PADDY CROP MONITORING USING LANDSAT 8 AND SENTINEL DATA: A CASE STUDY INKANDI MANDAL OF TELANGNA, INDIA

ABSTRACT: Monitoring paddy crop using remote sensing data has become increasingly prevalent due to its ability to provide timely and spatially comprehensive information. This study focuses on the utilization of Landsat 8 and Sentinel satellite imagery for monitoring paddy crops in the Kandi Mandal of Telangana, India. The primary objective is to assess the feasibility and effectiveness of these satellite datasets in capturing key agricultural parameters such as vegetation indices and land use changes throughout the crop growth cycle. The methodology involves preprocessing of satellite imagery to derive spectral indices like Normalized Difference Vegetation Index(NDVI). Ground truth data collected through field surveys are used for validation and accuracy assessment. Temporal analysis of satellite data over multiple growing seasons provides insights into crop health, growth stages, and phenological changes. Results indicate that combining Landsat 8 and Sentinel data enhances the accuracy of crop monitoring compared to using a single dataset alone. The study demonstrates the potential of remote sensing technologies in supporting precision agriculture practices and informing decision-making processes for sustainable crop management.

Keywords: Remote Sensing, Landsat 8, Sentinel, Paddy Crop Monitoring, NDVI, Telangana

INTRODUCTION

In India, rice holds a crucial position as a staple food to maintaining the highest self-sufficiency rate compared to other agricultural products. Furthermore, it serves as a primary food source for more than half of the global population (Fukagawa*et al.*, 2019). The significant effects of global warming on crop cultivation, particularly heat stress, where high temperatures damage plants are increasingly undeniable and demand thorough assessment concerning their impact on productivity and food security (Karthikeyan, L.*et al*, 2020).

Rice crops are highly vulnerable to heat stress, which can result in stress and a decline in grain quality, primarily manifesting as cracked grains or white immature grains. These issues are often triggered by high temperatures occurring during the early grain-filling stage (Fahad, S. *et al*, 2019). Therefore, it is advisable to conduct harvesting promptly after the grain-filling stage to prevent exposing the plants to heat stress. Delayed harvesting can lead to excessive reduction in water content in paddy rice, resulting in cracked grains. Consequently, determining the optimal harvesting time is a pressing issue that requires resolution. In Japan, this timing is traditionally determined through field observations by local or regional authorities, using accumulated average daily air temperatures following the heading stage as a key factor in calculations (Sakaiya, E and Inoue, Y, 2013). Typically, the rice growth cycle starts with the vegetative stage, encompassing activities such as transplanting and tillering, which involves the development of multiple stems on a single plant (Brouwer, C, 1989). Once maximum tiller number is reached, the panicle initiation and heading begin, signifying the emergence of the panicle from the stem. This is followed by flowering and ripening stages. During grain filling, the grain initially contains milky liquid, which later turns sticky and eventually hardens as it matures. Consequently, the water content of the panicle gradually decreases throughout the ripening stage (Morris, M.L, 1980 and Yoshida, S, 1981). Indeed, yellowing and reduced water content in the panicle serve as practical indicators of harvest maturity. Satellite remote sensing is currently used for a variety of agricultural monitoring purposes (Ishitsuka, N and Ouchi, K, 2017, Liu, C, 2019).

Under the current global conditions of rising temperatures, remote sensing techniques provide a crucial means for accurately estimating harvest times at the individual paddy field level. This is particularly important as the spatial resolutions of satellite imagery data continue to improve. Optical remote sensing and vegetation indices calculated from near-infrared and visible bands are used to retrieve crop and canopy water contents (Xu, C, et al. 2020 and Pan, H, 2018). The Multi Spectral Remote Sensing images are very efficient for obtaining a better understanding of the earth environment (Ahmadi and Nusrath, 2012). The multispectral remote sensing images carry essential integrating spectral and spatial features of the objects. In this study, the multispectral image of Kandi Mandal is used to extract Vegetation index (VI) is a simple and effective measurement parameter, which is used to indicate the earth surface vegetation covers and crops growth status.

The Normalized Difference Vegetation Index (NDVI) is widely recognized as the gold standard for assessing vegetation and crop health. NDVI is the most commonly used vegetation index (VI), with other indices being refined versions of it (Ramli *et al.*, 2014). The health of a plant is determined by the amount of chlorophyll in its leaves (Pavlovic et al., 2015). Chlorophyll absorbs near-infrared light (NIR) and reflects visible light. By comparing NIR reflectance and visible light, healthy plants exhibiting strong photosynthetic activity can be analyzed (Mee *et al.*, 2017). Vegetation indices, which are mathematical transformations of image bands, are used to qualitatively extract specific spectral properties such as vegetation cover, vigor, and growth dynamics (Xue and Su, 2017). Each vegetation index is designed for specific applications and has unique advantages. These indices also enhance plant health classification and evaluation algorithms (She *et al.*, 2015).

