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ASSESSMENT OF WHEAT YIELD USING NDVI IN THE DOBROGEA REGION

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Abstract. *The increasing need for efficient crop monitoring and management in agriculture has driven the adoption of precision farming techniques, such as the use of vegetation indices. Among these, the Normalized Difference Vegetation Index (NDVI) has gained widespread recognition for its ability to assess crop health and predict yield outcomes. This study focuses on the relationship between NDVI values and wheat yield in the Dobrogea region, an area characterized by its dry climate and variable precipitation patterns. By utilizing satellite imagery collected at multiple stages of the crop growth cycle, we aim to evaluate the effectiveness of NDVI in predicting wheat yield and identifying areas of crop stress. Data collected over several agricultural seasons (2019-2023) were analyzed to examine the correlation between NDVI values from key growth stages and the corresponding wheat yield. The results indicate a significant positive correlation between NDVI during the late vegetative stages and yield outcomes. Additionally, NDVI proved to be a reliable indicator for assessing crop performance in response to varying precipitation levels. This study provides valuable insights into the application of NDVI as a practical tool for precision agriculture in arid and semi-arid regions. Our findings suggest that NDVI-based monitoring can enhance decision-making processes related to irrigation, fertilization, and harvesting, ultimately leading to more sustainable farming practices.*

Keywords: *NDVI, Vegetation Indices, Wheat Yield, Precision Agriculture, Crop Monitoring, Satellite Imagery, Dobrogea Region, Semi-Arid Regions*

INTRODUCTION

Dobrogea, located in southeastern Romania, is known for its arid and semi-arid climate, characterized by inconsistent rainfall and variable temperature patterns (Trif et. al. 2014). These climatic conditions create significant challenges for farmers, as the available water supply is often insufficient or unevenly distributed throughout the growing season. This variability makes agricultural production outcomes difficult to predict from year to year (Grigorieva et. al., 2023). The soil in Dobrogea, especially the sandy ones, has a low water retention capacity, which exacerbates water stress on crops (Popescu et. al, 2020).

Rainfall plays a crucial role in the growth and development of wheat crops (Joniyas et. al., 2014), and in Dobrogea, the irregular distribution of precipitation can negatively affect productivity. Farmers in this region frequently face challenges in resources management, making solutions based on precise and real-time data extremely valuable for optimizing production.

The Normalized Difference Vegetation Index (NDVI) is one of the most widely used indicators for monitoring vegetation health, especially due to its ability to provide detailed information on plant photosynthetic activity (Radočaj et. al., 2023). NDVI compares the light reflected in the red and near-infrared (NIR) spectrum, with values ranging from -1 to +1. Values close to +1 indicate dense and healthy vegetation, while lower values reflect either plant stress or the presence of bare soil or water (Berca et. al, 2022).

In agriculture, NDVI is essential because it provides real-time information to farmers about:

- Crop health – NDVI helps detect early stress caused by drought, nutrient deficiencies, or pest infestations, enabling farmers to intervene quickly and efficiently (Radočaj et. al., 2023).
- Plant growth cycle – by regularly monitoring NDVI, farmers can identify key moments in crop development, such as tillering, ear formation, or grain maturation (Zsebő et. al., 2024).
- Resource management – NDVI can assist in planning irrigation and variable-rate fertilization, thereby optimizing water and fertilizer use (Vélez et. al., 2023)

For wheat crops, NDVI is particularly valuable for monitoring critical growth stages. In the early stages, this index can identify areas of suboptimal growth, allowing corrective measures such as irrigation or additional treatments. In later stages, NDVI helps anticipate yield, providing insights into canopy density and overall plant health (Naser et. al., 2020).

Advantages of NDVI include:

- Non-invasive – NDVI uses satellite or drone images, allowing the evaluation of plant health without affecting them (Vélez et. al., 2023).
- Real-time monitoring – images are updated regularly, providing farmers with a constant overview of crop conditions (Zahra et al., 2024)
- Scalability – NDVI can be used at both field and regional or national levels, offering a detailed perspective on agricultural productivity (Vélez et. al., 2023).

