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Study on paddy phenomics ecosystem and yield estimation using space-borne multi sensor remote sensing data

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ABSTRACT

In the present study three phenological stages of rice namely transplanting stage, heading stage and harvesting stages were derived from MODIS EVI data. SMAP L-band was used to identify the puddling field. The performance of the estimated phenological stages from MODIS EVI and SMAP were evaluated with field data and root mean square error (RMSE) was calculated. The rice yield estimation was also performed by application of second order polynomial method. The performance of the polynomial model showed good results with the coefficient of determination of 0.74.

Keywords : Phenology, rice, MODIS EVI, SMAP, yield,remote sensing.

Agriculture contributes 14 per cent of total gross domestic product (GDP) of India. Rice occupies significant share in agricultural products output in India. In India Andhra Pradesh is major stockholder in rice production (Dadhwal *et al.*, 2002). The innovations in agricultural machinery facilitates the farmers to generate more income with smart work. The monitoring and management are difficult with traditional methods, therefore the advance technology like remote sensing helps policy makers for better understanding and prediction of agricultural crops. The remote sensing technology can be used as cost effective tool to examine and supervise the agricultural crops. The United states geological survey organisation (USGS) and MOSDAC (ISRO) providing remote sensing data at free of cost to the researchers and academicians.

Chlorophyll plays a vital role to identify the crop growth and vegetation monitoring.Enhanced vegetation index (EVI) is developed to investigate on the biophysical parameters of the vegetation. The EVI provides an opportunity to investigate rice crop phenology and yield estimation. Shihua *et al.*(2014) studied the rice phenomics using enhanced vegetation index data. They used Savitzky–Golay filter to remove the noise in data and restructured the levelled data. Park *et al.*(2018) classified and mapped rice using SAR and Landsat time series information and proposed paddy mapping index (PMI) using support of Google Earth. Li *et al.*(2016)used polarimetric SAR data and MODIS vegetation data to study to rice phenology. Wang *et al.,*(2014)investigated on TIMESAT algorithm to assess phenology metrics from EVI data. The present research aims to identify crop phenological stages and yield estimation using MODIS EVI data.

MATERIALS AND METHOD

Study area

The study areas. Rayalaseema of Andhra Pradesh located between latitudes of 12^0 37'N and 14^0 8'N and between longitudes of 78^0 33'E and 79^0 55'E. Nellore, Kadapa and Vellore districts of Tamil Nadu are the boarder districts of the study area. The total study area is 15,468 km^2.

MODIS enhanced vegetation index (EVI)

The present study used MODIS EVI with 500 m spatial resolution.The MODISEVI data were downloaded from USGS earth explorer from 1st December 2017 to 20th April 2018. EVI values were calculated using the following equation 1.

$$EVI = G\left[\frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + (C_1 \times \rho_{RED} - C_2 \times \rho_{BLUE}) + L}\right]$$

where, ρ_{blue}, ρ_{red}, and ρ_{nir} are reflectance of MODIS, *red, NIR*, and blue bands respectively; *L (= 1); C1 (= 6)* and *C2 (= 7.5);* and *G (= 2.5)*.Fig. 1 shows the methodology adopted to identify the phenological stages.

L-band (SMAP)

