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TRADITIONAL AND MODERN (GAT AND MZT) METHODS OF ASSESSMENT AND MONITORING OF SOIL FERTILITY

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Abstract
The article provides a systematic analysis of traditional and modern methods that are used to assess soil fertility and regularly monitor its condition. Traditional approaches consider agrochemical analysis, field experiments, fertilization, and soil-climatic zoning methods. Modern approaches highlight the role of geographic information systems (GAT) and remote sensing technologies (MZT) in spatial and temporal assessment of soil fertility indicators. Through the integration of GAT and MZT data, the possibilities of comprehensive assessment of the state of soil resources, early detection of degradation processes and justification of agricultural management decisions are provided with scientific and practical justification.

Keywords: Soil fertility, soil monitoring, GAT, remote sensing, agrochemical analysis, fertilization, spatial analysis, degradation.

Introduction

Soil fertility is the main natural resource of agricultural production. Its status directly determines crop yields, food security, and sustainable development of areas [1; pp. 15–18]. Shavkat Mirziyoyev Therefore, systematic assessment of soil fertility and the creation of a scientifically based monitoring system are becoming urgent [3; 7–12 p.].

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Traditional approaches – agrochemical analyses, bonivision, field experiments and classical cartographic methods – have provided and still play an important role in practice [2; pp. 41–48]. However, the main disadvantage of these methods is the limited ability to cover large areas, the high time and cost requirements, and the rapid obsolescence of information [9; 33–40 pp.].

In recent decades, new approaches to soil fertility assessment and monitoring have emerged based on geographic information systems (GAT) and remote sensing technologies (MZT). While GAT allows for the integration, analysis, and cartographic visualization of spatial and attributive data in a single geobase, MZT provides the ability to observe large areas in a systematic and rapid manner [4; 12–20 p.], [5; 21–30 p.]. The integration of traditional methods with GAT and MZT data paves the way for the formation of a new, improved methodology for assessing soil fertility [8; pp. 56–64].

This article provides a systematic analysis of traditional and modern (GAT and MZT) methods for assessing and monitoring soil fertility, comparing their advantages and limitations, and highlighting the scientific and practical advantages of an integrated approach.

LITERATURE REVIEW

The concept of soil fertility was formed in classical soil science on the basis of the scientific works of D.N. Dokuchaev and his followers, and is interpreted as the ability of the soil to yield [1; 15–24 p.]. Later, scientists such as V.R. Volobuyev, I.P. Gerasimov, V.V. Egorov substantiated the relationship between them by dividing soil fertility into natural, artificial and productive varieties [2; 41–52 pp.]. In modern approaches, soil fertility is seen not only as a reserve of chemical elements, but as a set of physical, biological, hydrological and environmental indicators [3; pp. 13–20].

Of the traditional methods, agrochemical analyses are the most commonly used. On the basis of soil samples, the amount of macro- and microelements, pH, humus reserves, the level of salinity are determined [7; pp. 110–122]. Chuvashova et al. (2006) emphasize the importance of developing an agrochemical monitoring system and forming a database of periodic analyses when assessing soil fertility

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dynamics [9; 33–48 pp.]. However, this approach is economically expensive and labor-intensive on a large scale [3; pp. 21–27].

Another traditional form of soil fertility assessment is bonitirization, in which soil quality scores are determined based on soil types, agroclimatic indicators, and yield results [11; 5–14 p.]. Bonitet scores are one of the main indicators for land tax determination, territorial placement of crops, and land cadastre. However, many literature criticizes the infrequent updating of bonitet scores and the insufficient account of changes in modern crop varieties, water supply, and agrotechnics [2; pp. 90–98], [7; pp. 130–137].

On the application of geographic information systems in agriculture such scientists as Baturov, Kachinsky, Burrough, Goodchild conducted a comprehensive study [4; 12–35 p.], [8; 56–72 p.]. Their work substantiates the methods of creation of digital soil maps based on GAT, conversion of point agrochemical data to a continuous spatial surface using interpolation methods, agroecological zoning and mapping of risk zones [4; 4; 40–52 pp.]. Mirzaev et al. present their experience in creating digital soil maps for irrigated lands in Uzbekistan [11; 45–60 p.].

On remote sensing technologies, the works of authors such as Lillesand, Kiefer, Campbell, Wynne are recognized as the main theoretical and methodological source [5; 21–38 p.], [6; 60–75 p.]. In these studies, the features of reflecting the physicochemical properties of soil and vegetation cover of satellite images obtained in optical, infrared, microwave ranges, the possibility of estimating biomass using vegetation indices (NDVI, EVI, SAVI, NDWI and others) and forecasting yields are shown [5; 120–138 p.].