Remote sensing data is a valuable resource for monitoring and mapping vegetation cover. Vegetation indices were developed to track vegetation distribution and phenology.

This study focuses on how remote sensing can monitor paddy field conditions using indices like NDVI. According to a study by Kamaruddin (2018), NDVI values were classified into three categories: healthy, non-healthy, and non-vegetation. This classification method was also applied in this research. Additionally, the estimation values of NDVI is investigated. Landsat 8 and Sentinel data is processed using ArcGIS software for this analysis.

METHODOLOGY

Study Area

The study area was carried out at six different locations in kandi mandal of Sangareddy district, Telangana (fig.1) with the following latitude and longitude is 17.5830° N, 78.1074° E. Kandi mandal has a diverse population consisting of various communities and castes. The majority of the population is engaged in agriculture and related activities. The region has fertile soil and a favourable climate supporting the cultivation of crops like paddy, cotton, maize, and vegetables. Farmers employs traditional farming techniques as well as modern practices.

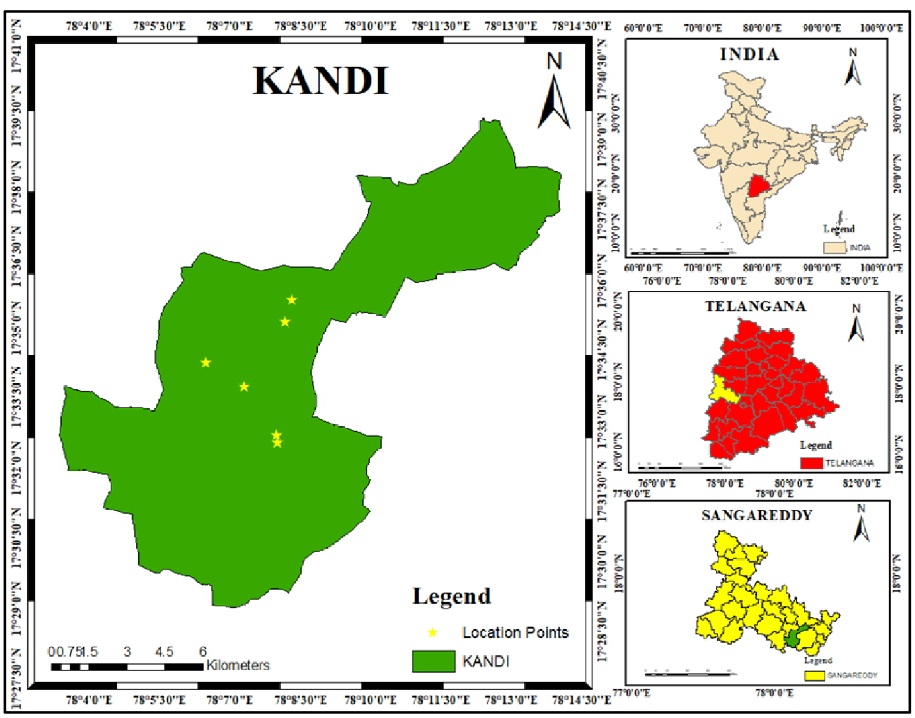


Fig 1: Location map of Kandi Mandal study area.

FIELD DATA:

Ground truth data such as crop type, planting date, and harvesting date can be collected from the field and location coordinates using a handheld GPS device. The samples were collected from following six different locations in the months of February, March and April, 2023.

Table 1: Different locations of data collection for study.

S.NO.	Location Name	LOCATION (COORDINATES)	CROP TYPE	SOWING DATE	HARVESTING DATE
1.	Kandi 1	17° 34' 14.709"N, 78° 6' 28.61496"E	Paddy	03/01/2023	30/04/2023
2.	Kandi 2	17° 33' 44.24976"N, 78° 7' 17.66712"E	Paddy	05/01/2023	01/05/2023
3.	Cheriyal 1	17° 32' 32.42868"N, 78° 8' 0.3102"E	Paddy	27/12/2022	29/04/2023
4.	Cheriyal 2	17° 32' 42.6804"N, 78° 7' 58.92816"E	Paddy	24/12/2022	27/04/2023
5.	Mamidipalli 1	17° 35' 7.02636"N, 78° 8' 9.99744"E	Paddy	02/01/2023	29/04/2023
6.	Mamidipalli 2	17° 35' 35.6118"N, 78° 8' 18.5514"E	Paddy	03/01/2023	01/05/2023

CHLOROPHYLL

Chlorophyll is a green pigment found in plants and other photosynthetic organisms such as algae and some bacteria. It plays a critical role in the process of photosynthesis, which is the conversion of light energy into chemical energy that fuels plant growth and development.