SMAP (soil moisture active passive). SMAP L-band

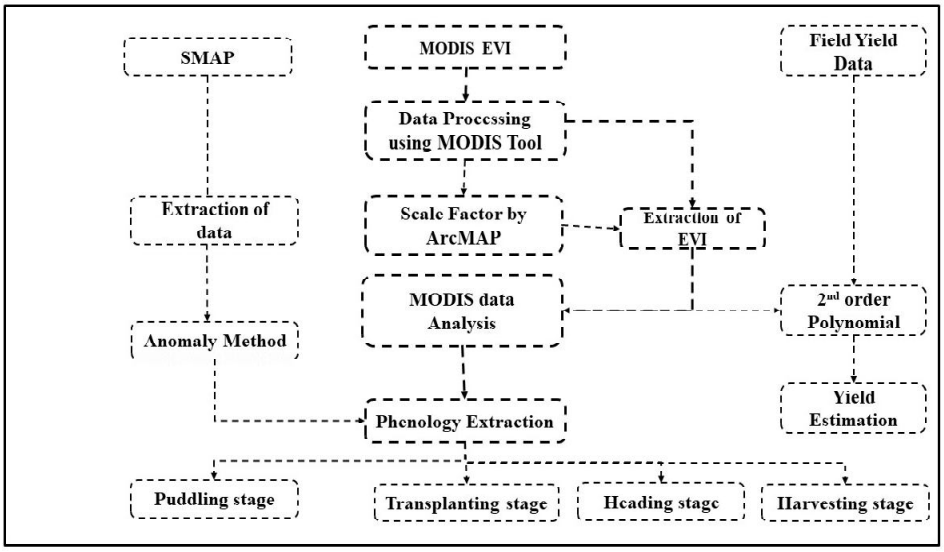

Fig. 1: Methodology adapted to identify and mapping of phenological stages

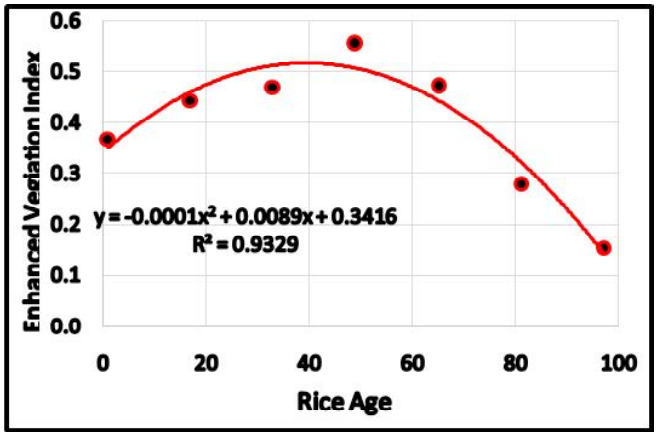

Fig. 2: Rice age and rice EVI relationship

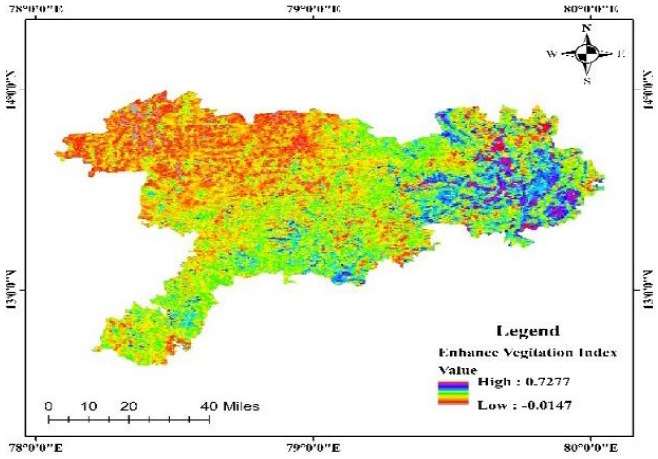

Fig 3: Enhanced vegetation index (EVI) in the study area

provides HH, HV and VV polarisations. The SMAP data are provided freely by the Alaska satellite facility. The SMAP data with 9 km resolution and 3-day composite was used to identify the puddling (Mahesh *et al.* 2018).

Anomaly method was used to calculate the soil moisture index anomaly present in the study area.

$$Anomaly\text{-}moisture\ \ Index\ = \frac{d\ (moisture\ \ Index)}{dt} \quad (2)$$

A second order polynomial of type $y=ax^2+bx+c$ was fitted between rice age and EVI , where y is EVI and x is rice age, a, b, c are coefficients. Rice age can be calculated when $\frac{\Delta y}{\Delta x}$ is equal to 0.

RESULTS AND DISCUSSION

The rice phenological stages namely puddling stage, transplanting stage, heading stage and harvesting stages are estimated using the MODIS (EVI) and microwave SMAP L-band data. The polynomial relationship between rice age and EVI is satisfactory with $R^2$0.93. The relationship between EVI and rice age was performed at all 20 locations. Fig. 2 shows the graphical representation between EVI and rice age relationship. Fig. 3 shows the spatial distribution of EVI in the study area.

