



# **Characterising Rice (*Oryza indica*) Ecology in East and Southern Eastern Plateau of Odisha using Multi Source Remote Sensing**

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. Author MSSR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AB and BSR managed the analyses of the study. Author BSR managed the literature searches. All authors read and approved the final manuscript.*

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## **ABSTRACT**

Rice is the most important crop of Odisha occupying 41.24% of net sown area in Kharif season and contributing 65.85 % of total food grain production of Odisha state and this is being cultivated in various types environmental and ecological condition. Assessment of rice phenology is prime for management and yield prediction. In view of characterizing rice ecology in East and South Eastern Plateau from 2008 – 2018 to know the time series analysis , remote sensing tools were used . MODIS can0 acquire data over a wide area with high spatial and temporal resolutions easily providing regional scale information .In order to study the seasonal /annual as well as spatial variability of kharif rice vigour and wetness spectral vegetation indices like NDVI(*Normalised Difference Vegetation Index*),LSWI(*Land surface water index*) derived from 15 day composite 250 m data were analysed at block level for Odisha state. For studying the start of season variability, SASI index was used. The season maximum NDVI, LSWI were computed for the year 2008-2018 for kharif rice in East and Southern eastern coastal plain zone of Odisha and graphs were generated which shows the variability of the kharif rice vigour and wetness.

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**Keywords:** *Kharif season; rice phenology; east and southern eastern plateau; Odisha; remote sensing; MODIS; NDVI; LSWI.*

## ABBREVIATIONS

*LSWI* : *Land Surface Water Index*  
*MODIS* : *Moderate Resolution Imaging Spectro Radiometer*  
*NDVI* : *Normalised Difference Vegetation index*

## 1. INTRODUCTION

With its ability to adopt itself to a wide range of geo-hydrological situations, rice enjoys a unique place among the field crops. In Odisha, rice is grown under diverse growth conditions makes classification and characterization of the rice environments a challenging task. In Odisha Rice is cultivated on an area of 4.17million hectares, which can be classified into six different ecosystems: irrigated kharif (27.4%), rainfed upland (19.1%), medium land (12.4%), shallow lowland (22.5%), semideep (7.9%), deep (3.4%), and irrigated rabi (7.4%).Moreover, rice fields represent an important aquatic ecosystem ,hosting a large variety of terrestrial land aquatic species that typically remain flooded during the growing season. Despite the positive functions of rice systems, such systems also cause environmental degradation [1]. Rice water consumption and greenhouse gas emissions from paddy fields are especially critical issues. In upcoming years, the world will face the challenge of meeting global demands for rice while preserving land and water resources. Thus, monitoring these systems will become essential at both the local and global scale [2].

Remote sensing use started in the field of agriculture in 1960's since from then remote sensing is operating many global and National operational system of crop growth and monitoring. These techniques have proved their efficiency in providing information on the character and distribution of various natural resources. Remote sensing has various applications in farming. Some of them include areas related to agriculture are management of land and water resources, crop acreage and production forecasting, crop condition.Remote sensing evolved and used as an ideal technique for crop monitoring and management because of some of the inherent characteristic of agriculture [3]. some of the characteristics include:

- Efficient techniques to obtain spatial and temporal crop information invariably.
- Remote sensing techniques act as instrumental for monitoring of crop production at both regional and global scale and also used for detecting seasonal vegetation changes.
- Remote sensing data delivers information for procuring crop phenological stages.

Remote sensing technology fulfil the requirements because it's rapid, accurate, economic, dynamic, repetitive monitoring and timely. Remote sensing use started in the field of agriculture in 1960's since from then remote sensing is operating many global and National operational system of crop growth and monitoring [4-6]. Direct monitoring method can be done with remote sensing indices, which monitor crop condition such as NDVI, LSWI. Based on the value of such indices the crop condition is monitored precisely. In this context satellite derived remote sensing images play an important role as it can provide long time series data [7,8].The non-destructive and synoptic coverage of remote sensing images proves to be a potential role by crop ecology analysis along with growth condition and monitoring. Several spectral indices like NDVI, LSWI have been widely used in research and operational projects by crop growth monitoring and ecological characterization. For studying the start of season variability, SASI index was used. Block wise SASI was extracted and analysed in order to study the temporal and spatial variability in the start of season as well as total soil wetness duration [9-11]. Holistic management practices can be developed after proper suitable characterization of different rice crop ecology or growing environment in terms of length of growing period, start of the season and management regimes. In this context present study is composed with "Characterising Rice ecology in east and southern east plateau of Odisha using Multi source Remote sensing" through analysis of spectral data with the following objectives 1. Decadal analysis of start of the season in different blocks in particular districts of east and southern east zone of Odisha particularly kharif rice in terms of spectral characteristics derived from remote sensing data. 2. Characterising rice phenology in terms of remote sensing derived from Infra -Red spectral data.

