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REMOTE SENSING AND GIS BASED CROP MONITORING: A CASE STUDY OF TAVRA VILLAGE IN VADODARA

Abstract: Food security is increasingly challenged by environmental changes, natural resource degradation, and population growth. Crop yields have already stagnated in many regions and are further affected by rising temperatures. The growing global population imposes a direct demand on agriculture to produce food, fiber, and fodder, necessitating the consumption of vast amounts of water. To maximize agricultural productivity and ensure sustainable crop yields, continuous crop monitoring is essential. Remote sensing has emerged as a powerful technology for vegetation monitoring, enabling spectral analysis of high-resolution satellite imagery to assess crop health and development. This study utilizes remote sensing techniques in conjunction with Geographic Information Systems (GIS) to monitor crop conditions. The Green Chromatic Coordinate (GCC) and Normalized Difference Vegetation Index (NDVI) were estimated using Landsat-9 satellite imagery. The analysis was conducted using QGIS for Tavra Village Farm, near Parul University, Waghodia, Vadodara, Gujarat, India. The observed GCC values ranged from 0.9352 to 0.3297, while NDVI values varied between 0.3300 and 0.0398 over the temporal period. The trend analysis of GCC and NDVI indicated an initial increase from November (early crop growth stage) to January (mid-growth stage), followed by a decline by February (crop maturity stage). These findings demonstrate the effectiveness of remote sensing and GIS in monitoring crop growth patterns, offering valuable insights for precision agriculture and resource management.

Keywords: Crop Monitoring, Remote Sensing, GIS, GCC, NDVI

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Introduction

Agriculture is fundamental to global food security, providing essential resources such as food, fiber, and fodder. Smallholder farmers contribute significantly to food production, making their success crucial in sustaining national and global food supplies. However, climate change-induced challenges, including extreme weather events, soil degradation, and water scarcity, have led to fluctuating agricultural productivity, resulting in reduced yields and economic losses for farmers. In this context, efficient crop monitoring has become vital for optimizing agricultural production and mitigating climate variability (Jongmin et al., 2019). Crop monitoring involves real-time vegetation index analysis through high-resolution spectral imaging, enabling continuous observation of crop growth and health (Infantial & Anitha, 2017). Key parameters such as plant density, leaf area index, crop height, and chlorophyll content are assessed using advanced techniques (Toshihiro et al., 2011), including satellite-based remote sensing, Unmanned Aerial Vehicle (UAV) monitoring (Hunt et al., 2010), and Internet of Things (IoT) applications (Sakthipriya, 2014). Among these, Remote Sensing (RS) and Geographic Information Systems (GIS) play a critical role in agricultural monitoring, providing large-scale, cost-effective, and accurate data for crop health assessment, soil moisture estimation, and land use classification (Dadhwal, 2006). By integrating RS and GIS, thematic maps can be generated to analyze vegetation indices, detect plant stress, and support precision farming (Singhal et al., 2018).

Remote sensing platforms, including ground-based, airborne, and space borne sensors, facilitate continuous monitoring of crop phenology throughout the growing season (Li et al., 2022). Satellites like Sentinel and Landsat provide high-resolution imagery that captures spectral reflectance variations, particularly in the visible and near-infrared regions, revealing insights into plant health and chlorophyll content (Khabbazan et al., 2019). Vegetation indices such as the Green Chromatic Coordinate (GCC) and the Normalized Difference Vegetation Index (NDVI) are widely used to assess crop vigor, detect stress conditions, and estimate yield potential (Gandhi et al., 2015). The integration of RS and GIS in agriculture enhances resource efficiency, ensuring timely decision-making for improved productivity (Mamatkulov et al., 2021). Given the increasing threats to food security from environmental changes and resource depletion, adopting advanced crop monitoring techniques is essential (Norasma et al., 2018). Traditional methods, such as field surveys and census-based assessments, are labor-intensive and time-consuming, whereas RS and GIS provide efficient, scalable, and real-time solutions (Shanmugapriya et al., 2019). This study focuses on the application of RS and GIS for crop monitoring using GCC and NDVI indices, aiming to prepare biophysical variable maps and analyze spatial and temporal crop variability. By leveraging these technologies, precision agriculture can be enhanced, leading to sustainable farming practices and better resource management (Mishra, 2017).