Puddling stage

The field is flooded with water, therefore the soil moisture index shows high value. The estimated puddling date using SMAP data was 12-12-2017. Fig.4 shows the graphical representation of puddling stage identification. It was validated with the ground truth data collected at 20 locations with RMSE of ±5.5 (Fig. 6)

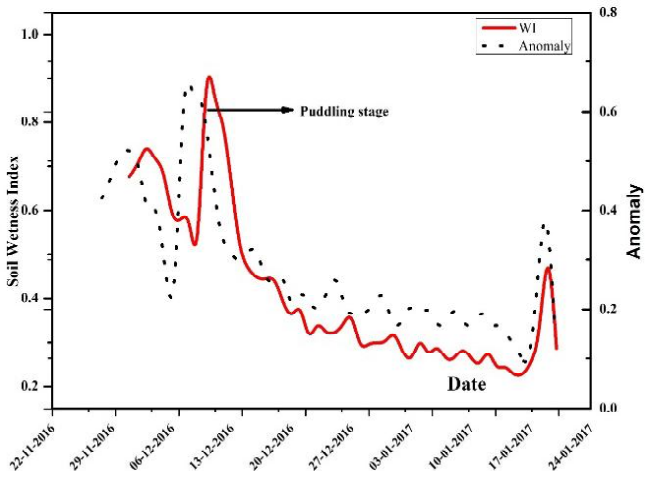

Fig 4:Puddling stage identification using SMAP data

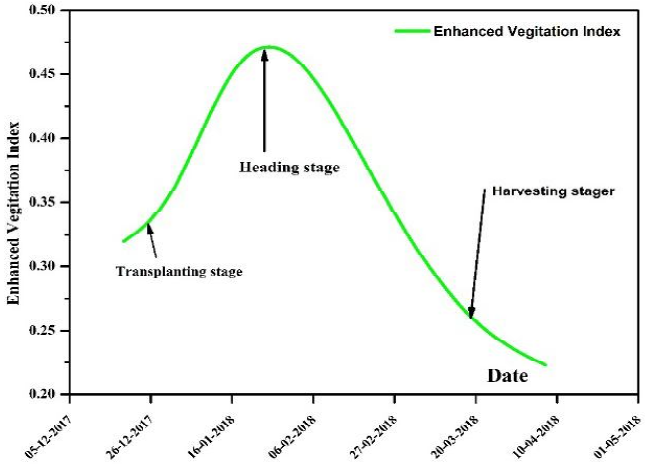

Fig. 5: Phenological stages of rice crop in the study area

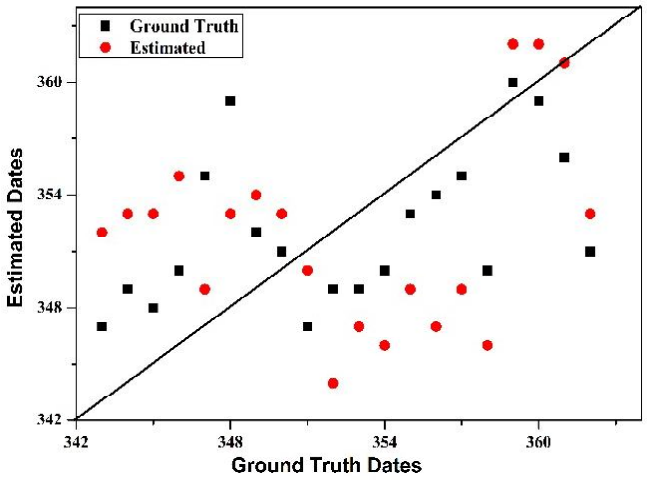

Fig. 6: Comparison of EVI derived dates and ground truth dates at puddling stage

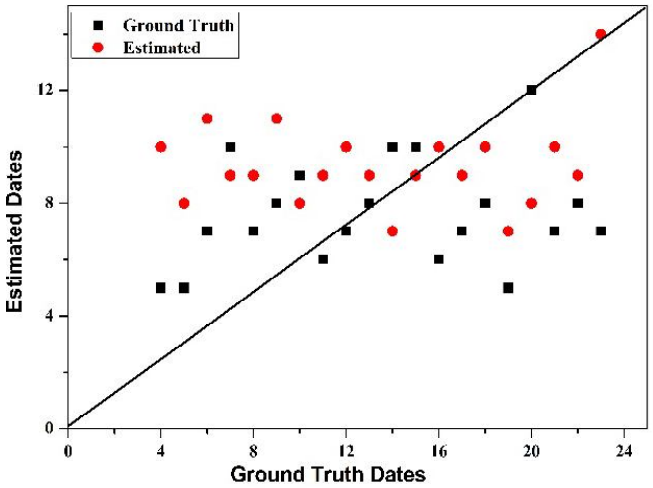

Fig. 7: Comparison of EVI derived dates and ground truth dates at transplanting stage