There are several types of chlorophyll, with the most common forms being chlorophyll-a and chlorophyll-b. Chlorophyll-a is the primary pigment responsible for capturing light energy during photosynthesis. Chlorophyll-b helps to expand the range of light wavelengths that can be absorbed by plants.

In remote sensing, chlorophyll is used as an indicator of vegetation health and productivity.

Spectrophotometer:

SYSTRONICS UV-VIS SPECTROPHOTOMETER 119 PC based instrument. It offers 1 nm bandwidth. It provides three measuring modes: Percent Transmittance (% T), Absorbance (ABS) and Concentration (CONC) with factors. The available operating modes are Single-Wavelength, Multi-Wavelength, Spectrum Scan and Time Scan.

It covers the wavelength range from 200-1000 nm Special software supports Multi-standard Calibration with linear or non-linear curve fitting for concentration measurements. The Personal Computer & application software enhance the data processing ability and offer: Peak-Pick, Point-Pick, Expansion of Spectra, Overlaying of Spectra, 1" to 4" Derivatives, Averaging of two Scans, Subtraction of two Scans and Concentration Calculations.

NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

This study aims to process images and return the Normalized Difference Vegetation Index (NDVI) using landsat-8 and sentinel-2 satellite images. NDVI is an index commonly used in satellite image analysis to get basic information on vegetation distribution. Two of these bands used to generate NDVI are NIR and Red. The negative values indicate water, close to +1, there’s a high possibility that it is dense green leaves. The NDVI is close to zero, could even be an urbanized area. Soils typically produce low NDVI values (0.1–0.2). Moderate NDVI values may be produced by sparse vegetation, such as shrubs and grasslands (0.2–0.5). NDVI was calculated by using the following formula:

$$\text{NDVI} = \frac{NIR - RED}{NIR + RED}$$

Here, NIR and RED stands for the spectral reflectance attained in the near infrared regions and red (visible) regions respectively.