Materials and Methods

The outlines of materials and methodologies used for crop monitoring using Remote Sensing and GIS techniques are described in the following flowchart (Figure 1). This methodology ensures precise spatial data analysis for assessing vegetation dynamics, crop health, and environmental impacts over time (Koen et al., 2018).

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Crop Monitoring Objective
    ↓
Metadata of Landsat-9
    ↓
Data Acquisition
    ↓
Image Processing
        ├─ Band Composition
        ├─ Clipping/Subsetting
        ├─ TCC/FCC Maps
    ↓
Calculate GCC & NDVI
    ↓
Extraction of Point Values from Satellite Image Data
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Fig. 1. Flowchart of Crop Monitoring Process using RS and GIS
Source: Own elaboration

Study Area:

Vadodara district, located in the state of Gujarat, India, spans a total geographical area of 4,110 km^2. The study area for crop monitoring is a section of Tavra village farm near Parul University in Waghodia taluka of Vadodara district. This specific study area is geographically positioned at 22°17'32" N latitude and 73°24'44" E longitude. The total land coverage of Tavra village farm is approximately 461.95 hectares, and a selected portion of this land (Figure 2) was analyzed for vegetation monitoring. The primary objective of this study was to assess the greenness and overall vegetation health of the region, contributing to better agricultural management and resource utilization.

To achieve this, satellite imagery from the Landsat-9 OLI/TIRS C2 Level-2 dataset was utilized. These images, formatted in GeoTIFF and referenced to the WGS84 datum, were sourced from Path 148 and Row 45 (Figure 3). This dataset provided high-resolution temporal data crucial for accurately monitoring vegetation dynamics, assessing crop health, analyzing growth patterns, and evaluating environmental changes over time (Torres-Sanchez et al., 2014).

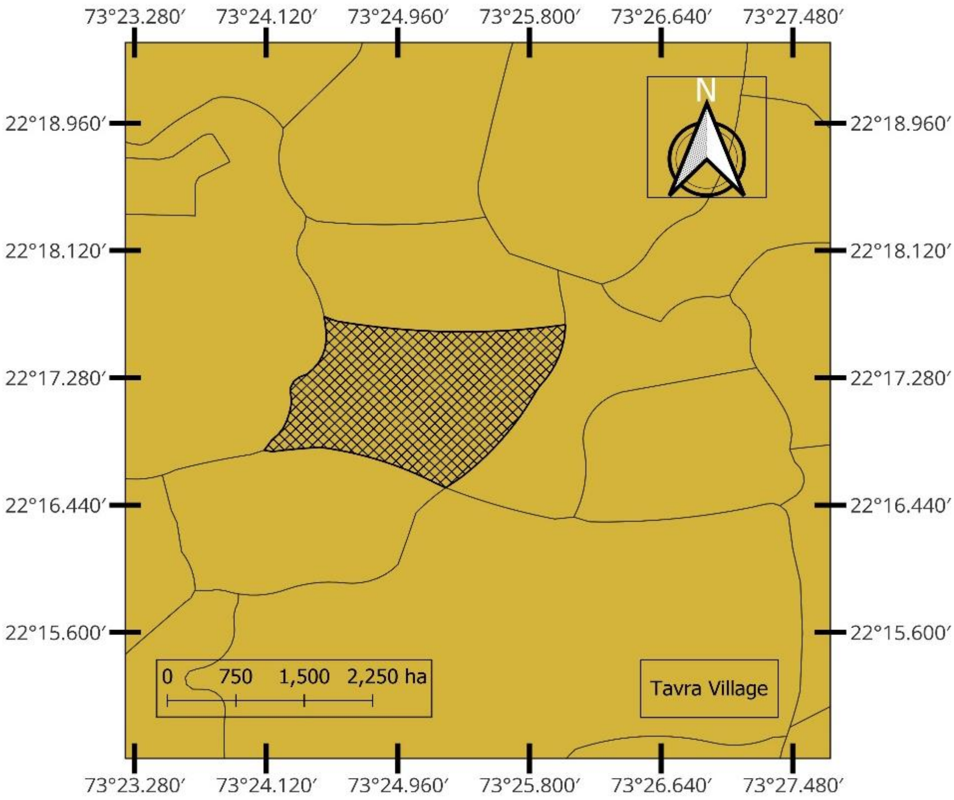

Fig. 2. Location Map of Study Area
Source: Own elaboration

Fig. 3. Clipping of Study Area from Landsat-9 Imagery
Source: Own elaboration

Estimation of Remote Sensing based Vegetation Indices:

Green Chromatic Coordinates (GCC). GCC is a widely used vegetation index that quantifies greenness using reflectance values from visible spectral bands. It is calculated as the ratio of the green digital number (DN) to the sum of red, green, and blue DNs:

$$GCC = \frac{Green\ DN}{Green\ DN + Blue\ DN + Red\ DN}$$

GCC values range from 0 to 1, where higher values indicate healthy vegetation, while lower values represent bare soil or non-vegetated surfaces. This index effectively tracks plant chlorophyll content and overall vegetation health (Vyas et al., 2020).

Normalized Difference Vegetation Index (NDVI). NDVI is a widely used vegetation index that measures plant health by comparing the reflectance of red and near-infrared (NIR) light (Rahman et al., 2004):

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

NDVI values range from -1 to 1, where negative values correspond to water or barren land, while values closer to 1 indicate dense, healthy vegetation (Zalavadiya et al., 2019). This index helps assess vegetation density, biomass, and moisture content (Bhandari et al., 2012).

Estimation of Crop Health Using QGIS:

Using QGIS, GCC and NDVI were calculated via the raster calculator for crop health assessment. Extracting temporal GCC and NDVI values at specific points allowed for monitoring vegetation dynamics over a 16-day interval. Steps include:

– GCC Calculation: Raster Calculator → Apply GCC formula.
– NDVI Calculation: Raster Calculator → Apply NDVI formula.
– Point Value Extraction: Identify feature tool → Select points on the map → Extract temporal values.

These indices provide crucial insights into crop conditions, aiding precision agriculture and land management.

Results and discussion

Estimation and Temporal Variability of Bio-Physical Variable Maps:

The estimation and temporal variability of bio-physical variables, including Green Chromatic Coordinate (GCC) and Normalized Difference Vegetation Index (NDVI) maps, derived from Landsat-9 images collected between November 20, 2022, and February 24, 2023, using QGIS.

GCC Maps. GCC maps were generated using reflectance from red, green, and blue channels of Landsat-9 (Figure 4) to monitor the stability of greenness over time. The GCC values for the study area ranged from 0.2953 to 0.4146, with the highest observed in December 2022. The temporal variability trend of GCC shown fluctuations (Figure 5) across different periods from November 2022 to February 2023.