NDVI's relevance in Dobrogea is even greater given the region's frequent water stress and challenging climatic conditions. In an environment where precipitation is irregular and soils have low water retention capacity, NDVI offers an efficient way to monitor the impact of climate on crops and make informed decisions to maximize productivity and minimize losses (Jabal et. al., 2022).

Numerous studies have established the significant role of NDVI in predicting crop yield and managing agricultural resources efficiently, Zahra et al. (2024) found that NDVI, derived from UAV-based phenotyping, can accurately monitor wheat growth stages, enabling timely interventions to optimize crop productivity. Similarly, Thapa et al. (2019) showed that NDVI measurements from satellite imagery were highly correlated with wheat yield in semi-arid regions, reinforcing the index's utility for predicting crop performance in water-stressed environments.

Furthermore, studies like Belmahi et al. (2023) have shown strong correlations between NDVI values and wheat yield across multiple agricultural seasons, highlighting NDVI's potential in yield prediction, especially in regions like Dobrogea where climate variability poses significant challenges.

These findings emphasize the necessity of collecting region-specific data to refine NDVI models, especially in arid and semi-arid climates, to enhance their predictive accuracy.
As agriculture in Dobrogea is highly sensitive to erratic precipitation and soil conditions, more research is required to understand how NDVI can be adapted to these unique environmental stresses. By incorporating NDVI into precision agriculture, farmers can improve decision-

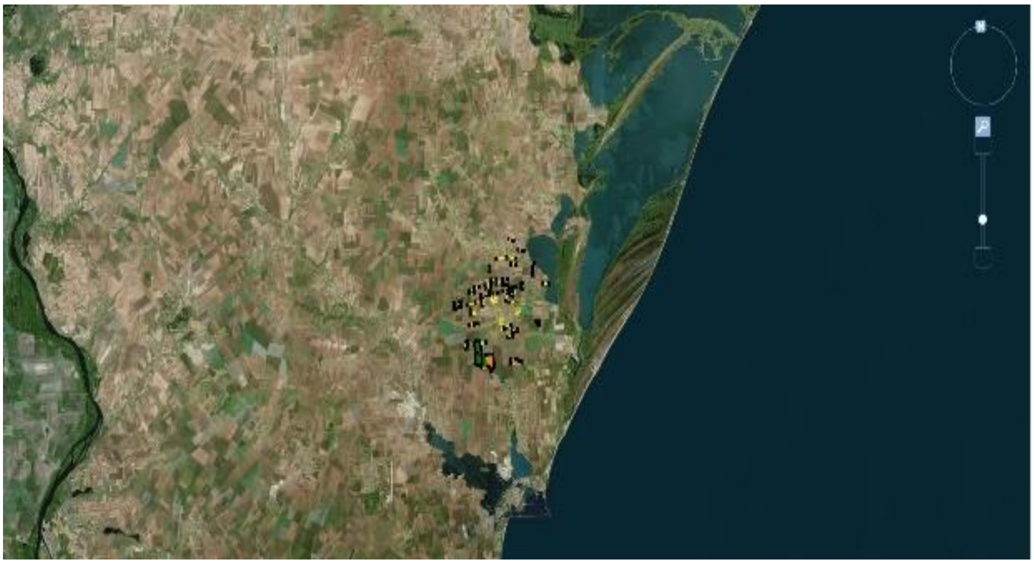
making processes related to irrigation, fertilization, pesticides application and harvesting, ultimately leading to more sustainable and productive agricultural practices in challenging climates (Papadopoulos et. al., 2024).

This study aims to investigate the correlation between NDVI values measured at key moments during the wheat growth season and the final yield in the Dobrogea region. Additionally, we evaluate the impact of variable climate conditions and NDVI on wheat quality, measured through hectoliter weight. Lastly, we aim to demonstrate how this data can be utilized within precision agriculture to optimize decisions related to fertilization, treatment application, and harvest timing, giving farmers an advantage in efficiently managing resources.

MATERIAL AND METHODS

Study Area and Climate

The study was conducted in the central-north part of Dobrogea region, which is in southeastern Romania, characterized by an arid and semi-arid climate. The area experiences irregular precipitation patterns, with dry periods alternating with short, intense rainfall events (Bădăluță et. al, 2024), which significantly affect wheat production. The fields that were studied are located in Constanța County, between Săcele commune and Corbu commune (44.4519318, 28.6177580; 44.4921235, 28.6191739; 44.5012202, 28.6430509; 44.5000038, 28.6625848).



