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Seasonal Assessment of Perennial Tree Stand Conditions Using Landsat-Derived NDVI and NDMI: Evidence from Quva District, Uzbekistan

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Abstract: *Perennial tree stands in irrigated agricultural landscapes are affected by seasonal vegetation development, water availability and stand structure. This study evaluates the seasonal condition of perennial tree stands in Quva district, Fergana Region, Uzbekistan, using Landsat 8 OLI/TIRS Level-2 Surface Reflectance data and the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI). Four observation periods in 2025 were analyzed: April, June, August and October. The workflow included QA/cloud screening, index calculation, clipping to the district boundary and zonal statistics for 32 cadastral contours of perennial tree stands. Field-inventory data for 2025 were used as contextual reference information. The weighted mean NDVI was 0.2090 in April, 0.2069 in June, 0.2206 in August and 0.1611 in October. The weighted mean NDMI was 0.0851, 0.0631, 0.0829 and 0.0442 for the same periods. August showed the highest NDVI and relatively high NDMI, while October showed the lowest values of both indices, reflecting autumn vegetation decline and reduced moisture-related spectral response. The correlation between contour-level NDVI and NDMI remained very high across all months (r = 0.984–0.992), indicating that vegetation activity and moisture condition were closely related in the investigated perennial tree stands. The results demonstrate that seasonal NDVI-NDMI analysis is useful for identifying periods of vegetation weakening and moisture stress, supporting field inspection planning, cadastral clarification and land-resource monitoring in irrigated agricultural areas.*

Keywords: Landsat 8; NDVI; NDMI; seasonal dynamics; perennial tree stands; GIS; zonal statistics; Quva district

1. Introduction

Perennial tree stands, including orchards, vineyards, mulberry plantations and other long-term agricultural plantations, are an important component of irrigated landscapes in the Fergana Valley. Their condition influences agricultural productivity, ecological stability, microclimate regulation and the efficient use of irrigated land resources. In regions where horticulture depends on irrigation infrastructure, the monitoring of seasonal vegetation activity and moisture conditions is also relevant for land-resource management and cadastral decision making.

Traditional field surveys provide direct and detailed information about plantation condition, but they are often time-consuming and cannot always capture spatial variation across a district within a short period. Satellite remote sensing provides a repeatable and spatially consistent source of information for screening vegetation condition. The Normalized Difference Vegetation Index (NDVI) is widely used to characterize green vegetation activity and canopy vigor because it is based on the contrast between red and near-infrared reflectance [1,2]. However, for perennial tree stands, NDVI can be affected by inter-row soil background, sparse canopy structure, young plantations and mixed pixels at the Landsat spatial resolution [3].

The Normalized Difference Moisture Index (NDMI) complements NDVI by using near-infrared and shortwave infrared reflectance to indicate vegetation moisture-related conditions [4]. Combining NDVI and NDMI allows a more balanced interpretation of vegetation activity and moisture stress than a single-index approach. Landsat Level-2 Surface Reflectance products are especially useful for such assessments because they provide atmospherically corrected observations suitable for multi-date comparison [5–7].

Previous remote-sensing studies emphasize that vegetation monitoring should consider cloud screening, consistent preprocessing and seasonal phenology [8,9]. In applied land monitoring, geospatial information is also increasingly used for agricultural decision support and sustainable land-cover assessment [10]. The purpose of this study is to evaluate the seasonal condition of perennial tree stands in Quva district, Uzbekistan, using Landsat-derived NDVI and NDMI for April, June, August and October 2025. The study focuses on seasonal differences within one year rather than long-term trend detection.

2. Materials and Methods

2.1. Study area and reference information

The study area is Quva district in Fergana Region, Uzbekistan. It is located in an irrigated agricultural zone where perennial tree stands are closely related to water supply, soil conditions, cadastral land units and landscape management. The analysis was performed using 32 cadastral contours of perennial tree stands in a GIS environment.