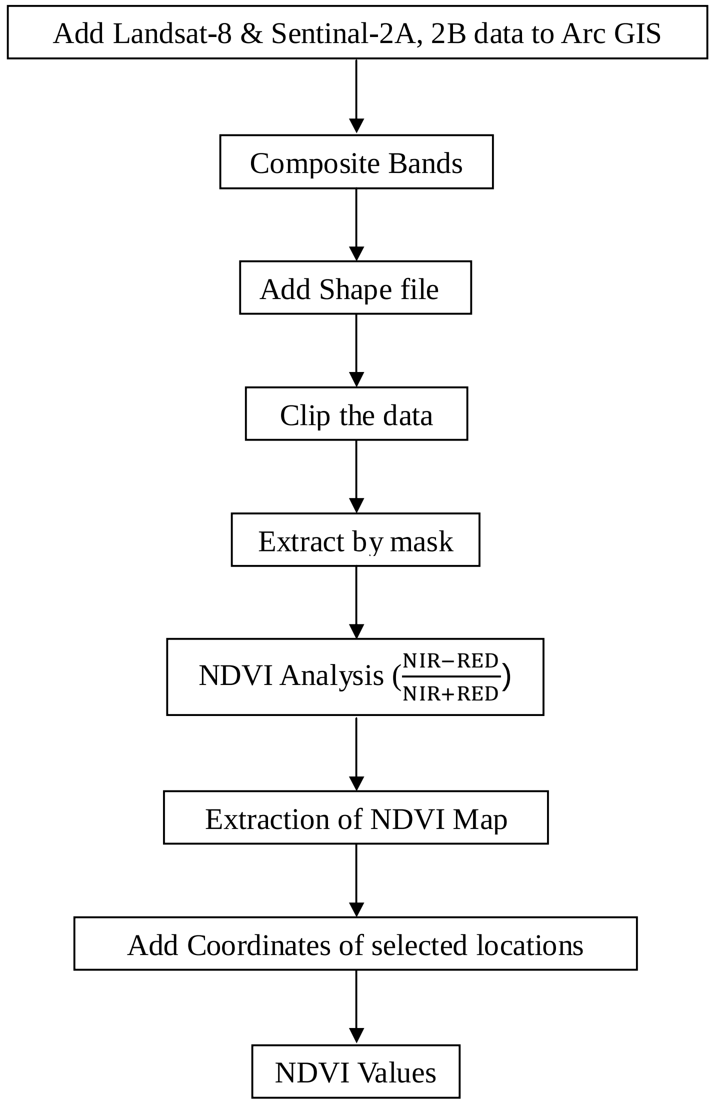


Fig 2: Flowchart for NDVI extraction using Arc GIS

RESULTS AND DISCUSSION

Estimation of chlorophyll concentration of paddy crop and NDVI

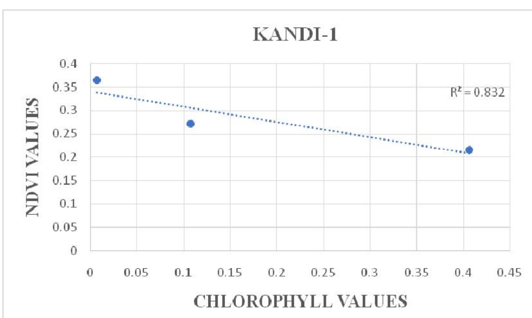
Chlorophyll is the essential component of photosynthesis, and occurs in chloroplasts as green coloured pigments. Estimation of chlorophyll content of paddy crop at six different locations, destructive method was followed by using spectrophotometer. The following results were obtained from spectrophotometer.

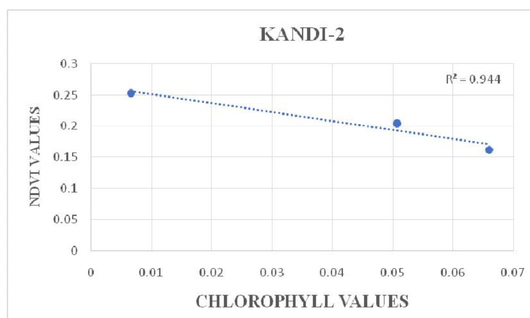
Table 2 Spectrophotometer Readings of Paddy crop and NDVI values of Lansat-8, Sentinel-2 Satellite data.

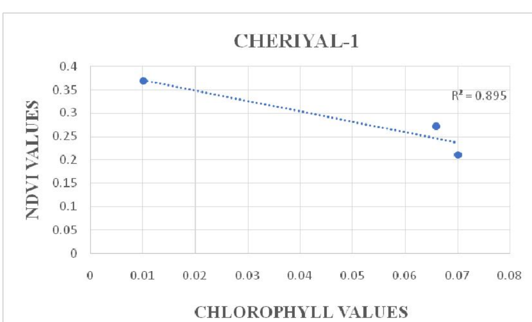
Location	Chlorophyll values			NDVI values Landsat-8			NDVI values Sentinel-2		
	Feb	March	April	Feb	March	April	Feb	March	April
Kandi-1	0.41	0.11	0.01	0.22	0.27	0.36	0.36	0.57	0.58
Kandi-2	0.07	0.05	0.01	0.16	0.21	0.25	0.17	0.20	0.23
Cheriyal-1	0.07	0.06	0.01	0.21	0.27	0.37	0.43	0.54	0.47
Cheriyal-2	0.06	0.05	0.02	0.18	0.23	0.34	0.40	0.53	0.55
Mamidipalli-1	0.06	0.058	0.02	0.24	0.28	0.32	0.44	0.49	0.52
Mamidipalli-2	0.07	0.05	0.01	0.17	0.19	0.36	0.31	0.34	0.57

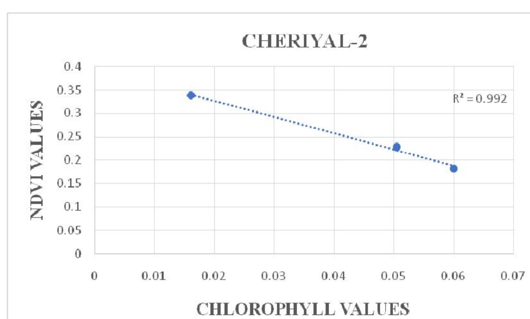
Correlation between Chlorophyll content and NDVI values

Higher chlorophyll content in plants is associated with healthier and more vigorous vegetation, leading to higher photosynthetic activity and, consequently, higher NDVI values. Conversely, lower chlorophyll content may indicate stressed or less productive vegetation, resulting in lower NDVI values.









