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Sesame crop growth monitoring using time-series green chromatic coordinate (GCC) from sentinel-2 and digital camera data

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Abstract

Accurate monitoring of crop growth is essential for precision agriculture. This study evaluated the spatio-temporal variability of Green Chromatic Coordinate (Gcc) for the sesame crop using ground-based digital camera images and Sentinel-2 satellite imagery during the 2019-20 summer season. Gcc maps were generated for multiple dates from March 01 to May 10, 2020, using QGIS 3.16. Temporal analysis showed that Gcc values increased up to peak vegetative stages and decreased during crop maturity, reflecting canopy development and senescence. Camera-based Gcc values ranged from 0.00 to 0.94, while Sentinel-2 Gcc values ranged from 0.24 to 0.37. Comparative analysis demonstrated the effectiveness of integrating both ground and satellite data for crop monitoring. The findings indicate that Gcc can serve as a reliable indicator of sesame crop growth for spatio-temporal assessment and precision agriculture applications.

Keywords: Crop monitoring, Digital Camera, Green Chromatic Coordinate (Gcc), Sentinel-2, Sesame crop, Spatio-temporal analysis

Introduction

Sesame (*Sesamum indicum* L.) is an important oilseed crop cultivated widely in tropical and subtropical regions due to its high oil content and nutritional value. The crop performs best under warm climatic conditions and is generally classified as a short-day plant, requiring temperatures of about 25-27 °C for optimal growth and development. Summer cultivation of sesame in regions such as Gujarat is particularly advantageous because of favourable temperature regimes, suitable photoperiod, and availability of irrigation, which together contribute to improved crop establishment and higher productivity (Ranganatha, 2010; Monpara and Vaghasia, 2016) [4, 3]. Despite its adaptability, sesame yield is highly sensitive to variations in weather conditions, soil moisture, and crop management practices. Therefore, timely monitoring of crop growth is essential for improving yield and supporting decision-making in crop management.

Conventional crop monitoring approaches, including field surveys and manual observations, are often labour-intensive, time-consuming, and limited in spatial coverage. These methods may not adequately capture the temporal variability of crop growth across large agricultural areas. Remote sensing techniques offer an efficient alternative by providing continuous, non-destructive, and spatially explicit information about crop conditions. Vegetation indices derived from satellite data, such as the Normalized Difference Vegetation Index (NDVI) and the Soil Adjusted Vegetation Index (SAVI), have been widely used to assess vegetation vigor, biomass, and crop phenology (Rouse *et al.*, 1974; Huete, 1988; Tucker, 1979) [6, 1, 8]. With the availability of high-resolution satellite platforms such as Sentinel-2, it is now possible to monitor crop dynamics at finer spatial and temporal scales.

In recent years, near-surface remote sensing using digital repeat photography has gained attention as a complementary tool for vegetation monitoring. The Green Chromatic Coordinate (Gcc), derived from RGB images, is a reliable indicator of canopy greenness and phenological transitions. Unlike traditional vegetation indices based on near-infrared reflectance, Gcc relies on visible-band information and provides high temporal resolution

observations of vegetation growth. This index captures seasonal changes in leaf emergence, canopy development, and senescence, making it particularly useful for monitoring crop growth stages.

Integration of satellite-based vegetation indices with ground-based digital camera observations enhances crop monitoring by combining broad spatial coverage with detailed temporal information. Sentinel-2 imagery offers multispectral data with high spatial resolution, while digital cameras provide continuous observations at the field scale. Time-series analysis of Gcc derived from both sources allows accurate assessment of crop phenology, leaf area development, and canopy cover dynamics. Such integrated approaches have been successfully applied for monitoring crops, estimating productivity, and evaluating growth patterns under varying environmental conditions (Liu *et al.* 2017) [2]

Therefore, the present study aims to monitor sesame crop growth using time-series Green Chromatic Coordinate (Gcc) derived from Sentinel-2 satellite imagery and ground-based digital camera data. The approach enables a detailed assessment of canopy greenness dynamics and provides insights into crop development stages. The integration of satellite and camera-based observations offers a robust framework for improving sesame crop monitoring, supporting precision agriculture, and enhancing yield prediction.