Field-inventory information from 2025 was used as auxiliary reference data. According to the inventory data, perennial tree stands in Quva district covered 6,897.19 ha. Of this area, 4,282.78 ha (62.1%) were in good condition, 1,763.83 ha (25.6%) were young plantations, 810.14 ha (11.7%) were sparse stands and 40.45 ha (0.6%) were old or unsuitable plantations. These data were used for contextual interpretation rather than pixel-level accuracy assessment.

2.2. Satellite data

Four Landsat 8 OLI/TIRS Level-2 Surface Reflectance scenes were selected to represent the main seasonal phases of perennial tree stand development in 2025: early vegetation stage, active growth stage, late summer moisture-stress period and autumn vegetation decline. All scenes belong to WRS-2 path/row 152/032 and had a reported cloud cover of 20% according to the available scene metadata.

Table 1. Landsat scenes used in the seasonal assessment.

Month	Acquisition date	Landsat scene ID	Sensor	WRS-2 path/row	Cloud cover
April	2025-04-30	LC08_L2SP_152032_20250430_20250502_02_T1	Landsat 8 OLI/TIRS	152/032	20%
June	2025-06-17	LC08_L2SP_152032_20250617_20250618_02_T1	Landsat 8 OLI/TIRS	152/032	20%
August	2025-08-12	LC08_L2SP_152032_20250812_20250821_02_T1	Landsat 8 OLI/TIRS	152/032	20%
October	2025-10-15	LC08_L2SP_152032_20251015_20251118_02_T1	Landsat 8 OLI/TIRS	152/032	20%

2.3. Index calculation and GIS processing

NDVI and NDMI were calculated from atmospherically corrected surface reflectance bands. For Landsat 8 OLI/TIRS, NDVI was calculated from the near-infrared and red bands, while NDMI was calculated from the near-infrared and shortwave infrared bands. The formulas used were:

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{Red}) / (\mathrm{NIR} + \mathrm{Red}) \qquad (1)$$

$$\mathrm{NDMI} = (\mathrm{NIR} - \mathrm{SWIR1}) / (\mathrm{NIR} + \mathrm{SWIR1}) \qquad (2)$$

The raster layers were clipped to the administrative boundary of Quva district and summarized by the 32 cadastral contours. For each contour, pixel count, area, minimum, maximum, mean, standard deviation and sum were extracted. Weighted mean values were calculated by dividing the total index sum by the total pixel count. The standard deviation reported in the results refers to variation among contour-level mean values.

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Figure 1. Workflow for seasonal NDVI–NDMI assessment of perennial tree stands.

3. Results and Discussion

3.1. Seasonal NDVI patterns

The NDVI maps show clear seasonal differences in vegetation activity within Quva district (Figure 2). The maximum NDVI increased from 0.4912 in April to 0.5004 in June and 0.5080 in August, followed by a decrease to 0.4370 in October. The weighted mean NDVI was relatively stable from April to August but declined sharply in October. This indicates that the late summer period retained strong vegetation activity in several irrigated contours, whereas the autumn image captured the beginning of vegetation decline and reduced canopy activity.

