

IMPROVING THE METHOD FOR COMPREHENSIVE ASSESSMENT OF DEHKAN FARM LANDS

Abdujabborova Muxlisa Ramzjon qizi
Fergana State Technical University
E-mail: muxlisaabdujabborova304@gmail.com

Abstract

This article proposes an improved method for comprehensive assessment of dehkan farm lands based on the integration of remote sensing, land-cadastral, soil, irrigation and official statistical data within a unified geospatial analysis framework. The methodological basis was developed through a comparative review of the European Union Area Monitoring System (AMS), the USDA Cropland Data Layer (CDL), the FAO WaPOR platform and the Indian FASAL/CAPE approach. Official statistics for Beshariq District show that agriculture, forestry and fisheries generated UZS 2.9 trillion in 2024, while dehkan and household farms accounted for 58.5% of agricultural output in January–September 2024. The proposed methodology treats the cadastral parcel as the principal assessment unit and combines multi-temporal Sentinel-2/Sentinel-1 observations with soil, irrigation, cadastral and production indicators. The indicators are normalized to a 0–1 scale, weighted using the Analytic Hierarchy Process (AHP), and aggregated into a Comprehensive Assessment Index (CAI). The paper also proposes a five-level classification and a validation scheme based on field observations, yield data and parcel-level spatial statistics. The approach is intended to improve the objectivity, repeatability and management relevance of land monitoring for dehkan farms.

Keywords: Dehkan farm, remote sensing, Sentinel-2, Sentinel-1, GIS, land cadastre, AHP, NDVI, NDMI, land monitoring, comprehensive assessment, Beshariq District.

Introduction

Improving the efficiency of agricultural land use is directly associated with reliable land monitoring, accurate cadastral information and timely assessment of parcel condition. Dehkan farms often operate on relatively small plots where crop type and agronomic practices may change frequently. Under these conditions, periodic field inspections or statistical reporting alone cannot provide spatially consistent and regularly updated information on actual land condition. The integration of remote sensing with cadastral boundaries, soil and agrochemical characteristics, irrigation status and production statistics therefore represents an important methodological direction for land monitoring.

Presidential Decree No. PF-5742 of 17 June 2019 established tasks related to the monitoring of crop cultivation practices and the use of land and water resources through geoinformation technologies and the wider application of Earth observation systems. Resolution No. 22 of the Cabinet of Ministers dated 14 January 2022 regulates monitoring activities on agricultural land,



while Resolution No. 914 of 30 December 2024 defines principles and criteria for rational agricultural land use. Presidential Decree No. PF-172 of 12 September 2025 identifies complete accounting of agricultural land, state registration of land rights and improved land-use efficiency as priority areas [1–4].

Beshariq District is one of the major agricultural districts of Fergana Region. According to official 2024 statistics, its total area is 0.774 thousand km² and the permanent population reached 245.9 thousand as of 1 October 2024. In January–September 2024, agriculture, forestry and fisheries produced goods and services worth UZS 2,186.7 billion, corresponding to 7.2% of the regional total; the district ranked third in the region for this indicator [5]. By the end of 2024, the annual value of output in these sectors reached UZS 2.9 trillion [6]. These figures underline the practical importance of systematic parcel-level assessment of land condition.

The objective of the study is to develop a mechanism for integrating remote sensing, cadastral, soil, water and statistical information in the comprehensive assessment of dehkan farm lands and to substantiate the methodological structure of a composite assessment index adapted to the conditions of Beshariq District. The scientific contribution consists in using the cadastral parcel as the basic assessment unit, integrating multi-temporal optical and radar observations with terrestrial and cadastral data, determining indicator weights through AHP, and transforming the result into five spatial management classes.

1. INTERNATIONAL EXPERIENCE IN ASSESSING DEHKAN AND AGRICULTURAL LANDS

In contemporary agricultural land assessment, remote sensing is no longer used only as a source of imagery. It increasingly functions as part of an integrated information infrastructure that links parcels, production processes and management data. Experiences from the European Union, the United States, FAO programmes and India reveal three recurring principles: regular time-series monitoring, linkage of satellite observations with parcel or field information, and independent validation of automated results.

