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Phenological Monitoring of Paddy crop using Time Series MODIS Data†

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Abstract: Rice is one of the important staple food crops worldwide, especially in India. Accurate and timely prediction of rice phenology plays a significant role in the management of water resource, administrative planning, and food security. Apart from the conventional method of rice yield estimate, remotely sensed time series data can provide the necessary estimation of rice phenological stages over a large region. Thus, the present study utilizes the 16-day composite Enhanced Vegetation Index (EVI) product with a spatial resolution of 250 m from the Moderate Resolution Imaging Spectroradiometer (MODIS) to monitor the rice phenological stages over Karur district of Tamil Nadu, India using the Google Earth Engine (GEE) platform. The rice fields in the study area were classified using the machine learning algorithm in GEE. The ground truth was obtained from the paddy fields during crop production which was used for classifying the paddy grown area. After the classification of paddy fields, local maxima, and local minima present in each pixel of time series EVI product was used to determine the paddy growing stages in the study area. The results show that in the initial stage, the pixel value of EVI in the paddy field shows local minima (0.23) whereas local maxima (0.41) were obtained during the peak vegetative stage. The results derived from the present study using MODIS data was cross-validated using the field data.

Keywords: Rice Phenology, MODIS, Enhanced Vegetation Index, Google Earth Engine, Machine Learning

1. Introduction

Major stable food crop of world population is Oryza sativa, which provides nearly 75% of daily calorie intake for people living mainly in Asian countries. Asian continent produces nearly 90% of total rice production in the world [1]. Rice is of almost importance in countries like India, China, Indonesia and Thailand, where the crop has a profound influence on the livelihood of many farmers [2]. Reliable and timely monitoring and mapping of rice is of global importance [3]. Mapping of paddy crop helps in the estimation of water supply required for irrigation, net production and yield estimation [4]. Inspite of being a stable food crop around the world, the paddy croplands accounts for the release of Green House Gas for about 10% [5]. Monitoring of paddy crop in a country also aids in assessing the national food security, for planning and sustainable management of available resources [6]. A real time monitoring of paddy production in a region or a whole country can be carried out through remote sensing techniques [7]. Various optical and Synthetic Aperture Radar datasets such as moderate resolution imaging spectroradiometer (MODIS) on board the Terra and Aqua satellites, Sentinel-1, ALOS PALSAR, RADARSAT, Landsat and EnviSat. The paddy croplands can be extracted easily as the cropland is filled with stagnant water during sowing and transplantation. Using the spectral indices such as Normalised Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) which is very sensitive to change in water and vegetation can help in differentiating normal crop and paddy crop, this aids in the extraction of paddy fields. Numerous studies have been carried out in past decades for monitoring of paddy crop using MODIS data [8-10]. Recently, after the arrival of various cloud platforms such as Google Earth Engine (GEE), the analysis time and data acquiring space have been greatly reduced. Various crop monitoring studies at various levels can be carried out with the massive computational power of GEE. A large number of Earth Observation (EO) including Landsat, MODIS, Sentinel and much more data products are available for open access which can be used with code written using JavaScript. The present study aims at utilizing the massive computational power of Google Earth Engine (GEE) cloud platform for monitoring the paddy crop using the MODIS time series data over the Karur district of Tamil Nadu.

2. Study Area

Karur district is selected as a study area, located in the Indian state of Tamilnadu between 10.95°N latitude and 78.08°E longitude. Black and red soils are the two major soil types found in the study area, which is suitable for agriculture practices. Temperature range between 39 °C to 17 °C. The climatic condition is warmer in April to June and colder in December to January. The Average rainfall of this region is 590-660 mm. During Northeast Monsoon, heavy rainfall occurs in the month of October to December. Major agriculture crops grown are rice, cotton, sugarcane and oil seed, while horticultural crops are banana, coconut, betel, and mango. System of Rice Intensification (SRI) techniques is commonly practiced in this study region for obtaining the maximum yield. Rice growing seasons in the study area is Samba (August), Kuruvai (June to July), Late Samba (September to October) and Thaladi (October to November). Depending upon the duration, variety of rice varies. They are Short duration (100 -120 days), Medium duration (121- 160 days) and Long Duration (141- 160 days).