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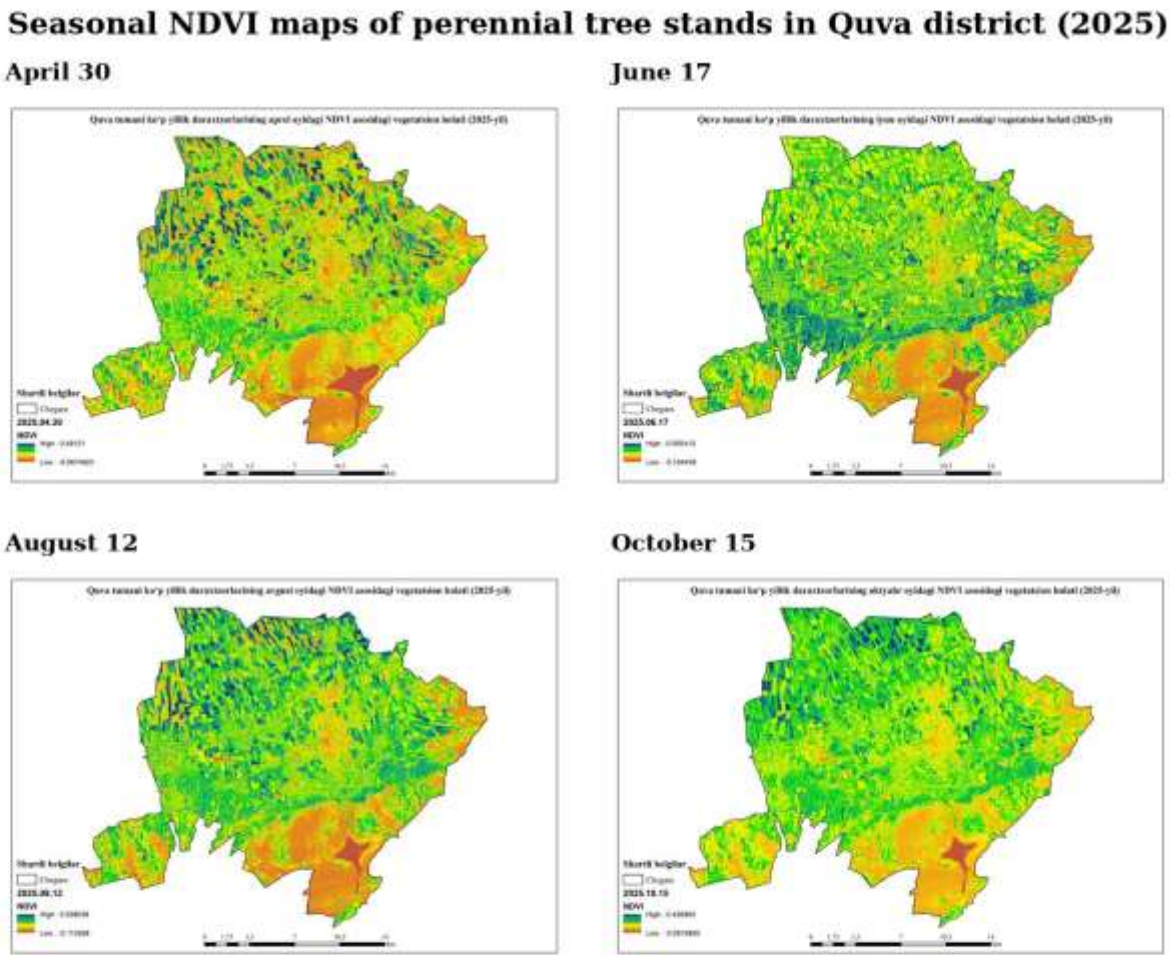

Figure 2. Seasonal NDVI maps of perennial tree stands in Quva district in 2025.

3.2. Seasonal NDMI patterns

The NDMI maps reveal seasonal differences in moisture-related spectral response (Figure 3). The weighted mean NDMI was highest in April (0.0851), decreased in June (0.0631), partly recovered in August (0.0829) and reached the lowest value in October (0.0442). The June decrease may reflect the effect of increasing evapotranspiration and early moisture stress during active vegetation growth. The August recovery suggests that irrigation and dense vegetation in some contours maintained relatively higher moisture conditions. The October decline indicates reduced vegetation moisture and seasonal weakening of canopy activity.