Table 1. Selected international approaches to agricultural land assessment using remote sensing

System / country	Main data	Assessment unit and approach	Methodological implication for Beshariq
EU Area Monitoring System (AMS)	Copernicus Sentinel-1/2, LPIS/GSA, geotagged evidence	Continuous monitoring of agricultural parcels; automated conclusion with additional checks for ambiguous cases	Use cadastral parcel as the core unit; maintain a time series and a signal–verification workflow for each parcel
USA USDA Cropland Data Layer	Sentinel-2, Landsat 8/9, ground data, DEM; Random Forest	Annual crop-cover mapping; 10 m products in 2024–2025	Use multi-sensor composites and machine learning; prioritize 10 m observations for small parcels
FAO WaPOR	Evapotranspiration, biomass, water productivity, rainfall, land cover	Pixel/irrigation-system assessment; global and regional layers at different spatial resolutions	Add water use and water productivity to vegetation indicators
India FASAL/CAPE	Remote sensing + agrometeorology + ground observations	Crop-area and yield forecasting through multi-source integration	Interpret satellite signals together with meteorological and statistical information

Source: Compiled by the author from European Commission, USDA NASS, FAO and Government of India sources [7–12].

In the European Union, the Area Monitoring System has been a mandatory component of the Integrated Administration and Control System since 1 January 2023. It links the Land Parcel Identification System, geospatial applications and Sentinel observations to monitor agricultural activity and practices. The important methodological feature is that the output is not merely a classified image but a decision signal for a defined parcel. When Sentinel data are insufficient, additional evidence or field verification may be required [7, 8]. This principle is directly applicable to Beshariq, where each cadastral parcel can be associated with a multi-temporal spectral profile. The Cropland Data Layer produced by the USDA National Agricultural Statistics Service is an operational example of integrating satellite observations with extensive ground information. Recent products use Sentinel-2 MSI and Landsat 8/9 data, multi-date composites and Random Forest classification [9, 10]. The approach is particularly relevant to dehkan farms because small parcels are more reliably represented by 10 m Sentinel-2 data than by 30 m Landsat pixels; Landsat nevertheless remains valuable for long-term retrospective analysis.

The FAO WaPOR platform assesses water productivity in agriculture from Earth observation data. It includes actual evapotranspiration, biomass production and water-productivity indicators [11]. Under irrigated agriculture, this experience demonstrates that vegetation greenness alone is insufficient: moisture availability and water-use components must also be incorporated into a comprehensive assessment.

India's CAPE and FASAL programmes combine remote sensing with agrometeorological and ground observations to estimate crop area and forecast yield [12]. The methodological lesson is that satellite information should be interpreted as one component of an integrated assessment rather than as an isolated source. Taken together, international experience supports a Beshariq-specific architecture of "cadastral parcel + multi-temporal remote sensing + soil and water indicators + official statistics + field validation."

Share of Multi-Criteria Evaluation Methods Used in Agricultural Land-Assessment Studies

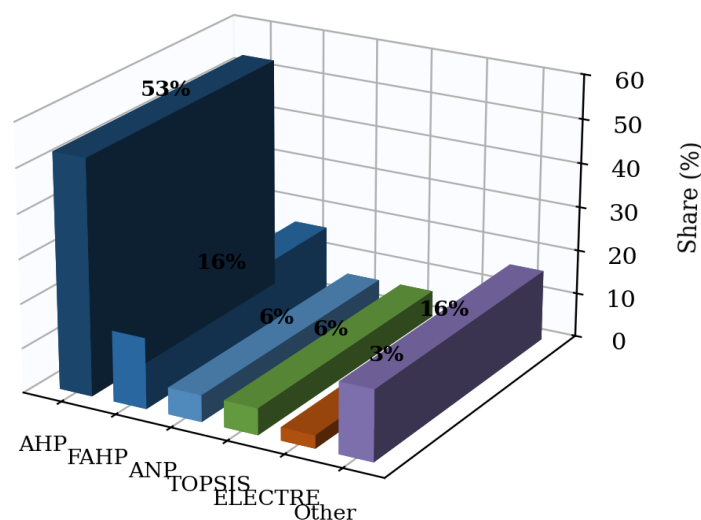


Figure 1. Share of multi-criteria evaluation methods used in agricultural land-assessment studies
Source: Based on the review of 64 sources by Shaloo et al. (2022) [13].

A 2022 review of multi-criteria evaluation methods reported that AHP was used in 53% of the analysed studies, FAHP in 16%, ANP and TOPSIS in 6% each, and ELECTRE in 3%. Soil, topography and climate were among the most frequently used criteria [13]. GIS-based multi-criteria decision analysis is therefore well suited to integrating heterogeneous environmental and production indicators into a composite land-assessment model [14–17]. AHP was selected in this study because the procedure is transparent, testable and compatible with expert judgement.