## 2. METHODOLOGY

### 2.1 Location and Extent

Odisha is located in the sub-tropical belt in the eastern region of India between 17 ° 31' N to 20 °31' N latitude and 81 ° 31' E to 87 ° 30' E longitude. It is bounded by Jharkhand in the north, Chhattisgarh in the west, Andhra Pradesh in the south, West Bengal in the north-east and the Bay of Bengal on the south-east. The state is comprised of 30 districts with 315 blocks. The state ranks 9th position in terms of area and Odisha comes under Agro-Climatic Zone 7 (ACZ 7) according to the classification by Planning Commission, Govt. of India.

### 2.2 Methods

It involves different spectral remote sensing methods that are followed for executing Study of crop discrimination using satellite data. The pre-processing steps, computation of spectral indices and data analysis. After that the generation of NDVI, LSWI images classification. The methodology involves creation of database, analysis of satellite data for study area, crop condition assessment and characterization of Rice ecology. The methodology overview the Rice crop delineation and condition assessment.

### 2.3 Computation of Spectral Indices

#### 2.3.1 Normalised difference vegetation index (NDVI)

Spectral response characteristics of healthy vegetation can easily be characterized in different parts of the electromagnetic spectrum. To further enhance the discrimination between different spectral vegetation classes, computation of different vegetation indices using infrared and red band data in the electromagnetic spectrum, for describing the crop growth conditions, are commonly used. The most commonly used vegetation index is NDVI. NDVI is most widely used for operational crop assessment because of its simplicity in calculation, easiness in interpretation and also its ability to partially compensate for the effects of atmosphere, illumination geometry etc. The Normalized Difference Vegetation Index (NDVI) is expressed as shows in equations Where:

$$NDVI = \frac{NIR - R}{NIR + R}$$

#### 2.3.2 Deriving NDVI from MODIS optical satellite images

MOD13Q1 provides MODIS band 1-2 surface reflectance at 250 m resolution. Each product pixel contains the best possible L2G observation during a 16-day period as selected on the basis of high observation coverage, low view angle, absence of clouds or cloud shadow, and aerosol loading. Using ERDAS Model maker, NDVI was calculated for entire India for the year 2008-18 Kharif rice crop season using band 2 (NIR) and band 1(Red) of MOD13Q1 250m 16days composite images.

MOD09A1 provides MODIS band 3-7 surface reflectance at 500 m resolution. Each product pixel contains the best possible L2G observation during an 8-day period as selected on the basis of high observation coverage, low view angle, absence of clouds or cloud shadow, and aerosol loading. Using ERDAS Model maker, NDVI was calculated for entire India for the year 2008-18 Kharif rice crop season using band 2 (NIR) and band 1(Red) of MOD09A1 500m 8days composite images.

#### 2.3.3 Land surface water index (LSWI)

Higher values of LSWI signify more surface wetness. Shortwave Infrared (SWIR) band (2-10µm) is sensitive to moisture available in soil as well as in crop canopy. In the beginning of the cropping season, soil background is dominant hence SWIR is sensitive to soil moisture in the top 1-2 cm. As the crop progresses, SWIR becomes sensitive to leaf moisture content. SWIR band provides only surface wetness information. When the crop is grown up, SWIR response is only from canopy and not from the underlying soil. The LSWI index is expressed with the following equation;

$$LSWI = \frac{NIR_{ref} - SWIR_{2ref}}{NIR_{ref} + SWIR_{2ref}}$$

Where:

$$NIR_{ref} = \text{Near Infra-Red band} \quad SWIR_{2ref} = \text{Short-Wave Infrared band}$$

#### 2.3.4 Deriving LSWI from MODIS Optical Satellite images

LSWI uses the SWIR and the NIR regions of the electromagnetic spectrum. There is strong light absorption by liquid water in the SWIR, and the

LSWI is known to be sensitive to the total amount of liquid water in vegetation and its soil background. The formula used for calculating LSWI from MOD09A1 product is given below:  $LSWI = \frac{(NIR858nm - SWIR2130nm)}{(NIR858nm + SWIR2130nm)}$  Using ERDAS Model maker, LSWI was calculated for entire India for the year 2008-18 Rice season using band 5 (NIR) and band 7 (SWIR2) of MOD13Q1 250m 16days composite images.

### 3. RESULTS AND DISCUSSION

In the present study, attempt was made to derive kharif rice growth and condition. Information from remote sensing derived from spectral remote sensing data. 10 years of MODIS data of 250m and 500m spatial resolution with 16 day and 8-day temporal resolution were used from 2008-2018 and statistics were extracted block wise for each time composite image as well as season maximum image. Kharif crop greenness, wetness condition informed in terms of NDVI, LSWI respectively.