Transplanting stage

Transplanting stage is the initial stage of vegetation i.e starting stage of vegetation growth. The leaf area index, chlorophyll and biomass are negligible (Wang *et al.,* 2014).Fig. 5 shows the EVI which defines the phenological parameters of rice crop. From the field observations it is concluded that the second season rice field preparation starts from third week of December 2018. The transplanting stage starts immediately after 3-10 days of puddling stage depending on available resources and climate conditions. The total crop period in the study area is 90-100 days, which is 3 months rice crop. EVI shows low vegetation in the transplanting stage i.e 0.36. The estimated transplanting date was 01-01-2018. The transplanting stage happened after two weeks of puddling stage, identified from remote sensing data. It was validated with ground truth dates at collected at 20 locations (Fig. 7) showing RMSE of ± 3.5

Heading stage

Heading stage can be identified by observing panicles emergence in the rice crop cycle.The stage is said to be heading stage, when panicle is clearly visible. Flowering begins a day after heading. The EVI at heading stage was maximum 0.47 in the sampling location(Fig.5). The heading stage estimated in the sampling location was 06-02-2018. The heading stage obtained from ground truth data was compared with derived dates (Fig. 8) having RMSE of ±6.0

Harvesting stage

At the harvesting stage the rice grains in the panicles get ripened,The chlorophyll main source for measuring crop growth is low at harvesting stage. The chlorophyll accounts negligible amount in the rice plant at harvesting stage.EVI shows less index value due to low chlorophyll content in the leaf. From Fig.5 EVI shows 0.27 at harvesting stage.The