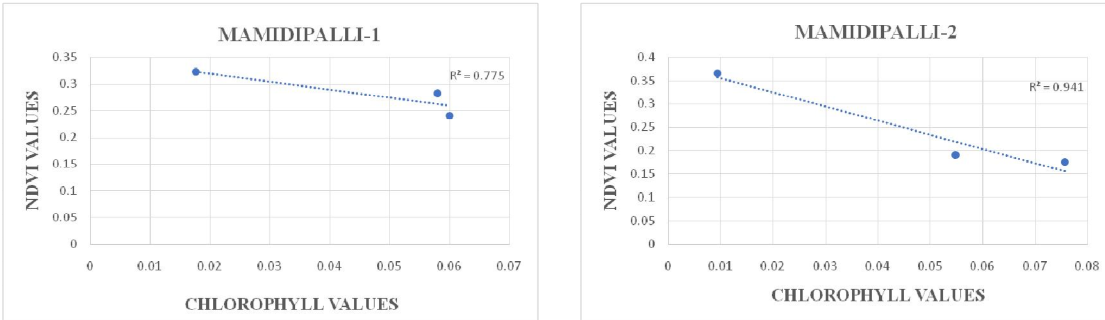


Fig:3Corrrelation between Chlorophyll and NDVI values of Landsat 8 Satellite Images.

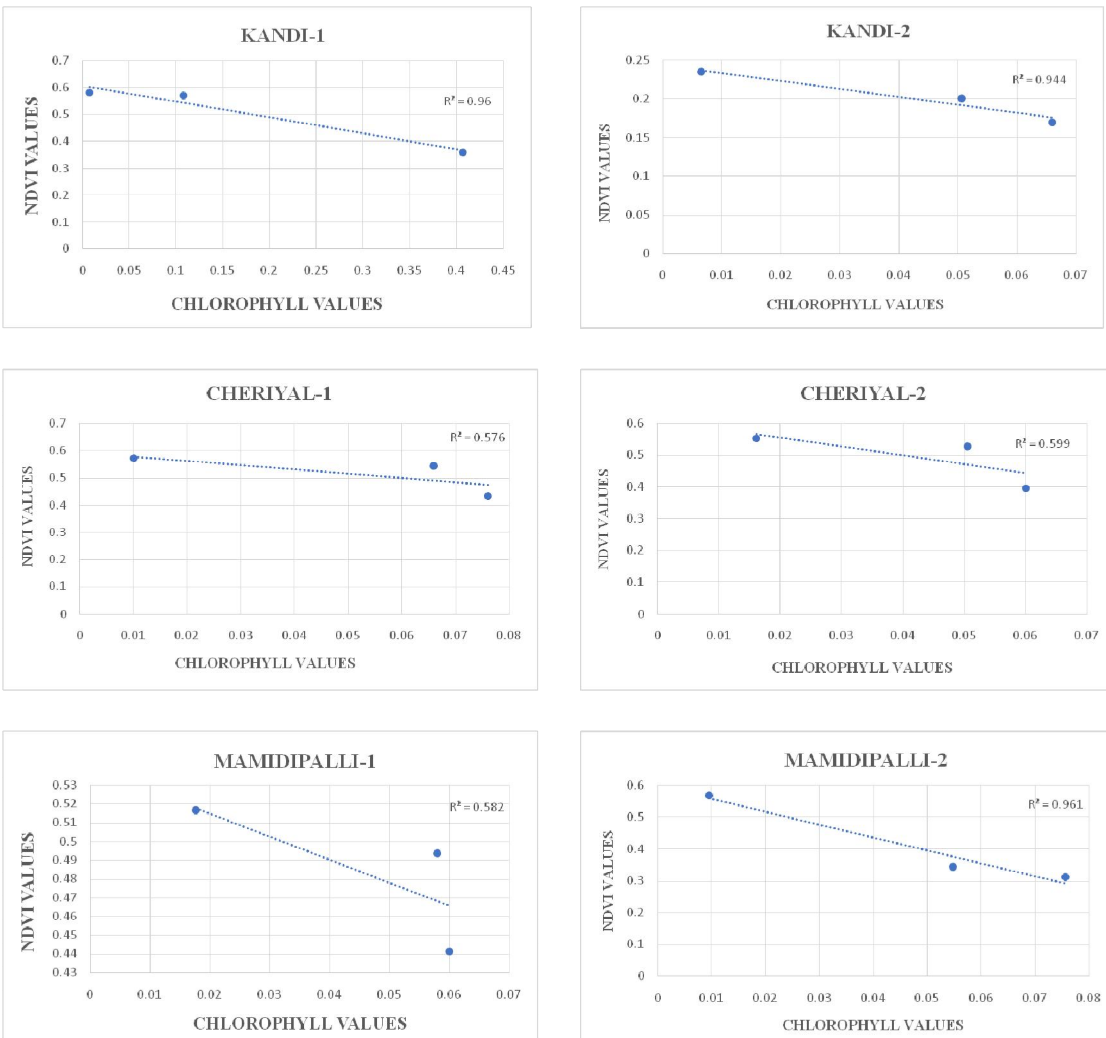


Fig:4 Correlation between Chlorophyll and NDVI values of Semtinel-2 Satellite Images.