2. STUDY AREA, DATA AND STATISTICAL BASIS

Beshariq District is located in the western part of Fergana Region. The 2024 statistical bulletin reports a total area of approximately 0.774 thousand km². The land-management planning table attached to Resolution No. 111 of the Cabinet of Ministers dated 4 March 2024 records a total district area of 77,385 ha, of which 26,964 ha are agricultural land [18]. Thus, agricultural land accounts for approximately 34.8% of the district territory. In the applied stage of the dissertation, these figures should be refined with verified parcel-level cadastral data for dehkan farms.

Table 2. Selected indicators relevant to the study of Beshariq District

Indicator	Value	Period / note
Total district area	77,385 ha	Land-management planning table
Agricultural land	26,964 ha	Land-management planning table
Permanent population	245,904 people	1 October 2024
Agriculture, forestry and fisheries output	UZS 2,186.7 billion	January–September 2024
Share in the regional total	7.2%	January–September 2024
Regional rank for the sector	3rd	January–September 2024
Agriculture, forestry and fisheries output	UZS 2.9 trillion	January–December 2024

Source: Fergana Regional Statistics Department and official legal documents [5, 6, 18].

**Nominal Dynamics of Agriculture, Forestry and Fisheries Output
in Beshariq District, 2019–2024**

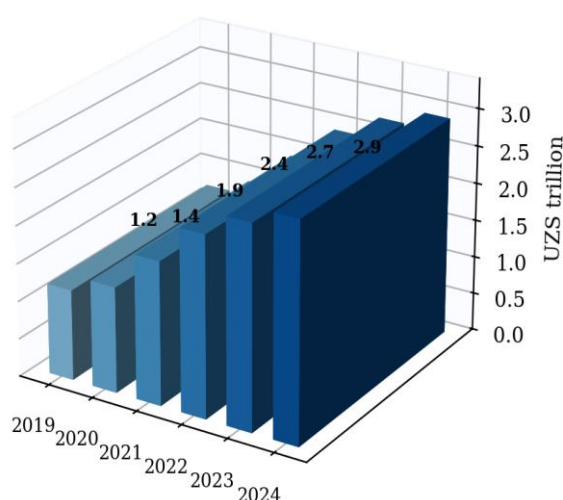


Figure 2. Nominal dynamics of agriculture, forestry and fisheries output (services) in Beshariq District, 2019–2024

Source: Fergana Regional Statistics Department [6].

Between 2019 and 2024, the nominal value of agriculture, forestry and fisheries output (services) increased from UZS 1.2 trillion to UZS 2.9 trillion, or by approximately 2.42 times. This change reflects nominal monetary dynamics and should not be interpreted as a direct measure of real physical growth because price effects and structural changes are also embedded in the indicator. Nevertheless, the trend illustrates the increasing economic significance of the agricultural sector in the district.

Distribution of Agricultural Output by Producer Category in Beshariq District

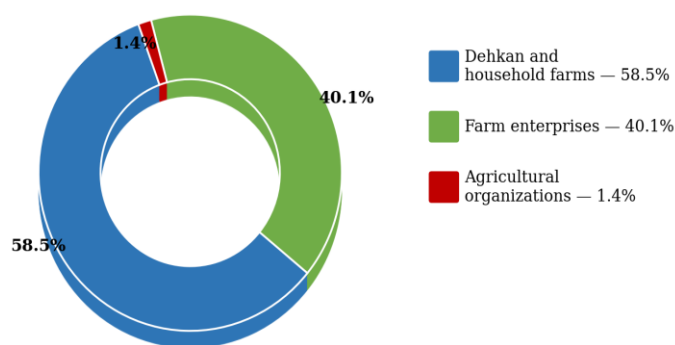


Figure 3. Distribution of agricultural output by producer category in Beshariq District
Source: Statistical bulletin of Beshariq District for January–September 2024 [5].

Dehkan and household farms produced 58.5% of total agricultural output in January–September 2024. Farm enterprises accounted for 40.1%, while agricultural organizations contributed 1.4% [5]. The high share of household-based production means that the quality of small-parcel monitoring can materially affect the reliability of district-level agricultural assessment.