#### 3.1 Seasonal and Interannual Analysis of NDVI, LSWI

NDVI value index represents greenness condition of crop .value of NDVI ranges from -1 to +1. NDVI is computed for each 16-day composite image of 250m resolution derived from MOD13Q1 from 2008-2018. Block wise zonal mean NDVI was extracted and plotted against Julian day. These images were masked with kharif rice crop; hence these statistics of this indices are inferred as kharif rice greenness condition. This NDVI profile matches with the kharif rice phenology in the state. the significant difference was observed among the blocks within the district. Peak NDVI matches the vegetation peak of mid-September to mid-October gradually it decreases and reaches minimum value at senescence.

LSWI value index represents wetness condition of crop. Value of LSWI ranges from -1 to +1. LSWI is computed for each 16-day composite image of 250m resolution derived from MOD13Q1 from 2008-2018. Block wise zonal mean. LSWI was extracted and plotted against julian day .these images were masked with kharif rice crop, hence these statistics of this indices are inferred as kharif rice wetness condition .this LSWI profile matches with the kharif rice phenology in the state ,the significant difference

was observed among the blocks with in the district . Peak LSWI matches the peak water content in crop July to mid-October gradually it decreases and reaches minimum value at senescence.

Season maximum NDVI LSWI were mapped with 5 classes starting from 0 to 0.9. The interannual maps of these season max NDVI, LSWI most of the area in the range of high range (more than 0.6), though these significances change in district within a block, NDVI statistics of this index are inferred as kharif rice greenness condition. This NDVI profile matches with the kharif rice phenology in the state. Similarly LSWI statistics of this indices are inferred as kharif rice wetness condition. This LSWI profile matches with the kharif rice phenology in the state. from the following figures / graphs showing highest and lowest peaks.

#### 3.2 Cuttack

**NDVI, LSWI:** As shown in Fig. 1. The range of NDVI is from 0.28-0.78 and range of LSWI is from 0.15-0.75. The highest values of NDVI are observed in Tigira block and lowest values is observed in Barkot block. The highest value of LSWI observed in Tigira block and lowest value is observed in Salepur block.

Both indices values are observed during 2<sup>nd</sup> fortnight of October shows highest peak and gradually start decreasing from the month of November up to January as shown in Fig. 2. for all the years from 2008-2018 but the NDVI values in 2009-2010 year relatively lower than all other years recorded.

#### 3.3 Jagatsinghpur

**NDVI, LSWI:** As shown in Fig. 3. The range of NDVI is from 0.28-0.78 and range of LSWI is from 0.15-0.75. The highest values of NDVI are observed in Parpan block and lowest values is observed in Rasulpur block. The highest value of LSWI observed in Jagatsinghpur block and lowest value is observed in Tirtol block.

Both indices values are observed during 2<sup>nd</sup> fortnight of September shows highest peak and gradually start decreasing from the month of November up to January as shown in Fig. 4. For all the years from 2008-2018 but the NDVI values in 2009-2010 year relatively lower than all other years recorded.