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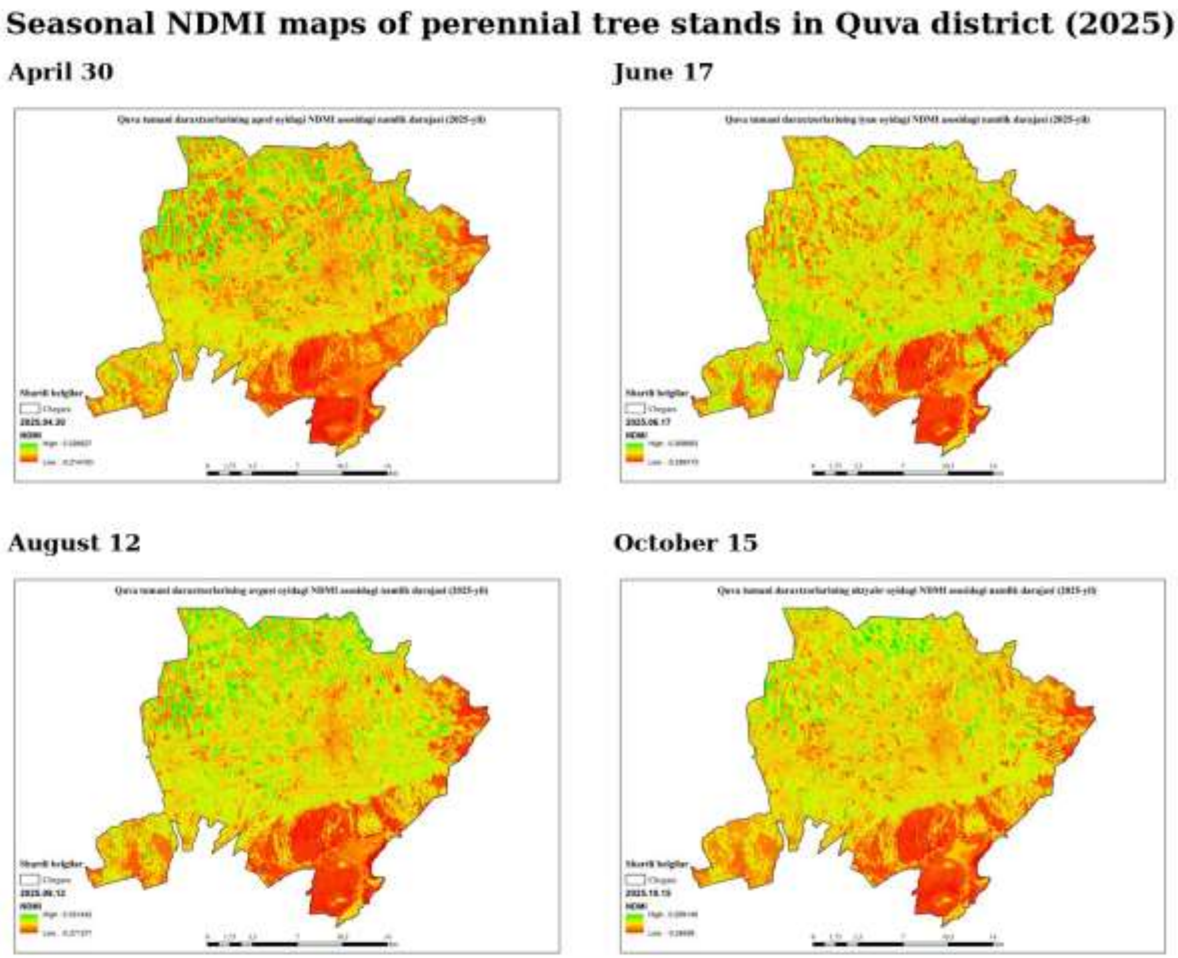

Figure 3. Seasonal NDMI maps of perennial tree stands in Quva district in 2025.

3.3. Zonal-statistics summary

The zonal-statistics results confirm the seasonal pattern observed on the maps (Table 2). August had the highest weighted mean NDVI, whereas April had the highest weighted mean NDMI. October had the lowest values of both indices. At the contour level, NDVI increased in 18 of 32 contours from June to August and decreased in all 32 contours from August to October. NDMI increased in 24 of 32 contours from June to August and decreased in 30 of 32 contours from August to October. This shows that the autumn decline was spatially consistent across almost the entire set of contours.

Table 2. Seasonal zonal-statistics summary for NDVI and NDMI in 2025.