There is a strong positive correlation between chlorophyll values and NDVI values, indicating a close relationship between plant health and photosynthetic activity. The correlation between chlorophyll values and NDVI values typically falls within the range of 0.7 to 0.9, indicating a strong positive relationship between the two variables as shown in Fig: 3& Fig.4.

Normalized Difference Vegetation Index (NDVI) Trends for Paddy Crop in Kandi

This analysis can involve plotting the NDVI values against time to observe the trend visually. Calculated statistical measures such as the mean or maximum NDVI values during the crop period. Generally, a rising or consistent NDVI trend throughout the crop period indicates healthy vegetation and productive growth. A declining trend might suggest issues like water stress, disease, pest infestation (Huang, J, et al. 2014).

The following are the Normalized Difference vegetation Index trend (landsat-8) of paddy crop during it's crop period i.e., December, 2022 to April, 2023.

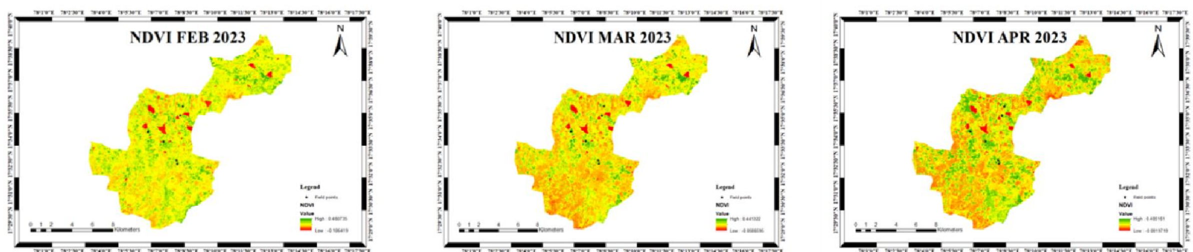


Fig 5. NDVI Map of Kandi of Feb, March, April 2023

The following are the Normalized Difference vegetation Index trend (Sentinel-2) of paddy crop during it's crop period i.e., December, 2022 to April, 2023.

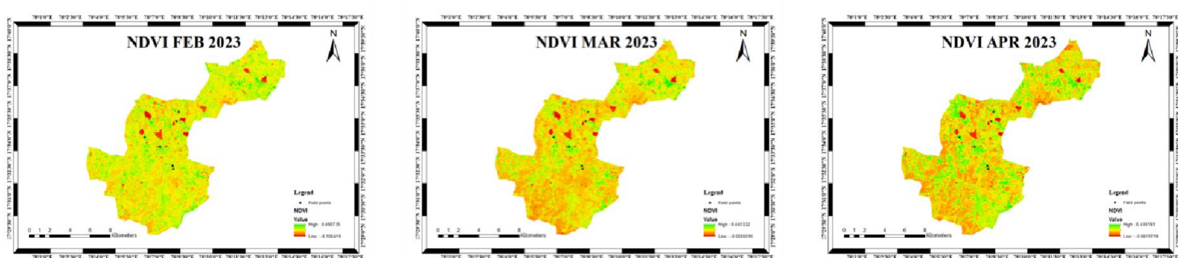


Fig 6: NDVI Map of Kandi of Feb, March, April 2023.