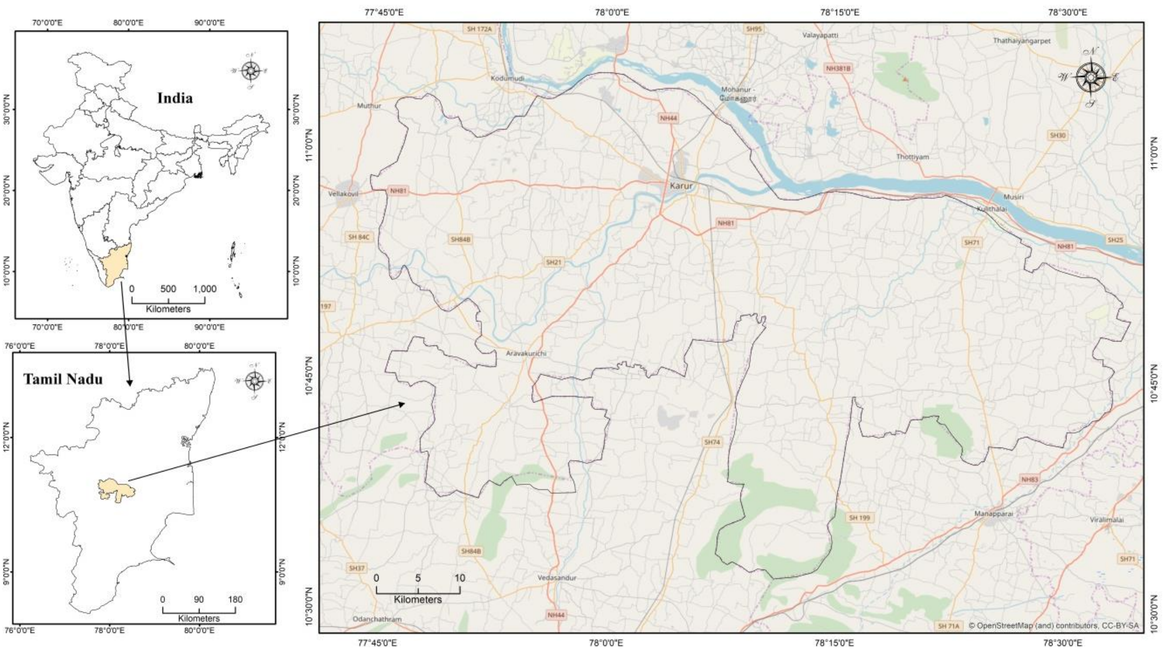

Figure 1. Geographical location of the study area

3. Dataset

MODIS Terra\Aqua 16-day Vegetation Indices L3 250m (MOD13Q1 and MYD13Q1) acquired from National Aeronautics and Space Administration (NASA) is used for mapping rice crop in the month of September to December in the Karur district of Tamil Nadu. This data set consists of two bands such as Normalized Difference Vegetation Indices (NDVI) and Enhanced Vegetation Indices (EVI) with a spatial resolution of 250m.

4. Methodology

This study is utilised GEE cloud platform where all the processing was carried out. GEE was a cloud-based platform that used for processing and computing huge geospatial data. Both MODIS Terra\Aqua EVI band data (time series) for the period of September to October were first acquired and these collected datasets for the study area were mosaicked.