There are many case studies on assessing agricultural crop yields based on indices such as NDVI. For example, in projects of FAO and other international organizations, high correlation indicators between NDVI dynamics and yields of grain, cotton, and maize have been identified [3; 45–55 p.]. Kolesnikov et al. (10; 88–97 pp.) proved the possibility of remotely assessing the efficiency of irrigation systems and changes in soil salinity by jointly analyzing NDVI, LST (Terrestrial surface temperature) and soil moisture indicators in Central Asian conditions [10; 88–97 p.].

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In recent years, work has been intensifying to create integrated assessment models of soil fertility based on the integration of GAT and MZT. Kadyrov et al. (2006) proposed GIS-models for assessing soil fertility by linking the results of agrochemical analyses on irrigated lands of Uzbekistan with vegetation indices calculated from Landsat and Sentinel images [12; 25–39 pp.]. Similarly, the preference for integrated approaches embodying field measurements, laboratory analysis, satellite data, and GAT analysis methods is emphasized in the foreign literature [6; 140–152 p.], [8; 90–105 p.].

Overall, the literature review shows that while traditional methods provide high-fidelity but local data, GAT and MZT provide an operational and spatially detailed picture over large areas. And their integration can take the system of assessment and monitoring of soil fertility to a qualitatively new level [3; 55–63 p.], [12; 40–48 p.].

CONCLUSION AND DISCUSSION

Based on the results of the literature review, the main differences between traditional and modern (GAT, MZT) methods for assessing and monitoring soil fertility and their complementary aspects can be explained as follows.

First, in terms of accuracy and reliability, traditional agrochemical analyses provide the most reliable information. Soil nutrients, salinity, pH, and other properties are determined directly by laboratory methods [7; 110–122 p.], [9; 33–48 p.]. MZT, on the other hand, evaluates soil condition mainly through indirect indicators (vegetation cover status, spectral reflection) [5; pp. 120–138]. Therefore, it is necessary to calibrate the MZT data with traditional analyses.

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Table 1 Comparison of traditional methods and GAT+MZT methods on key indicators

bullet	**Traditional methods (agrochemical, bonitirization)**	**Usular GAT+MZT**	**Note**
Precision	Too high (dot)	Medium–high (depending on model)	Traditional analysis relies on direct measurements, while MZT relies on indirect metrics
Spatial coverage	Limited	Too high (whole district/province)	GAT+MZT covers large areas
Time Recurrence	1 time in 3–5 years	Weekly/Monthly/Seasonal	Satellite archives are updated frequently
Cost (for a larger area)	High	Average/Relatively Low	Initial GAT/MZT infrastructure is expensive but cost-effective in the long run
Mehnat talabi	Extreme	Average	Less fieldwork, more computer analysis
Level of subjectivity	Sometimes high (depends on the evaluator)	Low	Satellite data is objective

Second, in terms of spatial coverage, the MZT and GAT methods have a clear advantage. Laboratory analyses are usually performed on the basis of a limited number of sample points, which need to be relied upon to interpolate methods to extrapolate to the entire area [4; pp. 40–52]. Satellite imagery, on the other hand, provides information simultaneously on an entire district or provincial scale; And the GAT makes it possible to analyze and visualize this data [8; pp. 56–72].
Third, time repetition is also an important factor. Agrochemical analyses are usually performed once every 3–5 years or over a longer period [2; pp. 90–98]. Satellite data, on the other hand, can be received at a weekly, monthly or even daily frequency; This makes it possible to dynamically track changes in an indirect indicator of soil fertility – the vegetation index, humidity, temperature [6; pp. 140–152]. Thus, MZT should be considered as the most appropriate tool for operational monitoring, while traditional methods should be considered as the most appropriate tool for baseline data.
Fourth, the issue of cost-effectiveness is also relevant. Performance of dense network agrochemical analyses over large areas requires significant funds and a

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network of laboratory assistants [3; pp. 21–27]. With MZT, it is possible to purchase multiple images for the same area and analyze them repeatedly for different purposes [5; pp. 21–38]. Although initially the creation of GAT and MZT infrastructure requires investment, in the long run it will provide significant cost savings [8; pp. 90–105].

Another important aspect is the decision support systems. GAT-based digital soil maps, agroecological zoning, risk zones, salinity and erosion level maps serve to optimize management decisions on reclamation, fertilization, and crop type placement [4; 52–60 p.], [11; 45–60 p.]. Such models, enriched with MZT data, are of high practical value, especially in irrigated areas where soil fertility changes rapidly [10; pp. 88–97].