Objectives of the study

1. To analyse the temporal variability of Gcc for the sesame crop using camera and Sentinel-2 data.

2. To assess the spatial distribution of Gcc for crop growth monitoring.

Materials and Methods

Study area

The experiment was conducted at the Instructional Farm, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh (Fig. 1.). The latitude and longitude of the study area are 21°28'59.19" N to 21°29'02.54" N (North latitude) and 70°26'09.83" E to 70°26'10.45" E (East longitude).



Fig 1: Location map of the study area

Data Collection and Software Used

Remote sensing and GIS analyses were carried out using QGIS 3.16. Sentinel-2A satellite data and ground-based digital camera images were used to derive vegetation indices, generate spatial maps, and perform image processing, raster calculations, spatial analysis, and visualization for crop monitoring.

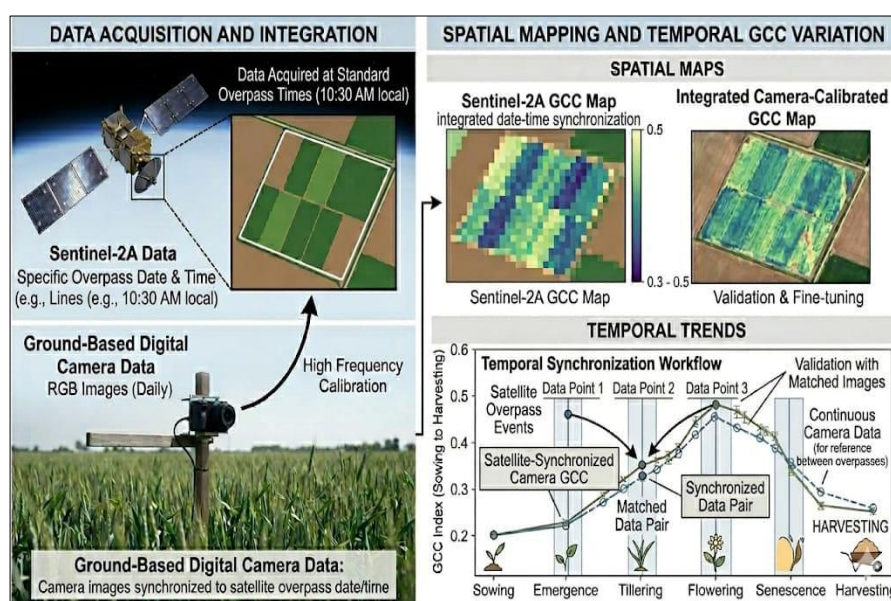


Fig 2: Synchronized Satellite and Ground-Based Crop Monitoring Framework.

Green Chromatic Coordinate (Gcc)

The Green Chromatic Coordinate (Gcc) is an RGB-based vegetation index commonly used to study plant phenology in forest ecosystems. It is derived from reflectance values recorded in the visible bands of digital images. Gcc serves as a simple and effective indicator of canopy greenness. It is calculated as the ratio of the green digital number (DN) to the total of the red, green, and blue digital numbers. In this study, Gcc was computed using the following formula as described by Sonnentag *et al.* (2012) [7]

$$Gcc = \frac{\text{Green DN}}{\text{Green DN} + \text{Blue DN} + \text{Red DN}} \quad (1)$$

Gcc is a useful indicator of plant greenness and overall vegetation health. The index produces values ranging from 0 to 1.0, primarily reflecting the level of green vegetation. Values close to zero generally correspond to non-vegetated surfaces such as rocks and bare soil, while values approaching one indicate dense green leaf vegetation. Therefore, higher Gcc values represent healthier and more actively growing plants.

Estimation of Bio-Physical Variables

Time-series Green Chromatic Coordinate (Gcc) maps were generated from Sentinel-2 satellite and ground-based digital camera images using the raster calculator in QGIS 3.16 to monitor sesame crop growth across different satellite overpass dates from February 22, 2020, to May 19, 2020.

Green chromatic coordinate (Gcc)

The raster calculator in QGIS 3.16 was used for preparing Gcc map for different dates of Satellite overpasses shown in Fig.3 (a-g). The Gcc maps were prepared from acquired NIKON digital Camera images for different dates: March 01, 2020; March 21, 2020; March 31, 2020; April 10, 2020; April 20, 2020 and April 30, 2020; May 10, 2020.