Share of Dehkan and Household Farms in the Production of Major Crops

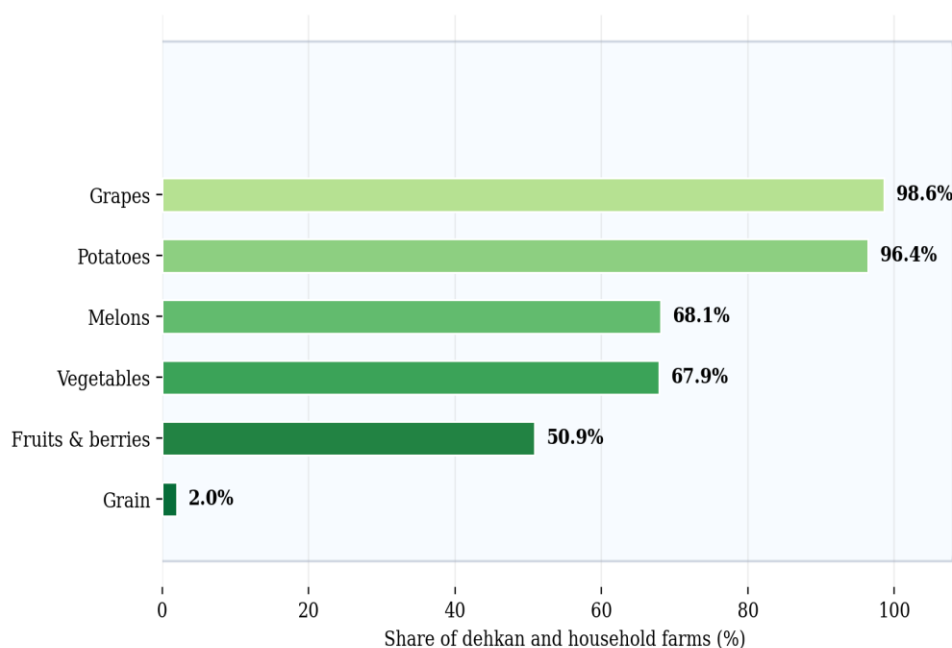


Figure 4. Share of dehkan and household farms in the production of major crops
Source: Beshariq District statistical bulletin, pp. 26–27 [5].

The role of dehkan and household farms varies considerably by crop. Their share reached 96.4% for potatoes, 67.9% for vegetables, 68.1% for melons, 50.9% for fruit and berries, and 98.6% for grapes, whereas only 2.0% of total grain production originated from this category [5]. Consequently, monitoring methods for dehkan lands should be sensitive to crop type and phenological season rather than applying identical thresholds across all parcels.

Table 3. Production of major crops by producer category in Beshariq District

Product	Total, t	Farm enterprises, t	Dehkan & household farms, t	Dehkan & household share, %
Grain, total	73,832.4	70,536.9	1,463.0	2.0
Potatoes	19,701.1	716.7	18,984.4	96.4
Vegetables	67,907.0	21,642.2	46,114.8	67.9
Melons	6,534.8	2,087.4	4,447.4	68.1
Fruit	27,552.0	13,517.2	14,030.0	50.9
Grapes	1,497.2	21.5	1,475.7	98.6

Source: Official statistical bulletin [5]. Percentages were checked from the source totals.

3. IMPROVED METHODOLOGY FOR COMPREHENSIVE LAND ASSESSMENT

The key distinction of the proposed method is that land condition is not assessed from a single vegetation-index value observed at one date. Instead, each cadastral parcel is represented by a multi-source and multi-temporal profile. The profile combines vegetation dynamics, moisture status, surface temperature, soil and degradation indicators, cadastral-use compliance and production efficiency. This structure reduces the risk of classifying a parcel as “good” solely because of high greenness at a particular moment.

3.1. Data architecture and indicator system

Sentinel-2 Level-2A data are recommended as the principal optical source because the 10 m bands represent small agricultural parcels more effectively than 30 m Landsat data. Sentinel-1 radar observations can complement optical imagery under cloud cover and provide information related to surface moisture and crop structure. Landsat is retained for retrospective analysis and thermal indicators, while WaPOR layers can be used where evapotranspiration and water-productivity information are required. These remotely sensed indicators should be linked spatially to verified cadastral parcels and accompanied by soil, irrigation and production data.