One of the controversial aspects is the question of the reliability of modeling results. Although some studies have noted that the correlation coefficients between NDVI and productivity are around 0.7–0.9 [3; 45–55 p.], in other cases it has been shown that this relationship may be significantly reduced due to climate, varietal characteristics, diseases, and agrotechnical factors [6; 150–152 p.]. This means that it is not enough to assess soil fertility based on just one vegetation index; It is necessary to analyze by adding complex indicators and field data [12; 40–48 b.].

Table 2 Humus, NDVI and yield measured at field points for Oltiariq district (conditional data)

Point	Silver, %	NPK Availability Rate	NDVI (Vegetation Peak)	G'alla hosildorligi, s/ga
N1	1,4	Low	0,45	27
N2	1,8	Average	0,50	29
N3	2,1	Average	0,54	31
N4	2,4	It's fine	0,58	34
N5	2,7	It's fine	0,61	36
N6	3,0	Sounds good	0,64	38

The above considerations show that the optimal approach to assessing and monitoring soil fertility is an integrated methodology, which includes:

- baseline data are collected through field and laboratory agrochemical analyses;

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- In the GAT environment, this information is converted into digital soil maps and spatial models;
- Dynamic tracking over time is provided by linking it with MZT data (vegetation indices, soil moisture, temperature);
- Visual cards, charts, and productivity forecasts are formed for decision-makers [4; 52–60 p.], [8; 90–105 p.], [12; 25–39 p.].

This multiparameter approach serves as a scientific and theoretical basis for improving the system for assessing and monitoring soil fertility in intensive irrigation farming areas, such as the Fergana region, in particular in the Oltiariq district.

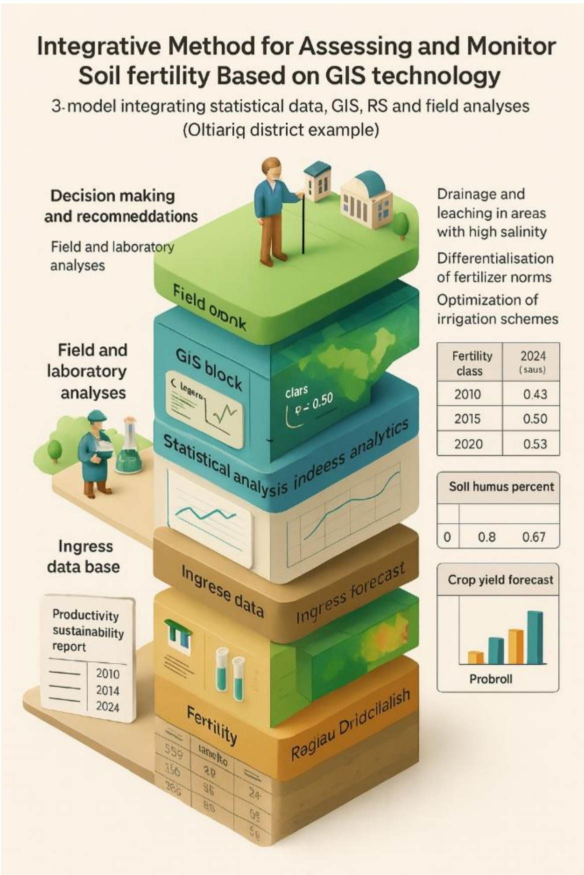

Figure 1. Integrative Method for Assessing and Monitoring Soil Fertility Based on GIS Technology (Oltiariq District Example)

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CONCLUSION

Assessment and monitoring of soil fertility is the main prerequisite for ensuring sustainable agricultural production, rational use and protection of land resources. Traditional methods – agrochemical analyses, boniturization, field experiments, and classical cartographic approaches – still remain a tool that provides scientifically based, reliable results, but their spatial coverage and agility are limited.

On the other hand, modern GAT and MZT technologies will allow to assess the spatial and temporal differentiation of soil fertility in large areas, to quickly detect changes in the degradation and melioration state, to carry out long-term dynamic analysis. However, because these technologies indirectly reflect soil properties, calibration with field and laboratory data is required.

Therefore, the promising direction for assessment and monitoring of soil fertility is the use of traditional field and laboratory methods in the integration with GAT and MZT data. Such an approach provides a wide opportunity for making science-based decisions to assess the state of soil resources with high accuracy, identify agroecological risk zones, and improve soil protection and fertility.

Currently, this integrated methodology serves as a solid theoretical and methodological basis for the creation of an improved system for assessing and monitoring soil fertility in intensive irrigated peasant areas in Fergana region, in particular in Oltiariq district.

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