Index	Month	Min	Max	Weighted mean	SD among contour means	Mean within-contour SD	Interpretation
NDVI	April	-0.0675	0.4912	0.2090	0.0491	0.0822	Early vegetation development
NDVI	June	-0.1045	0.5004	0.2069	0.0553	0.0717	Active growth, moderate canopy response

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NDVI	August	-0.1156	0.5080	0.2206	0.0615	0.0801	Highest vegetation activity
NDVI	October	-0.0820	0.4370	0.1611	0.0459	0.0535	Autumn vegetation decline
NDMI	April	-0.2141	0.3266	0.0851	0.0496	0.0662	Highest moisture-related response
NDMI	June	-0.2892	0.3087	0.0631	0.0482	0.0615	Lower moisture signal
NDMI	August	-0.2713	0.3314	0.0829	0.0532	0.0642	Partial moisture recovery
NDMI	October	-0.2670	0.2991	0.0442	0.0379	0.0440	Lowest moisture-related response

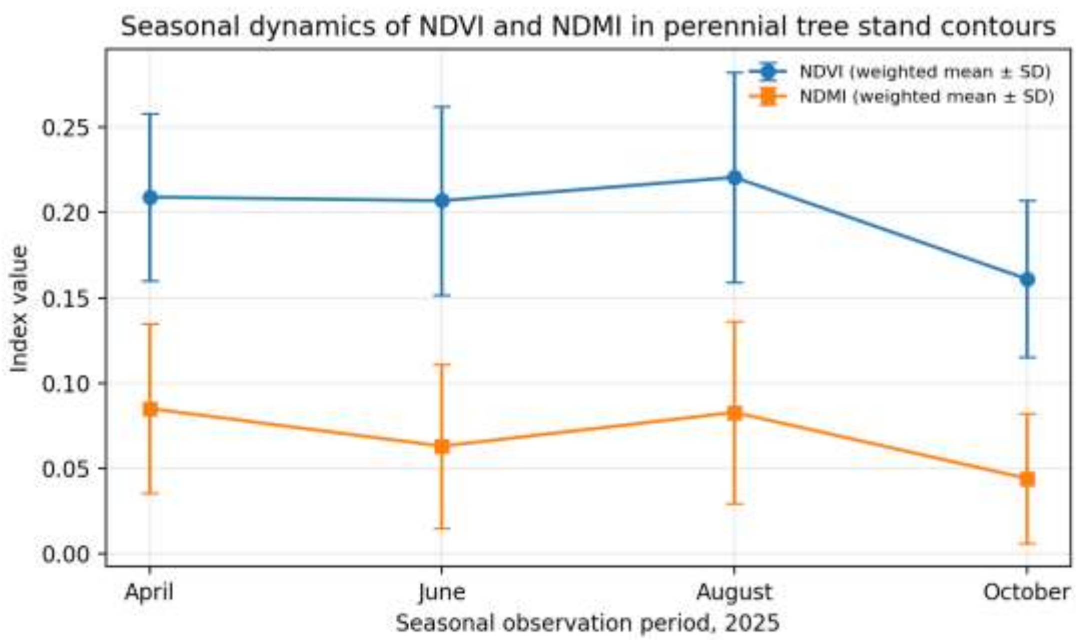

Figure 4. Seasonal dynamics of weighted mean NDVI and NDMI with standard deviation among contour means.

3.4. Integrated NDVI–NDMI interpretation

The relationship between contour-level NDVI and NDMI was very strong in all four observation periods (Figure 5). The correlation coefficient was 0.985 in April, 0.988 in June, 0.992 in August and 0.984 in October. This indicates that vegetation activity and moisture-sensitive spectral response were closely linked across the perennial tree stand contours. Such a relationship is expected in irrigated agricultural landscapes, where vegetation vigor depends strongly on water availability and irrigation management.