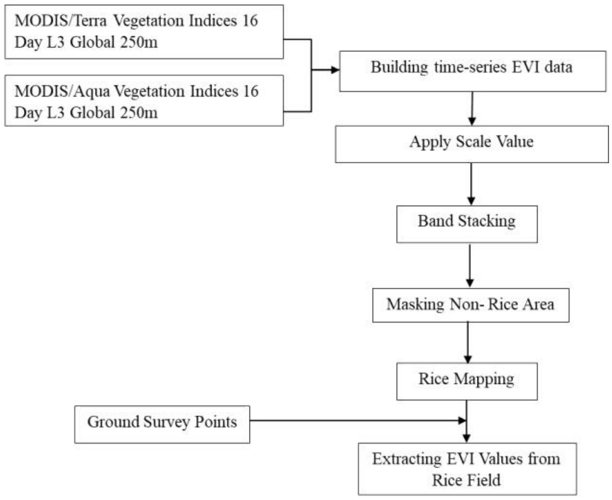

Figure 2. Methodology of the study

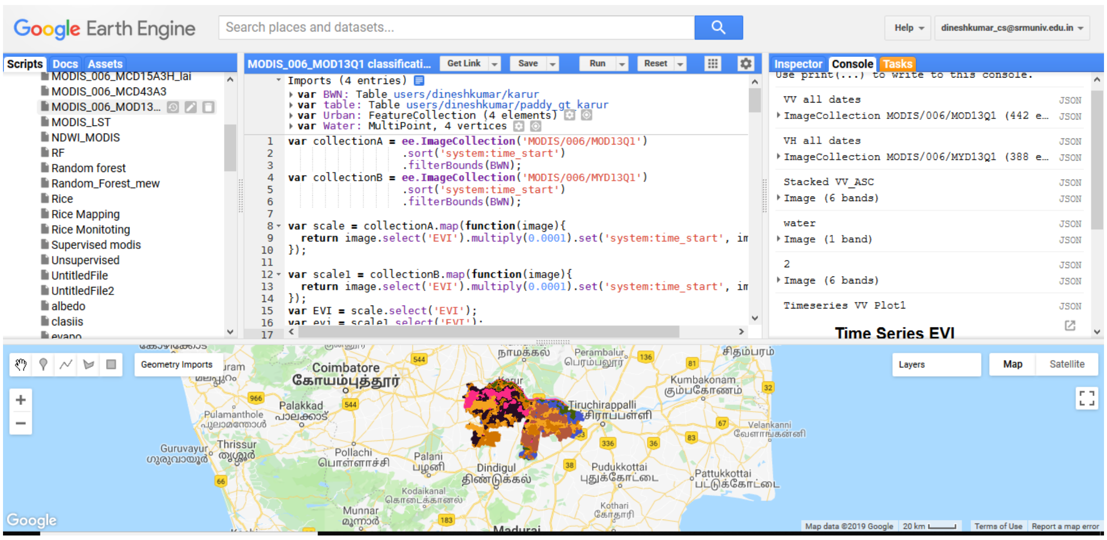

Figure 3. Processing in GEE

EVI is utilised in this study to explore the temporal response from paddy fields. The non-rice growing area like water, building and forest were masked from the EVI time series data. After masking out the non-rice growing area, the phenology based approach was utilized for classifying the rice fields in the study area. Heading stage of rice was identified as the maximum value in EVI time series data. In this study, there are some cases that exist, minimum MODIS EVI value does not match in the transplanting date as the weeds present in the rice fields were not properly removed before planting. Thus the effect of weed and grass outside the rice field provide a decrease of value in MODIS 250 m pixels. Therefore, in this study heading stage with maximum EVI value is used to identify rice phenology throughout the MODIS time series data.

4. Results and Discussion

In this study, three phenological stages of Rice were defined by change observed in EVI time series. The three phenological stages are Start of Season (SOS), Peak of Season (POS) and End of Season (EOS). SOS (September) denotes the time when the rice crop started to grow, it relates the date of flooding before transplanting. POS describes the heading stage, when the crop attains its maximum vegetation stage. At EOS (December), the crop is at matured stage which means harvest stage. Phenological stages of Rice and their corresponding EVI values are shown in the Figure 4.