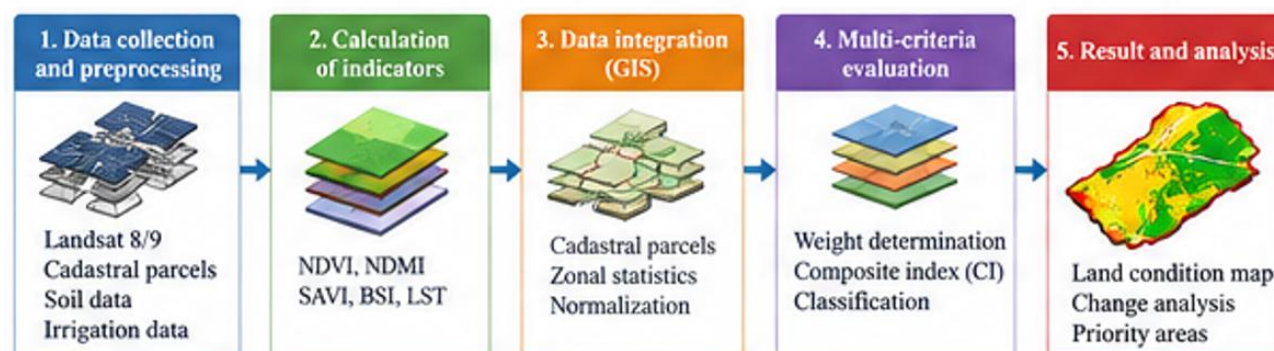


Figure 5. Improved workflow for comprehensive assessment of dehkan farm lands

Source: Author's methodological framework.

Table 4. Recommended indicator groups and initial weights for comprehensive assessment

Block	Indicators	Data source	Initial group weight
Vegetation and phenology	NDVI/EVI median, seasonal amplitude, p10/p90	Sentinel-2; Landsat for retrospective analysis	0.30
Moisture and water stress	NDMI, LST, Sentinel-1 VV/VH, ET/AETI	Sentinel-2, Landsat TIRS, Sentinel-1, WaPOR	0.25
Soil and degradation	BSI/SI, salinity class, organic matter, soil-quality or agrochemical score	Sentinel-2 + soil/agrochemical data	0.20
Cadastral and land-use compliance	Parcel boundary, actual crop cover, unused share, crop-rotation signal	Cadastral/GIS + classified remote-sensing data	0.15
Production efficiency	Yield, production volume, ratio to benchmark values	Statistics, farm records and field data	0.10

Source: Author's proposal based on international practice and GIS-MCDA literature [7–17].

The weights in Table 4 represent an initial methodological configuration rather than fixed normative values for Beshariq District. In the applied study they should be refined through pairwise comparisons by a panel of relevant experts, followed by calculation of the AHP consistency ratio (CR). A CR below 0.10 is commonly considered acceptable. Sensitivity analysis should also be performed to test whether reasonable changes in weights alter the final parcel classification.

3.2. Indicator normalization and composite index

To combine indicators measured in different units, all variables are transformed to a common 0–1 scale. For benefit-type indicators, where higher values represent a more favourable condition, min–max normalization is applied:

$$x_i^* = (x_i - x_{i,\min}) / (x_{i,\max} - x_{i,\min})$$

For cost-type indicators, such as excessive surface temperature, salinity or the proportion of unused land, the transformation is reversed:

$$x_i^* = (x_{i,\max} - x_i) / (x_{i,\max} - x_{i,\min})$$

Normalization should preferably be performed within agroecologically comparable groups or crop/phenology classes rather than by applying one global minimum and maximum to all parcels. Otherwise, differences between crop types may be interpreted incorrectly as differences in land condition.

The normalized indicators and AHP weights are aggregated into the Comprehensive Assessment Index (CAI):

$$CAI = 0.30 \cdot V + 0.25 \cdot W + 0.20 \cdot S + 0.15 \cdot C + 0.10 \cdot P$$

where V is the vegetation and phenology block, W represents moisture and water stress, S represents soil and degradation condition, C represents cadastral and land-use compliance, and P represents production efficiency. Each block may itself consist of several normalized sub-indicators. The additive structure makes the calculation transparent and allows the contribution of each component to be traced at parcel level.