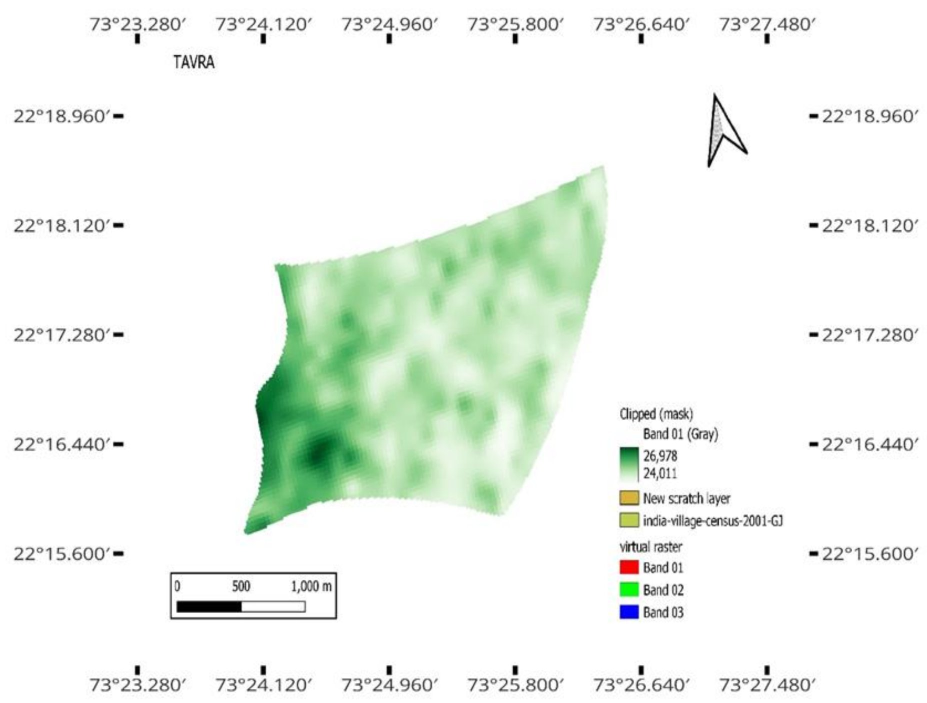

Fig. 4. GCC Map of Study Area
Source: Own elaboration

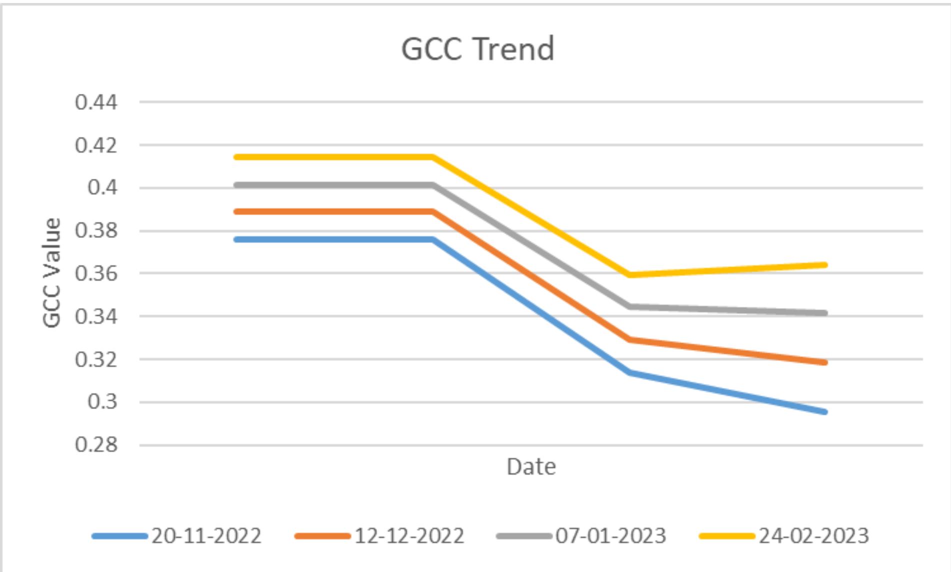

Fig. 5. Trend of GCC for Study Area
Source: Own elaboration

NDVI Maps. NDVI maps, created using visible and near-infrared reflectance (Figure 6), were used to assess vegetation density and health. NDVI values ranged from 0.0124 to 0.5486 during the study period. The temporal variability of NDVI for various plots (Figure 7) showed noticeable changes in vegetation cover, with trends observed from November 2022 to February 2023.