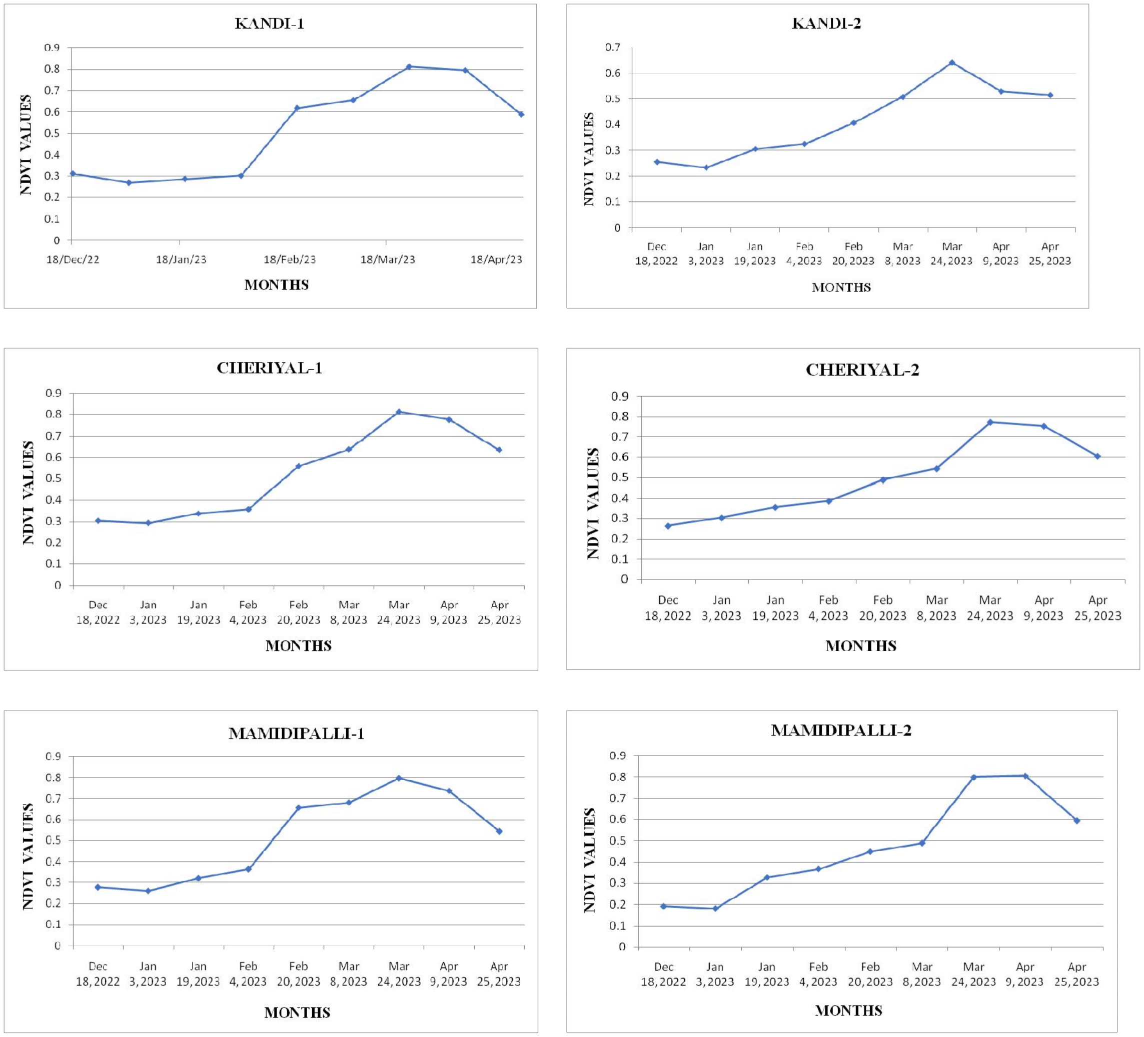
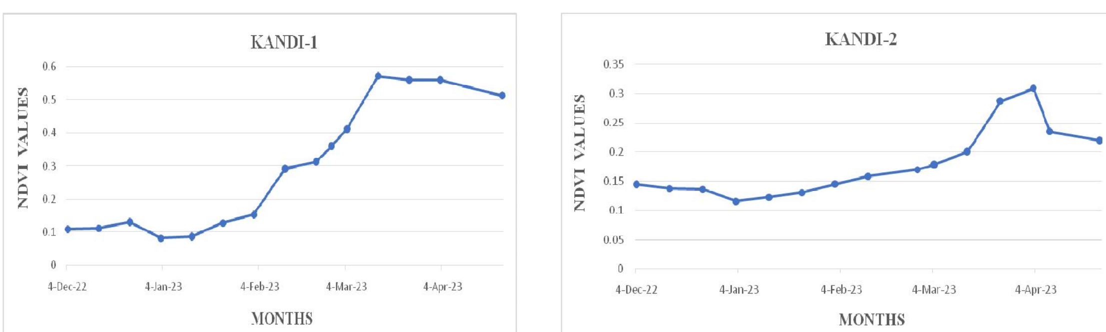