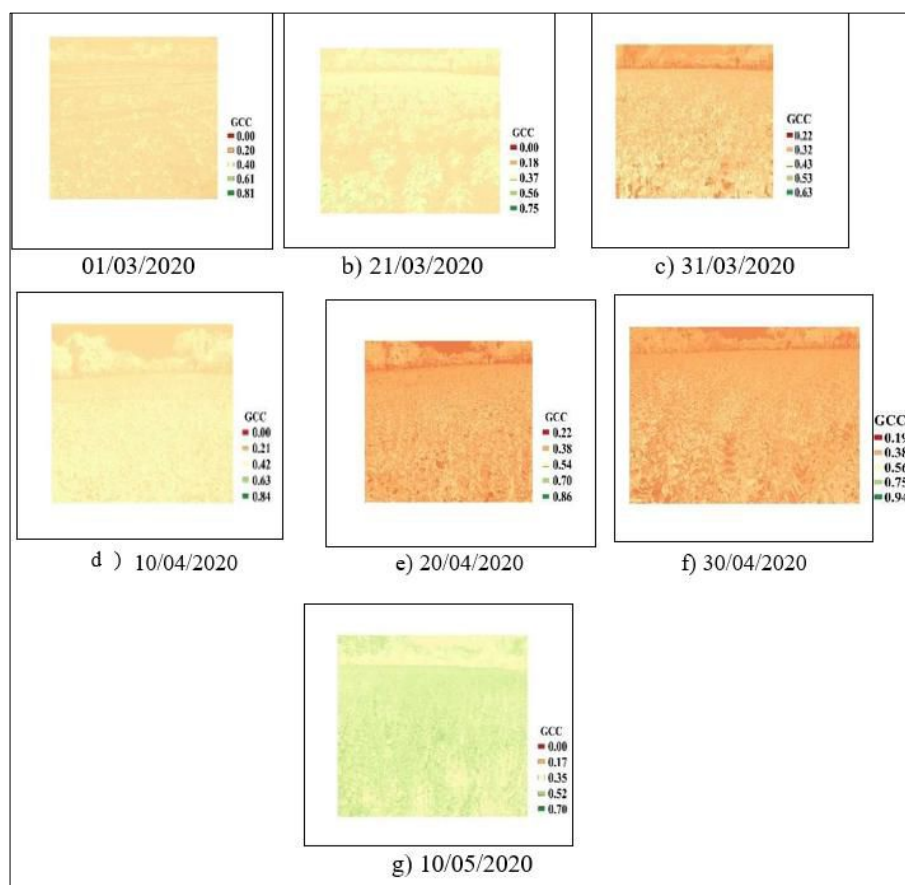


Fig 3: Green chromatic coordinates (Gcc) maps using Camera images (a to g)

The values of Gcc in the study area for summer season, 2019-20 were ranged from 0 to 0.81, 0 to 0.75, 0.22 to 0.63, 0 to 0.84, 0.22 to 0.86, 0.19 to 0.94, 0 to 0.70 for the March 01, 2020; March 21, 2020; March 31, 2020; April 10, 2020; April 20, 2020 and April 30, 2020, and May 10, 2020, respectively. The maximum Gcc in the study area was 0.94 on April 30, 2020, and the minimum Gcc was 0 on March 01, 2020; March 21, 2020; April 10, 2020, and May 10,

2020. It shows that Gcc values of the vegetation are continuously increasing up to certain growth stages, then decrease during the harvesting stage of the crop.

The Green chromatic coordinate (Gcc) for different locations of the Sesame crop and the temporal variability of Gcc for the period of March 01, 2020, to May 10, 2020, at an interval of 10 days is given in Table 4.10. The trends of Gcc for the Sesame crop are shown in Fig 4.

Table 1: Green chromatic coordinate (Gcc) values of the camera for the Sesame crop

Sr. No.	Date of Satellite overpasses	Average Gcc value
1	01-03-2020	0.355
2	21-03-2020	0.359
3	31-03-2020	0.378
4	10-04-2020	0.408
5	20-04-2020	0.399
6	30-04-2020	0.381
7	10-05-2020	0.359