Table 5. Proposed five-level interpretation scale for the Comprehensive Assessment Index

CAI interval	Assessment class	Interpretation and management signal
0.80–1.00	High / stable	Vegetation, moisture and land-use indicators are stable; routine monitoring continues
0.60–0.79	Good	Minor seasonal deviations in selected indicators; preventive agronomic recommendations
0.40–0.59	Moderate / control required	Persistent decline in at least one block; parcel-level causal analysis required
0.20–0.39	Low / at risk	High probability of water stress, degradation or land-use problem; field inspection required
0.00–0.19	Critical	Multiple adverse signals; urgent verification and rehabilitation measures

Source: Author's proposal. Thresholds must be calibrated with field validation for the study area.

3.3. Parcel-based spatial analysis and validation

Because dehkan parcels can be very small, strict quality rules are required for the pixel–parcel relationship. For Sentinel-2, pixels intersecting parcel boundaries should be treated cautiously because they may contain mixed land cover. Zonal statistics should therefore include not only the mean but also the median, p10, p90, standard deviation and the proportion of valid pixels. Where the parcel is sufficiently large, an internal buffer can reduce the influence of boundary pixels.

Validation should be implemented in three stages: (1) spectral and thermal indicators are compared with observed field condition; (2) crop-type classification is checked using a confusion matrix, overall accuracy and F1-score; and (3) CAI classes are compared with yield, soil, irrigation and field-observation information. Repeatedly misclassified parcels should be examined separately because the cause may be mixed pixels, incorrect cadastral geometry, unusual crop phenology or management changes.

4. RESULTS AND DISCUSSION

The review of international practice and the official statistical profile of Beshariq District reveal three methodological problems relevant to comprehensive assessment. The first is the small-parcel and mixed-pixel problem. Operational programmes such as the USDA Cropland Data Layer demonstrate the value of 10 m Sentinel-2 observations for detailed agricultural mapping. For dehkan parcels, this is a substantial advantage over 30 m Landsat data, although Landsat remains essential for historical trend analysis.

The second problem is the use of a vegetation index as a single measure of land condition. A parcel may exhibit high greenness while simultaneously experiencing inefficient water use, increasing soil salinity or non-compliance with its intended land use. For this reason, the improved method evaluates vegetation together with moisture, soil/degradation, cadastral compliance and production-efficiency blocks.

The third problem is the scale mismatch between statistical indicators and remotely sensed observations. District-level values such as UZS 2.9 trillion of annual sector output or the 58.5% contribution of dehkan and household farms are useful for characterizing economic significance, but they do not directly describe the condition of individual parcels. The methodology therefore uses statistics as contextual and validation information, while the main spatial assessment is performed at parcel level.





Table 6. Comparison of conventional and improved integrated approaches

Criterion	Conventional approach	Improved integrated approach
Assessment unit	Field inspection or aggregate farm indicator	Cadastral parcel + within-parcel time series
Data source	Separate field or statistical source	Sentinel-1/2 + soil + irrigation + cadastre + statistics
Repeatability	Periodic or episodic	Regular during the season and retrospective
Principal indicator	Often a single indicator	Multiple indicator blocks and CAI
Uncertainty management	Often not documented	Valid-pixel count, p10/p90, QA and field follow-up
Output	Text or table-based assessment	Parcel-level index, class, map and priority inspection list
Management potential	Reactive	Early-warning and risk-based monitoring

Source: Author's analysis.

A further advantage of the proposed approach is that the result is expressed as a risk-oriented management class rather than a simple suitable/unsuitable label. For example, high vegetation activity combined with low moisture may indicate emerging irrigation stress; moderate vegetation combined with stable moisture and satisfactory soil parameters may represent a normal phenological condition rather than degradation. Such combinations can be diagnosed only when several indicators are interpreted jointly.

The CAI weights and class boundaries presented in this article are a methodological prototype, not fixed regulatory thresholds for Beshariq District. Final thresholds must be calibrated using verified cadastral parcels, crop information, field observations, soil and irrigation data, and independent validation samples. This requirement is especially important for dehkan farms because very small parcels can increase uncertainty through mixed pixels.

Figures 6 and 7 illustrate how the proposed parcel-level classes can be communicated cartographically. They should be interpreted as methodological visualization prototypes rather than final empirical maps of verified Beshariq cadastral parcels. For dissertation-level results, the thematic layers must be regenerated from verified Beshariq parcel geometries and field-calibrated CAI values.