Fig:7 NDVI trend of six location in Kandi Mandl using Landsat-8 Satellite



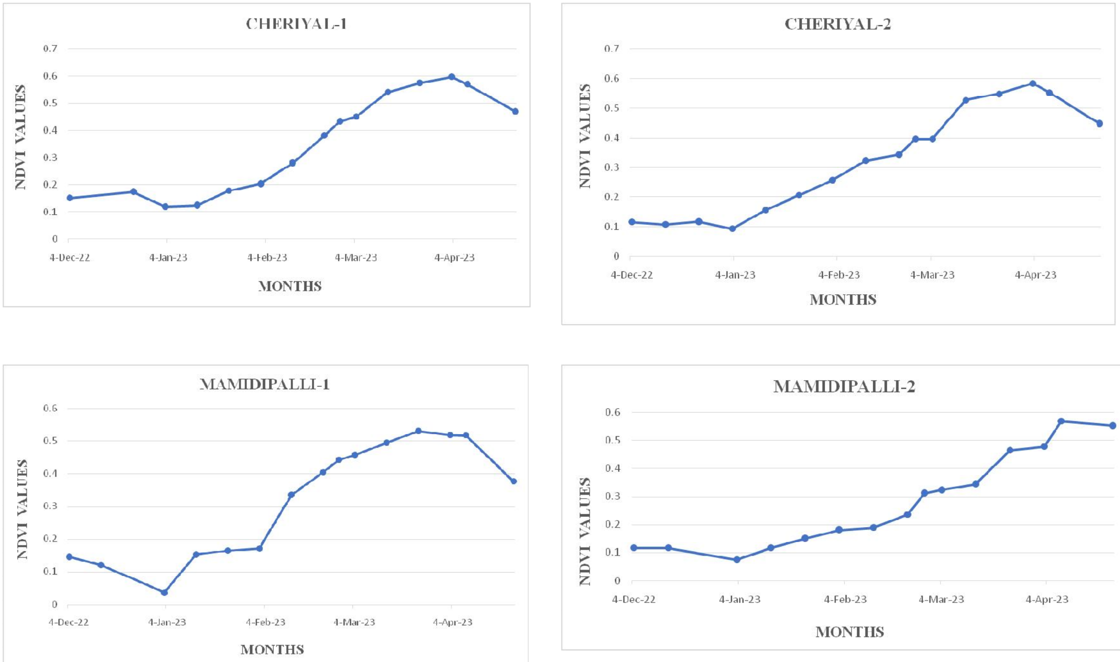


Fig:8 NDVI trend of six location in Kandi Mandl using Sentinel-2 Satellite

The NDVI (Normalized Difference Vegetation Index) trend of paddy fields is an important indicator of the health and productivity of rice crops. Paddy fields undergo distinct NDVI trends throughout their growth stages.

During the initial stage, when the paddy fields are flooded and seeds are sown, the NDVI values tend to be relatively low. As the plants begin to germinate and establish their root systems, the NDVI values gradually increase. During the vegetative stage, as the rice plants continue to grow and develop their leaf canopies, the NDVI values reach their peak. This indicates a dense and healthy vegetation cover, which is crucial for maximizing photosynthesis and biomass production.

As the rice plants enter the reproductive stage, the NDVI values may start to decline slightly. This is a natural phenomenon as the focus shifts from leaf growth to reproductive processes such as flowering and grain development. Towards the end of the crop cycle, when the rice plants mature and approach harvest, the NDVI values may decrease further as the vegetation begins to senesce and dry up. This decline in NDVI indicates the approaching end of the growing season. Monitoring the NDVI trend of paddy fields over time can provide valuable insights into the overall growth, vigor, and productivity of the rice crops. It helps farmers and researchers assess the health of the plants, identify stress or nutrient deficiencies, optimize irrigation and fertilizer applications, and make informed decisions regarding crop management practices.

The fig 7 shows the NDVI values of paddy crop during its crop period. The NDVI values are least during mid of December to mid of January, then increased from February to end of March and decreased in the month of April which is harvesting time. The peak NDVI value was observed in March i.e., 0.81 being highest vegetation in this period for the Lansat-8 satellite data. The following are the Normalized Difference vegetation Index trend (sentinel-2) of paddy crop during it's crop period i.e., December, 2022 to April, 2023.

The fig 8 shows the NDVI values of paddy crop during its crop period. The NDVI values are least during mid of December to mid of January, then increased from end of January to mid of March and decreased from end of March to April which is harvesting time. The peak NDVI value was observed in March i.e., 0.57 being highest vegetation in this period.

CONCLUSION

The chlorophyll content of paddy crops is essential for assessing plant health and productivity. Monitoring chlorophyll levels provides insights into growth, nutrient status, and stress levels. NDVI maps, ranging from -1 to +1, offer valuable information on vegetation health and density. Correlating chlorophyll content and NDVI values allows targeted monitoring. Strong positive correlations indicate healthy, high-yielding regions, while weak or negative correlations highlight areas needing interventions. Comparing NDVI trends across locations enables spatial analysis, identifying regional variations in crop performance. This information helps optimize land management, identify high-potential areas, and provide additional support where required. Overall, the correlation between NDVI values and chlorophyll content proves to be a good fit, aiding in effective monitoring and management of paddy crops.

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Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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