Data Collection

NDVI data were obtained from satellite imagery (Sentinel-2) provided by Ogor.ro, at key growth stages of winter wheat: November (early growth stages), January (dormancy or vegetative rest), March (wheat resumes its active growth process), April (intense growth phase), and May (intensive development, the final stages of crop formation). The NDVI values were extracted for each field to assess vegetation health during these periods.

Climate data, including monthly precipitation levels, were collected from meteorological stations in the Dobrogea region. These data were crucial for understanding the relationship between precipitation and NDVI values.

Wheat yield data (measured in kg/ha) and hectoliter weight (GH) were collected at harvest to assess the final production and quality of the crops.

Data Analysis

The study applied correlation and regression analyses to investigate the relationship between NDVI at various growth stages and wheat yield. We also evaluated the impact of precipitation on NDVI and its correlation with final yield and hectoliter weight. The data was processed using statistical software to identify significant trends and patterns.

RESULTS AND DISCUSSIONS

Table 1.

Detailed agricultural data for different wheat fields (A2, A41, A94, A51) over multiple years, including NDVI (Normalized Difference Vegetation Index), precipitation, yield, and GH (mass hectoliter). Data was collected by authors from Ogor.ro and harvest process.

FIELD	YEAR	NDVI (9 Nov.)	NDVI (18 Jan.)	NDVI (19 Mar.)	NDVI (28 Apr.)	NDVI (23 May)	PRECIPITATION (mm) November	PRECIPITATION (mm) January	PRECIPITATION (mm) March	PRECIPITATION (mm) April	PRECIPITATION (mm) May	YIELD (kg/ha)	GH (kg/hl)	CUMULATIVE PRECIPITATION/ YEAR (mm/year)
A2	2018-2019	0,26	0,33	0,44	0,84	0,85	54,1	26,8	12	22,8	16,8	5189	77	189
	2019-2020	0,85	0,89	0,79	0,52	0,31	16	1,6	4,3	3,7	22,8	1598	72	170
	2020-2021	0,23	0,49	0,54	0,82	0,92	8,1	64,1	20,2	7,5	18,3	6174	80	319
	2021-2022	-	-	-	-	-	-	-	-	-	-	-	-	
	2022-2023	0,6	0,78	0,79	0,82	0,75	20	24,5	10	74,8	12,6	5915	79	210
A41	2018-2019	0,3	0,35	0,53	0,83	0,72	54,1	26,8	12	22,8	16,8	5120	77	189
	2019-2020	-	-	-	-	-	-	-	-	-	-	-	-	
	2020-2021	0,21	0,51	0,64	0,84	0,85	8	65,2	17,1	12	8,6	6354	80	295
	2021-2022	0,42	0,99	0,77	0,86	0,73	20,8	11,5	14,7	10,1	13,3	5940	78	231
	2022-2023	-	-	-	-	-	-	-	-	-	-	-	-	
A94	2018-2019	0,18	0,26	0,47	0,86	0,83	54,1	26,8	12	22,8	17	5378	77	189
	2019-2020	-	-	-	-	-	-	-	-	-	-	-	-	
	2020-2021	0,24	0,71	0,68	0,87	0,91	10,5	64,3	17,2	13	6,1	6354	80	295
	2021-2022	0,54	0,87	0,63	0,79	0,74	20,9	11,8	14,2	9,2	12,6	6078	78	238
	2022-2023	-	-	-	-	-	-	-	-	-	-	-	-	
A51	2018-2019	-	-	-	-	-	-	-	-	-	-	-	-	
	2019-2020	0,81	0,85	0,8	0,52	0,43	16	2,3	3,3	4,8	24,5	1786	72	173
	2020-2021	0,22	0,6	0,67	0,88	0,86	9,5	65,3	16,9	13,3	6,4	6366	80	293
	2021-2022	-	-	-	-	-	-	-	-	-	-	-	-	
	2022-2023	0,31	0,61	0,79	0,81	0,72	19,5	22,5	9,2	75,9	13,3	4765	79	200

Correlation Between NDVI and Wheat Yield

The data collected across multiple seasons in Dobrogea shows significant variation in both NDVI values and wheat yield. An analysis of NDVI measured at key growth stages reveals that certain stages have a stronger correlation with the final wheat yield. For example, the NDVI values in April and May, critical period for determining the final productivity of wheat (leaf canopy development, heading, flowering, grain filling), exhibited the highest correlation with wheat yield.