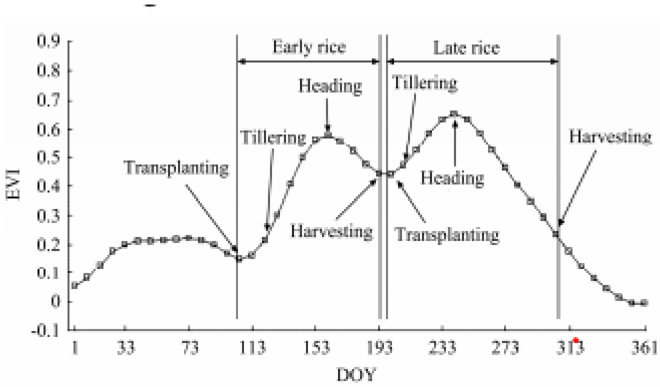

Figure 4. Phenological Stages of Rice for EVI

The lowest EVI value noted in MODIS time series during pre-planting or flooding stage (Sep 1 to Sep 15) the values were 0.3 moving towards negative. After transplantation, EVI value gets increased indicating the start of vegetative phase (Figure 6). This increase in EVI value during October, marks the characteristic of stem elongation which generates rice canopies. Maximum EVI (0.4) value were attained during panicle initiation and the heading of reproductive stage. After crop attains its ripening stage, leaves of Paddy crop undergo chlorosis with little deterioration in crop canopy. After this stage, EVI Value decreases towards 0.3 and 0.2. This EVI values demonstrate that the maximum EVI value is obtained during the reproductive stage followed by a decline in values at the matured stage resulting with the withering of crop leaves.

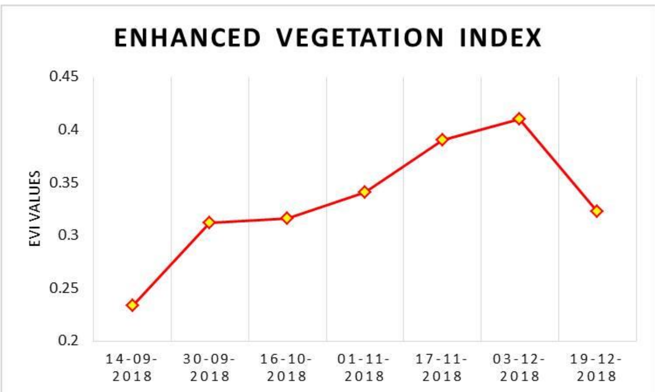

Figure 5. Time Series analysis of EVI

Time series analysis was carried out by using all the MODIS Terra\Aqua 16-day Vegetation Indices L3 250m (MOD13Q1 and MYD13Q1) data between September and December 2018. To delineate rice crop from other land classes, three statistic threshold for MODIS data were derived from the time series. Ground Survey Points were used for threshold selection. By using these threshold values masking of non-rice crop area like water bodies, buildings and forest areas were done. After masking these areas, classification was carried out in the study area for mapping rice crops (Figure 6).

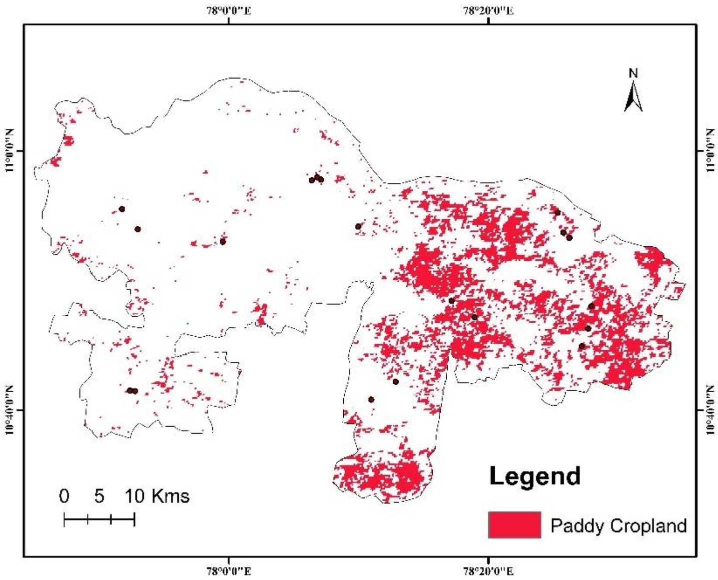

Figure 6. Rice Area Mapping

4. Conclusion

Open source earth observation data and cloud-based computing resources provide a remarkable advancement in the field of landuse/landcover mapping and in crop monitoring. In this study, Phenology based classification approach was used to delineate the Paddy crop in Karur district from MODIS EVI time series data using different phenological stages (such as transplanting, tillering, heading and harvesting) of rice. However, examination has been done to estimate the transplanting date directly from the minimum EVI value of Time series data. The estimated planted date has good agreement with field survey points. These values have some gaps in comparison with a small level. This satellite-based method for determining phenological stage in the paddy field can be utilised for both validation and simulation of the agro-hydrological model using GEE platform.

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