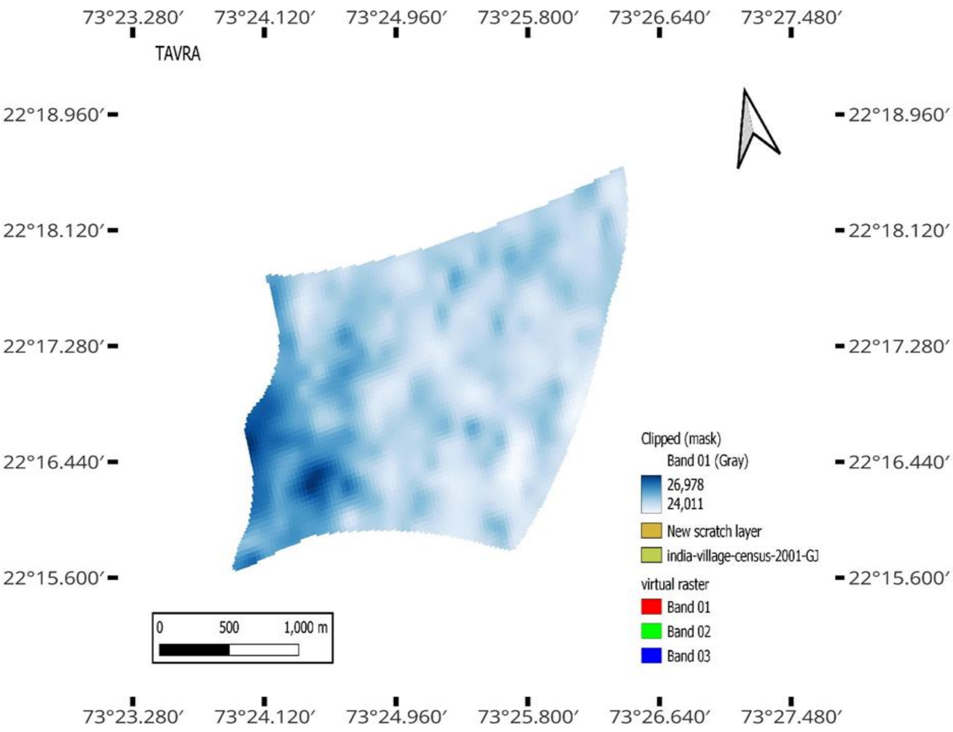

Fig. 6. NDVI Map of Study Area
Source: Own elaboration

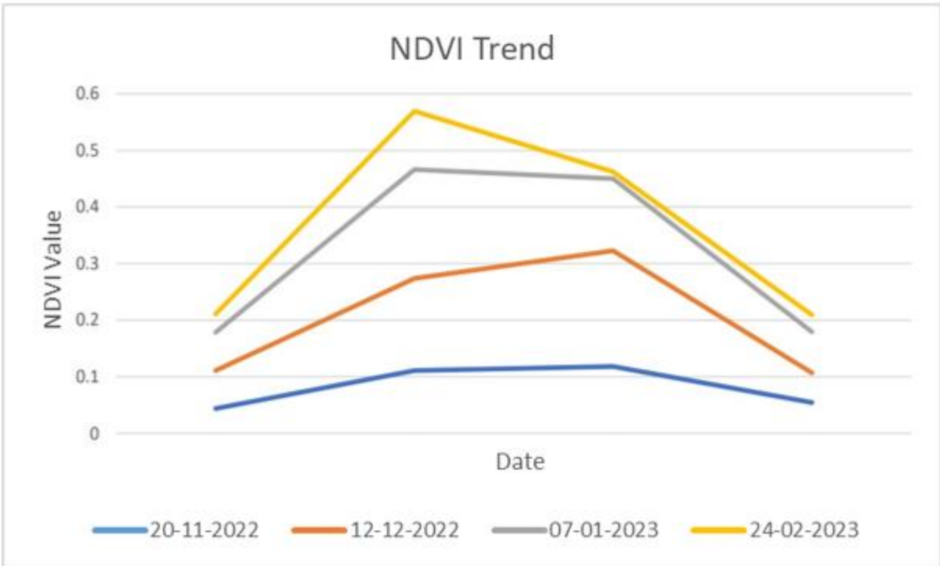

Fig. 7. Trend of NDVI for Study Area
Source: Own elaboration

Together, the GCC and NDVI maps provide valuable insights into the dynamic changes in vegetation over time, supporting the assessment of crop and vegetation health.

Conclusions

This research study demonstrated the effectiveness of Remote Sensing (RS) and Geographic Information Systems (GIS) in monitoring crop health and growth dynamics in Tavra Village, Vadodara, using satellite-derived vegetation indices, namely Green Chromatic Coordinate (GCC) and Normalized Difference Vegetation Index (NDVI). The results showed that GCC values ranged from 0.2953 to 0.4574, and NDVI values ranged from 0.0124 to 0.5486 between November 20, 2022, and February 24, 2023. Temporal analysis indicated a pattern where both GCC and NDVI values initially increased from November to January, reflecting the crop's growth, before decreasing by February at harvesting stage. These findings highlight the potential of RS and GIS technologies in providing accurate, timely assessments of crop conditions, aiding in efficient agricultural management and decision-making.

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