Table 2.

Strong positive correlation indicating a strong positive linear relationship between NDVI values and yield. As NDVI increases, the yield value also increases, which suggests that higher vegetation health or biomass (as indicated by NDVI) is associated with higher yields

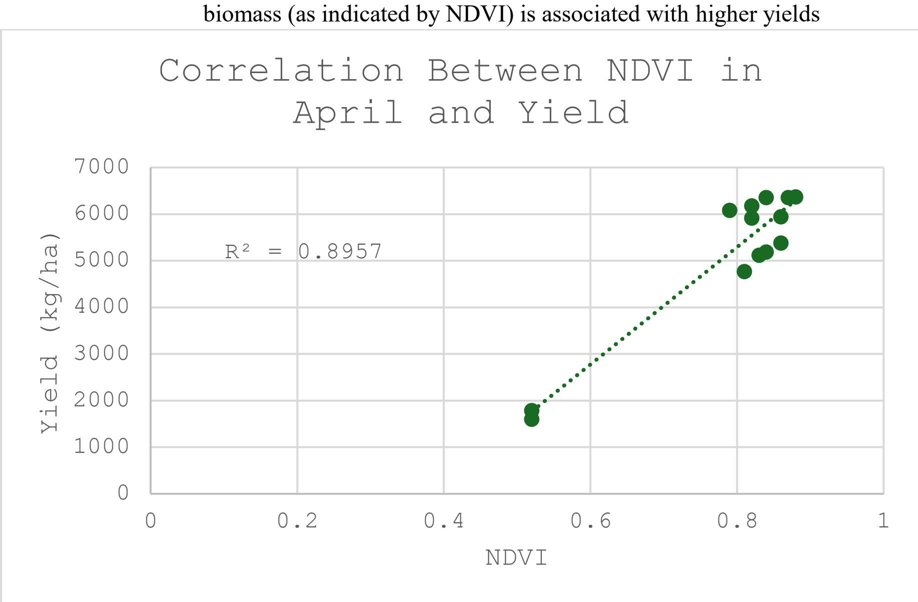
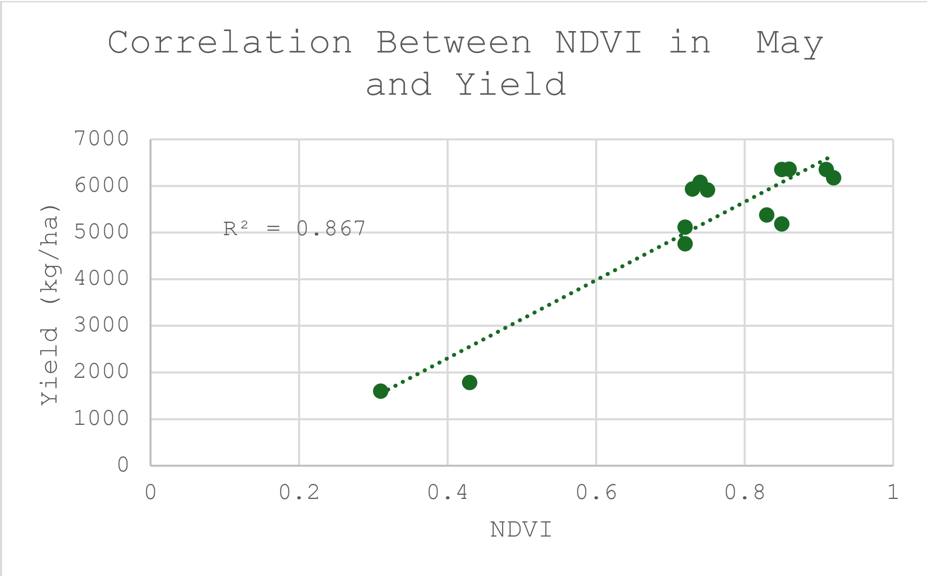


Table 3.

