a single methodological basis, identifying differences between regions and planning the use of land resources on a scientific basis. As a result of the study, the main stages of forming an integral index - selecting indicators, harmonizing data, normalizing them, determining weight coefficients, mathematical integration and cartographic representation based on GIS - were substantiated as a single methodological system. The hybrid weighting approach, which combines AHP and entropy methods, allows taking into account statistical differences with expert knowledge. At the same time, the problem of correlation between indicators, uncertainty in the selection of weights and compensation can directly affect the interpretation of the integral index. Therefore, the final results should be evaluated in conjunction with maps of individual indicators, field observations and sensitivity analysis.

The practical value of the integrated geospatial index is not only expressed in a single number, but also in the transparency of what data, what weights, and what mathematical rules are used to generate this number. The reproducibility of the methodology, data quality control, and the provision of independent validation results are important conditions for scientific reliability. In the future, implementing this methodology on the example of a specific area, testing it with multi-year satellite images, involving field data, and comparing the results with existing land assessment methods will further substantiate the scientific and practical effectiveness of the integrated index.



References

1. Yokubov S. DEVELOPMENT OF AGRICULTURAL CARDS USING ARCGIS AND PANORAMA TECHNOLOGIES //Innovations in Science and Technologies. – 2024. – T. 1. – №. 1. – C. 101-107.
2. Khakimova K., Yokubov S. CREATION AND MAINTENANCE OF STATE CADASTERS IN THEREPUBLIC OF UZBEKISTAN //Innovations in Science and Technologies. – 2024. – T. 1. – №. 1. – C. 85-93.
3. Yokubov S. SCIENTIFIC AND THEORETICAL FOUNDATIONS FOR THEDEVELOPMENT OF MAPS OF THE LEGAL STATUS OF STATE LANDCADASTERS IN THE TERRITORY USING GIS TECHNOLOGIES //Innovations in Science and Technologies. – 2024. – T. 1. – №. 1. – C. 80-84.
4. Eshnazarov D. et al. Describing the administrative border of Koshtepa district on an electronic digital map and creating a web map //E3S Web of Conferences. – EDP Sciences, 2023. – T. 452. – C. 03009.
5. Khakimova K. et al. Application of GIS technologies for improving the content of the tourist map of Fergana province, Uzbekistan //E3S web of Conferences. – EDP Sciences, 2023. – T. 386. – C. 04003.
6. Yusufovich G. Y. Shavkat o 'g 'li SY CARTOGRAPHIC RESOURCES USED IN THE CREATION OF ELECTRONIC AGRICULTURAL MAPS OF FERGANA REGION //Finland International Scientific Journal of Education, Social Science & Humanities. – 2023. – T. 11. – №. 3. – C. 1001-1009.
7. Abduvakhabovich A. A. Shavkat o 'g 'li, SY Improving the Method of Mapping Agriculture Using Remote Sensing Data //Finl. Int. Sci. J. Educ. Soc. Sci. Humanit. – 2023. – T. 11. – C. 1093-1100.
8. Abduvakhabovich A. A. Shavkat o 'g 'li, SY Improving the Method of Mapping Agriculture Using Remote Sensing Data //Finl. Int. Sci. J. Educ. Soc. Sci. Humanit. – 2023. – T. 11. – C. 1093-1100.
9. Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffmann, A., Giovannini, E. (2008). Handbook on Constructing Composite Indicators: Methodology and User Guide. OECD Publishing, Paris.
10. United Nations Convention to Combat Desertification (UNCCD). PRAIS4 Reporting Manual: Strategic Objective 1 — Land Degradation and Restoration Indicators. <https://prais4-reporting-manual.unccd.int/en/2026/SO1.html>