Comprehensive Assessment Map of Dehkan Farm Lands in Beshariq District

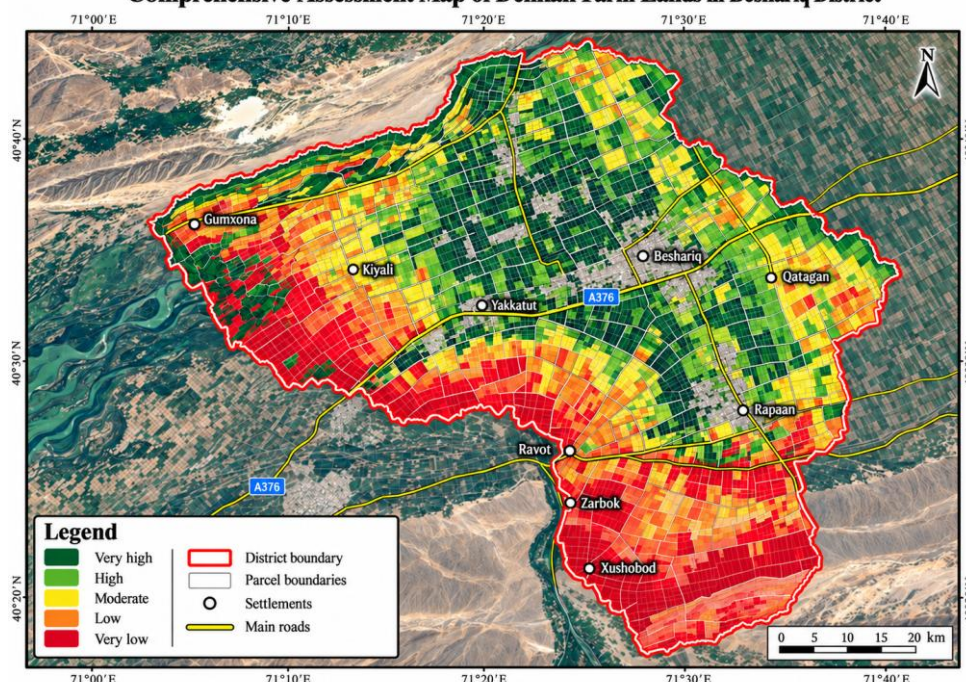


Figure 6. Illustrative comprehensive-assessment map for dehkan farm lands

Source: Methodological cartographic prototype prepared for the proposed assessment scheme.

The spatial pattern shown in Figure 6 demonstrates the intended five-level visualization: higher classes are concentrated in relatively favourable agricultural areas, whereas lower classes highlight parcels requiring closer inspection. In a verified application, such a map would allow land-monitoring agencies to move from uniform inspection schedules to parcel-specific prioritization.