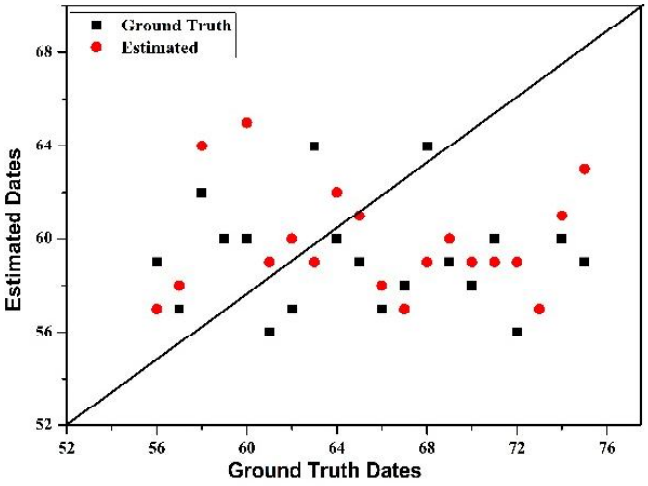

Fig.8: Comparison of derived and ground truth at heading stage

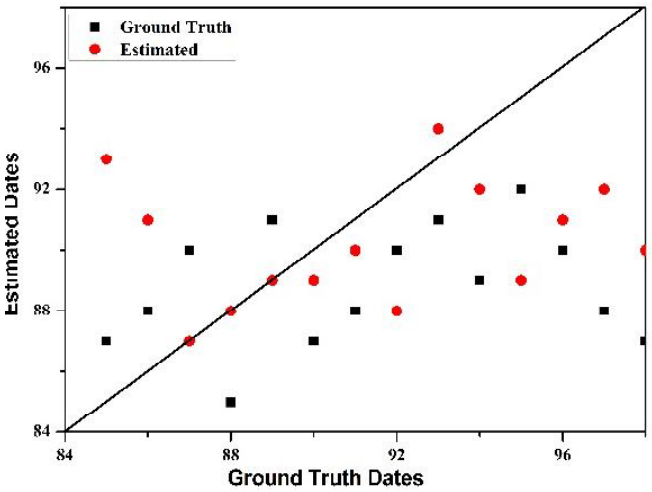

Fig. 9: Comparison of derived and ground truth at harvesting stage

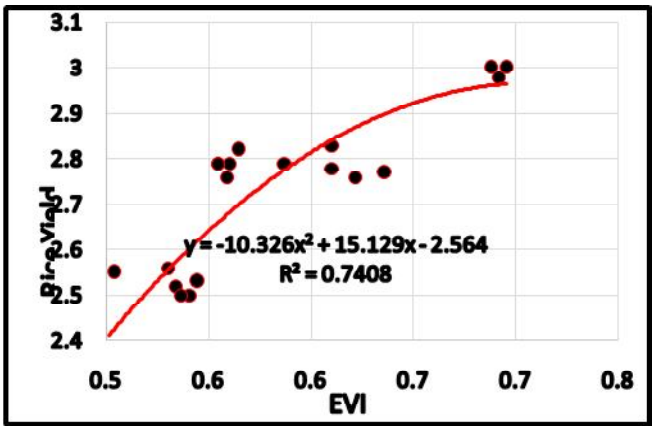

Fig 10: Rice yield and EVI $_{max}$ relationship

estimated harvesting stage date was 20-03-2018, the date of phenology is identified using EVI is well matched to every key stage of rice growth and concluded that remote sensing technique is better way to monitor rice growth conditions. The results showed that estimation of phenological parameters are feasible using MODIS EVI time series (Fig.9).

Yield estimation

The rice yield was estimated using EVI derived from MODIS sensor. The relationship was performed using polynomial method and an empirical formula was developed to yield estimation using ground truth data and MODIS derived EVI data. The second order polynomial relationship shows $R^2 = 0.74^{**}$ which was highly significant and gave satisfactory result to accept the model (Fig. 10).

CONCLUSIONS

The present experiment precisely acknowledged various rice crop phenological stages from MODIS enhance vegetation index data. The vegetation index at the transplanting stage is 0.36, at heading stage it was highest (0.45) and at harvesting stage lowest (0.27). The phenological stages like puddling, transplanting, heading and harvesting stages are observed on 13-12-2017, 01-01-2018, 06-02-2018 and 20-03-2018 respectively. The root means square error (RMSE) at puddling stage, transplanting stage, heading stage, harvesting stages are 5.5, 3.5, 6.0, 4.0 days respectively. The rice yield is estimated using EVI and R^2 is 0.74. The results concluded that MODIS EVI data is viable to identify the crop phenological stages and rice yield estimation effectively.

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REFERENCES

Dadhwal V.K, Singh R.P, Dutta, S. and Parihar J.S. (2002). Remote sensing based crop inventory: A review of Indian experience. *Tropical Ecol.,*43:107–122.

Li K, Yang Z, Shao Y, Liu, L. and Zhang F. (2016). Rice phenology retrieval automatically using polarimetric SAR Institute of Remote Sensing and Digital Earth , *Chinese Acad. Sci.,* 40:5674–5677.

Mahesh Palakuru, Kiran Yarrakula, NilimaRani chaube, S.K Khadar babu and Y.R Satyajirao (2018).Identification of paddy crop phenological parameters using dual polarized SCATSAT-1 (ISRO, India) scatterometer data. *Environ. Sci. Poll. Res.,*26(2):1565-1575.

Park S, Im J, Park S, Yoo C, Han H and Rhee J (2018). Classification and Mapping of Paddy Rice by Combining Landsat and SAR Time Series Data. *Remote Sens.,* 10:447-456.

Shihua L, Jiangtao X, Ping N, Jing Z, Hongshu, W. and Jingxian W. (2014). Monitoring paddy rice phenology using time series MODIS data over Jiangxi Province , China. *Intern. J. Agricul. Biol.,* 7: 28–36.

Wang L, Zhang F.C, Jing Y.S, Jiang X.D, Yang, S. and Bin Han, X.M. (2014). Multi-temporal detection of rice phenological stages using canopy stage spectrum. *Rice Sci.,* 21:108–115.

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