Strong positive correlation indicating a strong positive linear relationship between NDVI values and yield, although slightly lower than April. As NDVI increases, the yield value also increases, which suggests that higher vegetation health or biomass (as indicated by NDVI) is associated with higher yields



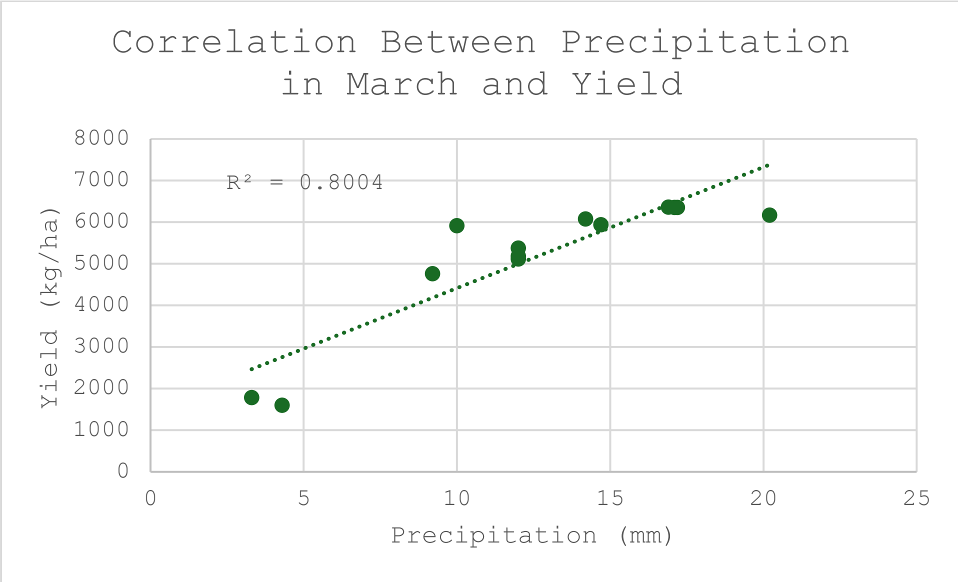
Since NDVI is correlated with vegetation health, these two graphics suggest that NDVI in April and May are strong predictors of production outcomes. The slightly lower r value in May compared to April (r_{May}= 0,931118; r_{April}= 0,94639687) might indicate that other factors beyond vegetation health start influencing the yield more as the growing season progresses. This suggests that monitoring during these periods can help farmers make more informed decisions regarding irrigation, nutrient application and crop protection.

Impact of Precipitation on NDVI and Yield

Precipitation data reveal considerable variability across the years, which has a direct impact on both NDVI values and the final wheat yield. For instance, in 2021, a year with cumulative precipitation around 300 mm, NDVI values were notably higher during the early growth stages (November and January), and the final yield passed 6000 kg/ha. In contrast, in 2020, when cumulative precipitation was only 170 mm, NDVI values remained lower throughout the season, resulting in a significantly lower yield (below 2000 kg/ha).

Table 4.

Strong Positive Correlation that suggests that March precipitation plays a significant role in determining the final yield of the wheat crop



March is often a critical month for wheat development, particularly in terms of water availability for the plant's early growth stages. Adequate moisture in March likely supports the wheat's vegetative development, ultimately leading to higher yields. The graph implies that ensuring sufficient water during this period, whether through irrigation or rainfall, could significantly boost wheat production. The R^2 value of 0.8004 indicates that 80.04% of the variation in wheat yield can be explained by the variation in March precipitation. This suggests a strong correlation, indicating that precipitation in March is a key factor influencing yield. The remaining 19.96% could be due to other variables such as soil conditions, temperature, or management practices.

Hectoliter Weight (GH) and its Relationship with NDVI

Hectoliter weight (GH) is an important measure of wheat quality, and its correlation with NDVI was also assessed. The results show that NDVI values during the reproductive stages (April and May) have a moderate to strong correlation with GH. This implies that higher NDVI values, indicative of healthier vegetation, are associated with better grain quality, as represented by a higher GH.