Management Priority Map of Dehkan Farm Lands in Beshariq District

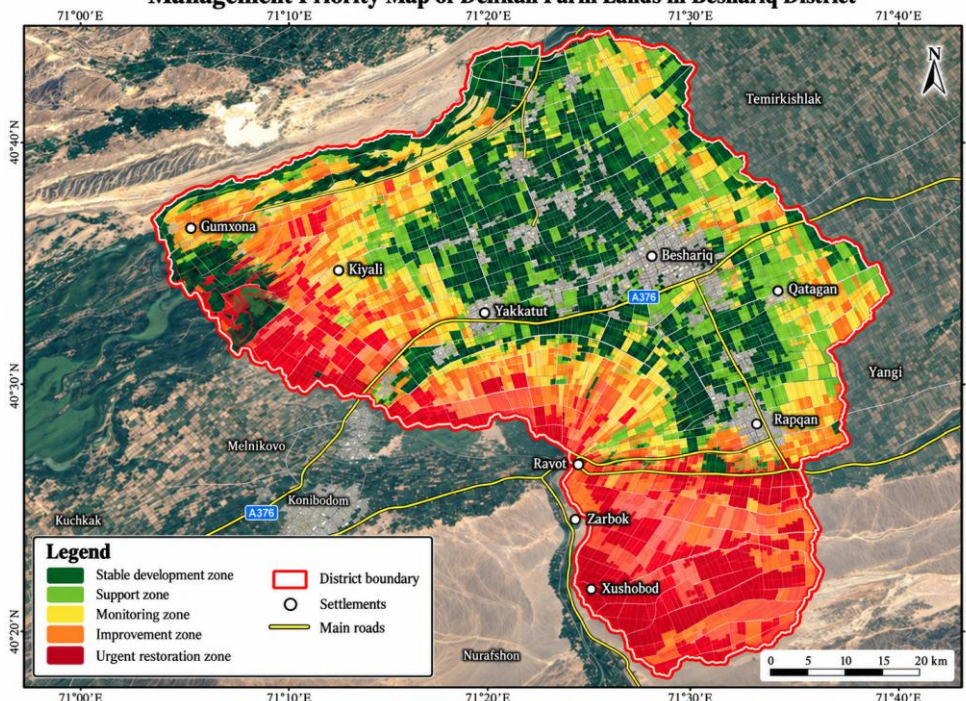


Figure 7. Illustrative map of management-priority zones for dehkan farm lands

Source: Methodological cartographic prototype derived from the proposed classification logic.

Figure 7 shows the management logic associated with the assessment classes. Stable parcels remain under routine support and monitoring; intermediate classes are directed to enhanced observation or targeted improvement; the most problematic classes are assigned to urgent verification and rehabilitation. This type of zoning can make field inspection and land-management interventions more targeted and cost-efficient.

4.1. Recommended practical workflow for Beshariq District

Table 7. Practical implementation algorithm for the improved assessment method

Stage	Operation	Main output
1	Prepare verified dehkan cadastral parcels in a common coordinate system; remove duplicates and topological errors	Clean parcel database
2	Select Sentinel-2 L2A and Sentinel-1 time series for the vegetation season; apply cloud/shadow masking and compositing	Quality-controlled imagery
3	Calculate NDVI/EVI, NDMI, BSI/SI, LST and radar indicators; add WaPOR ET where appropriate	Indicator rasters
4	Calculate median, p10, p90, standard deviation and valid-pixel share for each cadastral parcel	Parcel statistical profile
5	Normalize indicators to 0–1 within crop/phenology groups	Comparable indicators
6	Determine weights through AHP, check CR and calculate CAI	Composite index from 0 to 1
7	Classify CAI into five levels and place low/critical parcels on a priority list	Risk map and inspection list
8	Validate with field observations, yield, soil and irrigation data; recalibrate thresholds	Locally validated reliability metrics

Source: Author's methodological proposal.

The workflow can be implemented in ArcGIS Pro or QGIS together with Google Earth Engine for time-series processing. Cadastral data should remain in an authorized and protected information environment, while satellite-derived statistics can be linked to parcel identifiers. This separation supports both operational efficiency and responsible handling of land-right information.

5. RESEARCH LIMITATIONS

The principal limitation is spatial resolution. Even 10 m Sentinel-2 data may be insufficient where dehkan parcels are extremely small or narrow. In such cases, higher-resolution imagery or targeted unmanned aerial vehicle observations may be required. A second limitation is the temporal variability of crop phenology: a single threshold should not be applied to all crop types and seasons. Third, the accuracy of the integrated assessment is constrained by the positional quality and currency of cadastral boundaries as well as by the availability of field, soil and irrigation data. Another limitation concerns the methodological status of the maps presented in this article. They are visualization prototypes intended to demonstrate how parcel-level CAI classes and management priorities can be mapped. They should not be treated as final cadastral or regulatory products until the underlying Beshariq parcel database and field calibration are verified.

CONCLUSIONS

1. International experience shows that effective agricultural land monitoring increasingly integrates satellite data with parcel boundaries and ground information rather than relying on imagery alone.
2. In Beshariq District, dehkan and household farms accounted for 58.5% of agricultural output in January–September 2024. Their importance is particularly high in potato, vegetable, melon, fruit and grape production, which increases the need for reliable monitoring of small parcels.
3. The improved method treats the cadastral parcel as the basic assessment unit and integrates Sentinel-2/Sentinel-1 observations, retrospective Landsat or WaPOR products where appropriate, and soil, irrigation, cadastral and statistical information.
4. The comprehensive assessment is organized into vegetation, moisture/water-stress, soil/degradation, cadastral-compliance and production-efficiency blocks. Indicators are normalized to 0–1 and weighted through AHP before aggregation into the CAI.
5. For small parcels, zonal statistics should include the median, p10, p90, standard deviation and valid-pixel share, and mixed boundary pixels should be controlled through quality rules or internal buffering.
6. The next applied stage should calibrate indicator weights and CAI thresholds using verified Beshariq cadastral parcels, soil and irrigation data and independent field observations, and then quantify classification and assessment accuracy.

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