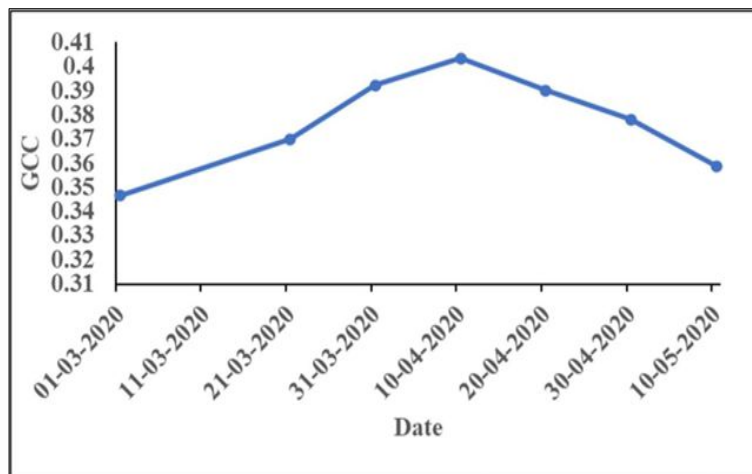


Fig 4: Temporal Variability of Green chromatic coordinate (Gcc) for Sesame crop

The temporal variability of average Gcc values ranged from 0.35 to 0.40 from March 1, 2020, to April 10, 2020. These show that the Gcc values of the vegetation are continuously increasing up to a certain growth stage and then decrease due to the maturity of the crop. It showed low foliage cover

and a change in the colour of vegetation. *i.e.*, during the harvesting stage of the crop. The Gcc maps were prepared from Sentinel-2 images of dates: March 01, 2020; March 21, 2020; March 31, 2020; April 10, 2020; April 20, 2020 and April 30, 2020; May 10, 2020 (fig. 4).

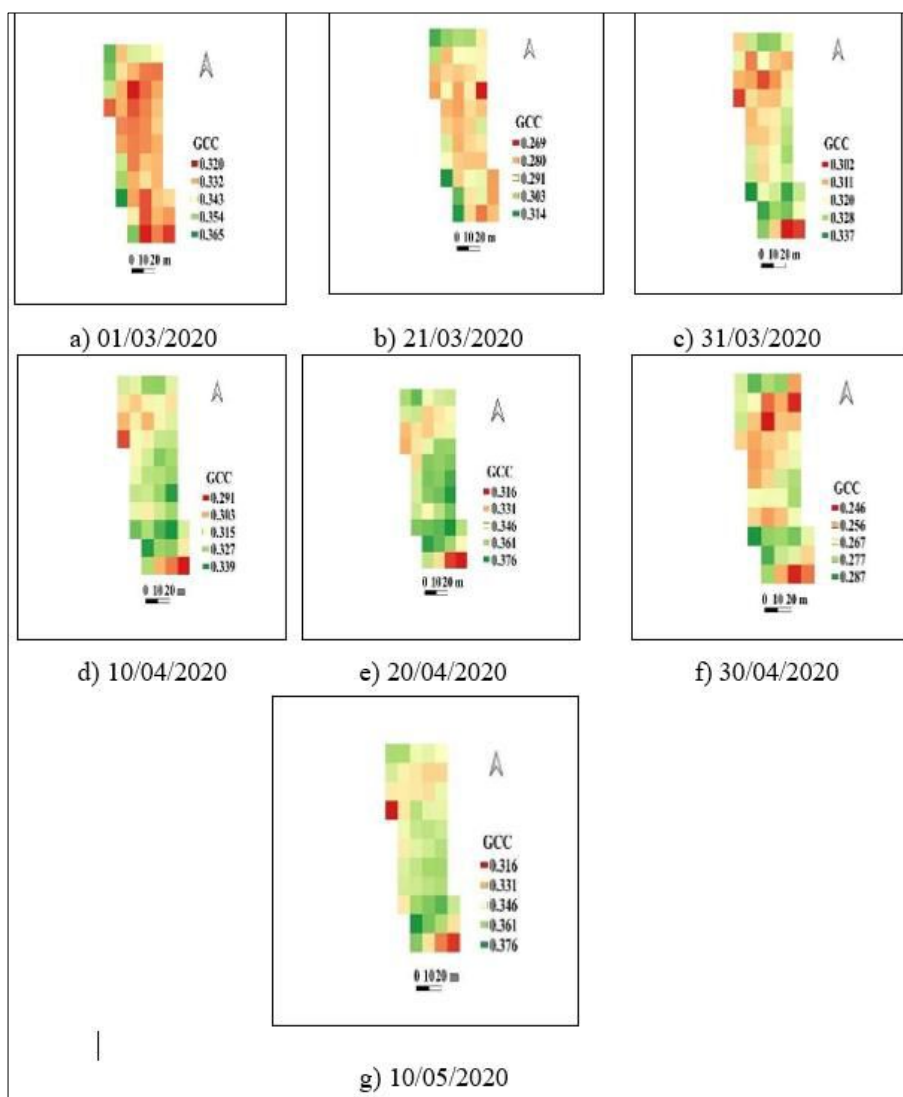


Fig 5: Green chromatic coordinate (Gcc) maps using Sentinel-2 Images (a to g)