For example, in 2021, with an NDVI of 0.82 in April and 0.92 in May, the GH reached 80 kg/hl, indicating high-quality grain. In contrast, in 2020, with significantly lower NDVI values (0.52 in April and 0.31-0.43 in May), the GH was only 72 kg/hl.

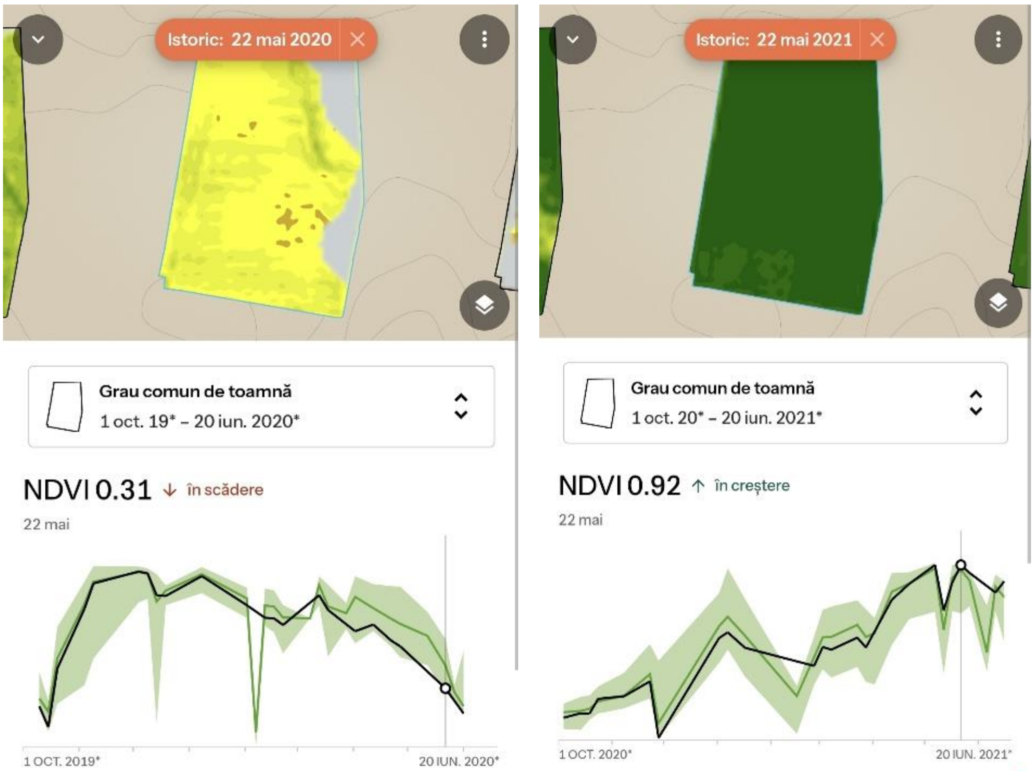
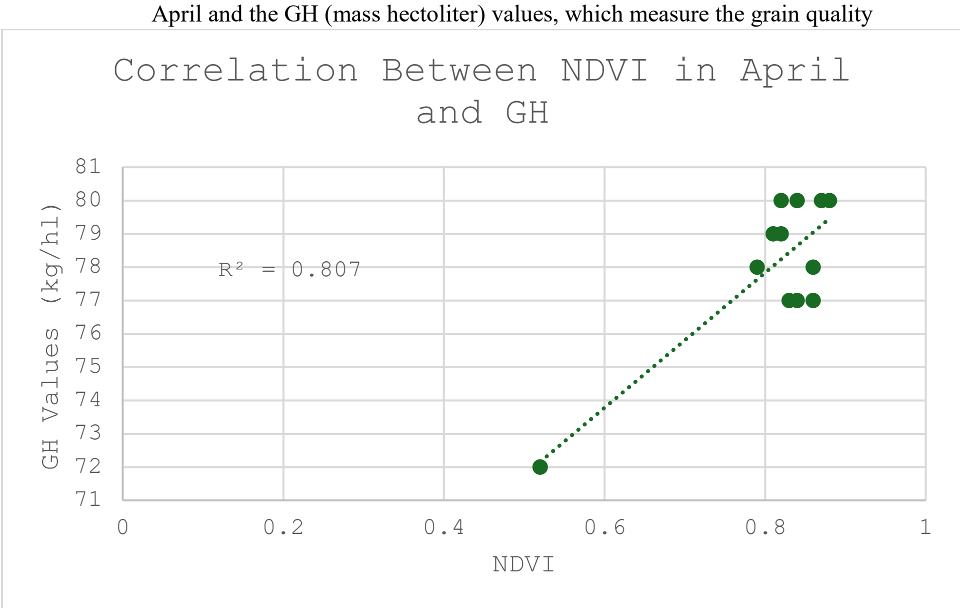