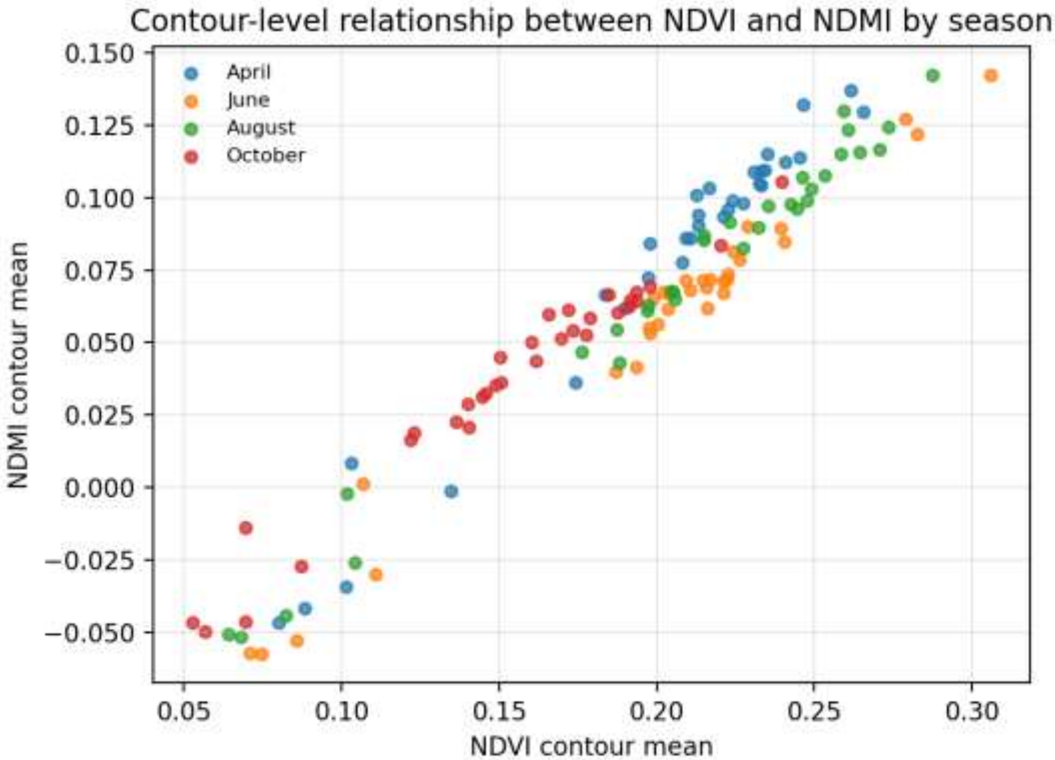

Figure 5. Contour-level relationship between NDVI and NDMI for the four seasonal observation periods.

The integrated interpretation suggests that seasonal NDVI–NDMI screening can help identify periods and locations where field inspection is most necessary. Contours with low NDVI and low NDMI are likely to include sparse stands, young plantations, open soil, roads, irrigation canals or moisture-deficient surfaces. The 2025 inventory data support this interpretation because a substantial share of the perennial tree stand area consisted of young plantations and sparse stands. Therefore, low index values should not be interpreted automatically as degradation; they must be interpreted together with stand age, density and field-inventory information.

4. Conclusion

This study assessed the seasonal condition of perennial tree stands in Quva district using Landsat-derived NDVI and NDMI for April, June, August and October 2025. The results show that seasonal variation is clearly visible in both vegetation activity and moisture-related spectral response. The weighted mean NDVI reached its highest value in August (0.2206) and its lowest value in October (0.1611). The weighted mean NDMI was highest in April (0.0851), decreased in June, partly recovered in August and reached its lowest level in October (0.0442).

The strong correlation between NDVI and NDMI across all months confirms that vegetation activity and moisture conditions are closely connected in the perennial tree stands of the irrigated Quva landscape. The most pronounced seasonal weakening occurred from August to October, when NDVI decreased in all 32 contours and NDMI decreased in 30 contours. These findings indicate that the combined use of NDVI and NDMI can support preliminary field-inspection planning, cadastral clarification and land-resource monitoring.

The proposed approach should be considered a screening tool rather than a substitute for field surveys. Future research should include multi-year seasonal composites, higher-resolution imagery and quantitative accuracy assessment using field sample points.

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Conflicts of Interest

The authors declare no conflict of interest.

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