The values of Gcc in the study area for the summer season, 2019-20 were ranged from 0.32 to 0.36, 0.26 to 0.31, 0.30 to

0.33, 0.29 to 0.33, 0.31 to 0.37, 0.24 to 0.28, 0.31 to 0.37 for March 01, 2020; March 21, 2020; March 31, 2020; April 10,

2020; April 20, 2020 and April 30, 2020; May 10, 2020 respectively. The maximum Gcc in the study area was 0.37 on April 20, 2020, and May 10, 2020.

The minimum Gcc in the study area was 0.24 on April 30, 2020. These show the Gcc values of the vegetation is continuously increasing, then after the Gcc value decreases due to the maturity of the crop, showing low foliage cover and changing the colour of the vegetation. *i.e.*, during the harvesting stage of the crop. The Green chromatic coordinate (Gcc) for different locations of the Sesame crop and temporal variability of Gcc for the period from March 01, 2020 to May 10, 2020, at an interval of 10 days is given in Table 2. The trend of Gcc for the Sesame crop is shown in Fig. 6.

Table 2: Green chromatic coordinate (Gcc) values for Sesame crop

Sr. No.	Date	1	2	3	4	5	6	Average
1	01-03-2020	0.286	0.266	0.286	0.302	0.286	0.279	0.284
2	21-03-2020	0.335	0.307	0.325	0.321	0.319	0.295	0.317
3	31-03-2020	0.365	0.346	0.355	0.329	0.366	0.365	0.354
4	10-04-2020	0.454	0.425	0.398	0.416	0.476	0.486	0.442
5	20-04-2020	0.337	0.376	0.366	0.376	0.374	0.369	0.367
6	30-04-2020	0.342	0.295	0.354	0.286	0.369	0.366	0.336
7	10-05-2020	0.247	0.256	0.269	0.277	0.280	0.273	0.267

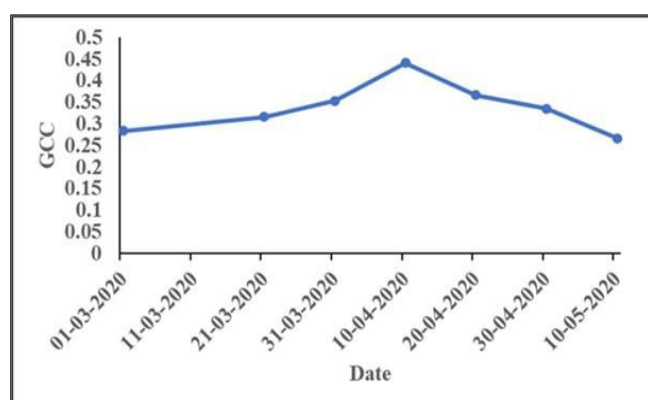


Fig 6: Temporal Variability of Green chromatic coordinate (Gcc) for the Sesame crop

Temporal Variability of Gcc values ranged from 0.28 to 0.44 from March 1, 2020, to April 10, 2020. These show that the Gcc values of the vegetation are continuously increasing up to certain growth stages, and then after, Gcc values decrease due to the maturity of the crop. *i.e.*, during the harvesting stage of the crop. (Richardson *et al.* 2018) ^[5]

5. Conclusion

The results showed that the Green Chromatic Coordinate (Gcc), derived from both digital camera images and Sentinel-2 data, is effective for monitoring sesame crop growth. The time-series analysis of Gcc clearly captured different crop phenological stages, with greenness increasing during the vegetative phase and gradually declining as the crop reached maturity and harvesting. Camera-based Gcc was more sensitive to changes in canopy greenness, whereas satellite-derived Gcc effectively represented the spatial and temporal variability of the crop. Overall, Gcc proved to be a simple, non-destructive, and reliable index for spatio-temporal monitoring of sesame crops and has strong potential for precision agriculture applications

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