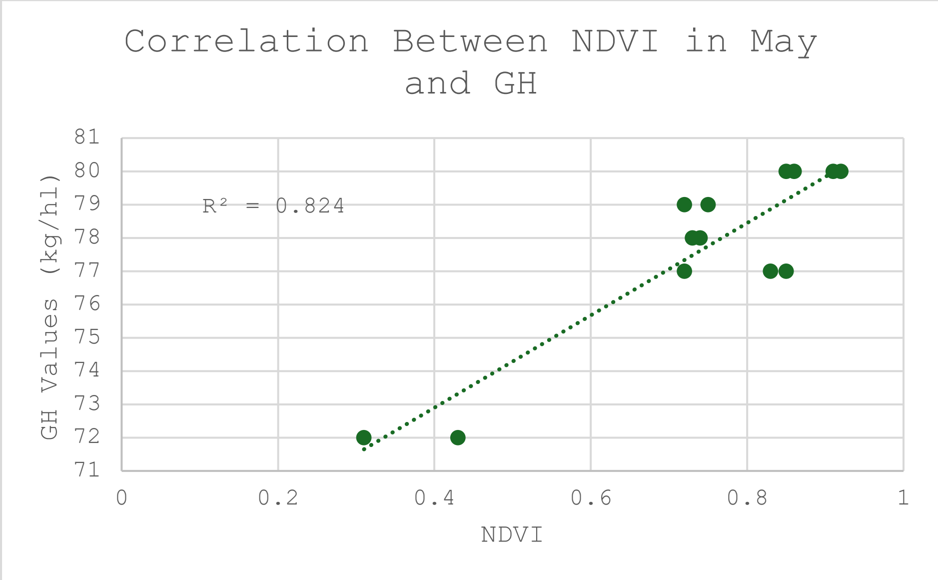
Table 5.
Positive Correlation between the NDVI values (indicating the health and density of the vegetation) in April and the GH (mass hectoliter) values, which measure the grain quality



The R^2 value of 0.807 shows that about 80.7% of the variation in GH can be explained by the variation in NDVI values in April. This suggests a strong correlation, indicating that the vegetation's health in April is a good predictor of grain quality (GH) at harvest.

Table 6.

Positive Correlation that shows a strong positive linear relationship between NDVI values in May and GH



Monitoring NDVI in April and May is an important tool for predicting grain quality, as plants with higher NDVI in this period generally result in denser, higher-quality wheat. Higher NDVI values, particularly those close to 0.8 and above, are associated with GH values above 78 kg/hl, indicating high-quality grain. This insight can guide farmers in decision-making regarding harvest timing, crop management, and potential yield quality.

CONCLUSIONS

NDVI values during the reproductive stages were the most reliable predictors of wheat performance. This suggests that NDVI can effectively guide farmers in making timely decisions regarding irrigation and nutrient management to maximize yield potential, especially in water-stressed environments like Dobrogea.

The results strongly indicate that integrating NDVI into precision agriculture practices can significantly enhance the decision-making process for farmers. By utilizing NDVI to monitor crop health during key growth stages, farmers can optimize their irrigation schedules, adjust fertilization, and anticipate yield outcomes with greater accuracy. In arid and semi-arid regions like Dobrogea, where water resources are limited and climate variability is high, NDVI provides a cost-effective, non-invasive tool for improving resource management and crop performance.

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