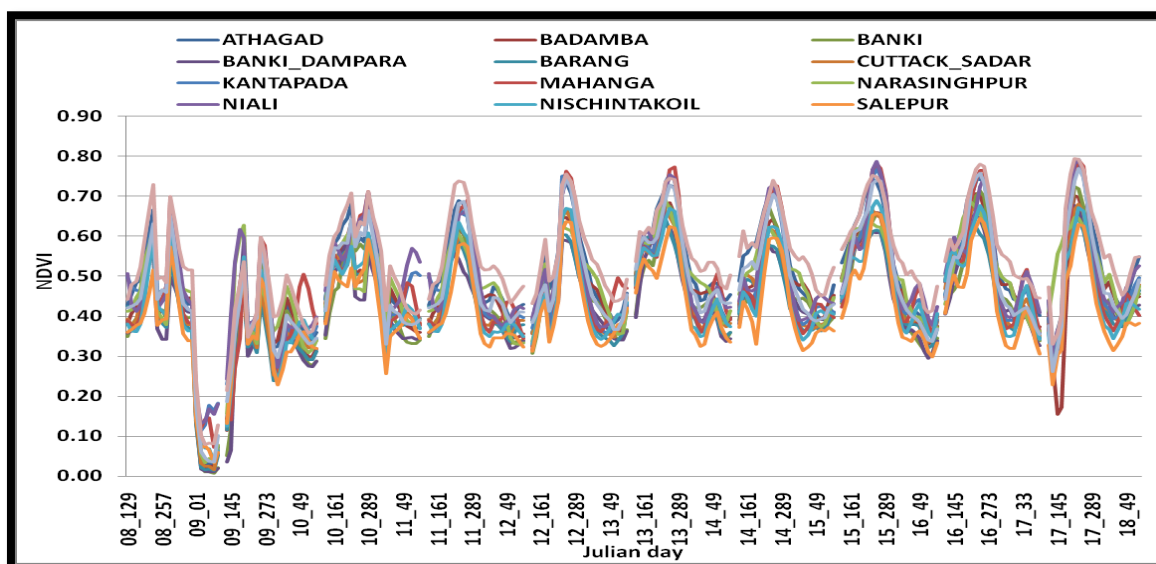


Fig. 1. Graphical representation of NDVI by using MODIS data CUTTACK district

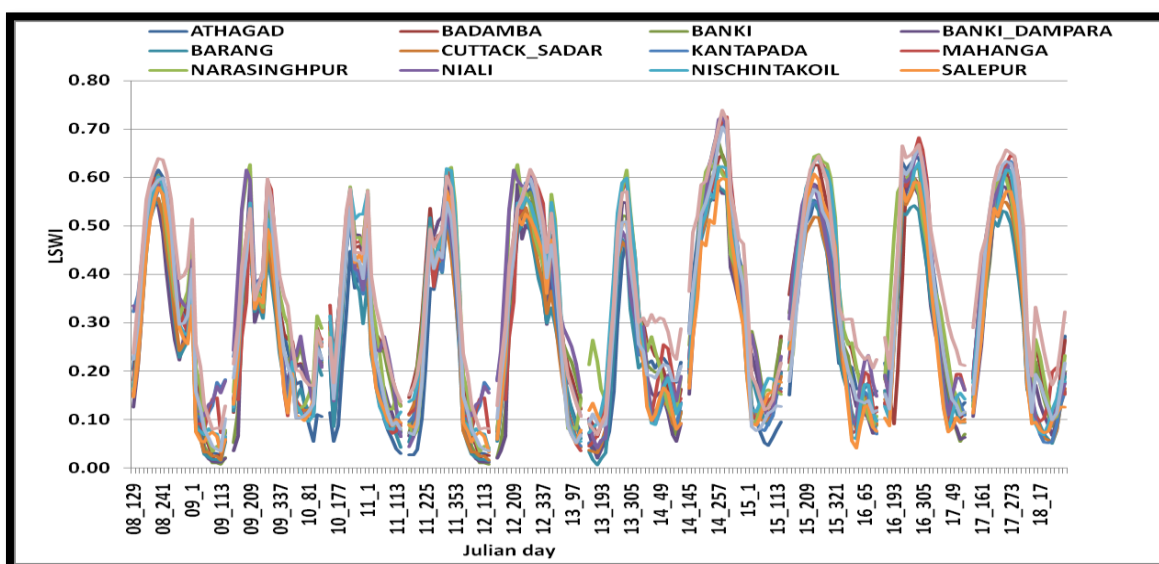


Fig. 2. Graphical representation of LSWI by using MODIS data CUTTACK district

### 3.4 Kendrapara

**NDVI, LSWI:** As shown in Fig. 5. The range of NDVI is from 0.28-0.78 and range of LSWI is from 0.15-0.75. The highest values of NDVI are observed in Derabisi block and lowest values is observed in Rajnagar block. The highest value of LSWI observed in Rajnagar block and lowest value is observed in Mahakalapada block.

Both indices values are observed during 2<sup>nd</sup> fortnight of September shows highest peak and gradually start decreasing from the month of

November up to January as shown in Fig. 6. For all the years from 2008-2018 but the NDVI values in 2009-2010 year relatively lower than all other years recorded.

### 3.5 Puri

**NDVI, LSWI:** As shown in Fig. 7. The range of NDVI is from 0.28-0.78 and range of LSWI is from 0.15-0.75. The highest values of NDVI are observed in Nimapada block and lowest values is observed in Krushnapada block. The highest value of LSWI observed in Satyabadi block and lowest value is observed in Nimapada block.

Both indices values are observed during 2<sup>nd</sup> fortnight of august shows highest peak and gradually start decreasing from the month of November up to January as shown in Fig. 8. For all the years from 2008-2018 but the NDVI values in 2009-2010 year relatively lower than all other years recorded.

### 3.6 Khordha

**NDVI, LSWI:**As shown in fig no. 9 the range of NDVI is from 0.28-0.78 and range of LSWI is from 0.15-0.75. The highest values of NDVI are

observed in Banapur block and lowest values is observed in Balianta block. The highest value of LSWI observed in Banapur block and lowest value is observed in Balipatna block.

Both indices values are observed during 1st fortnight of September shows highest peak and gradually start decreasing from the month of November up to January as shown in fig no.10 for all the years from 2008-2018 but the NDVI values in 2009-2010 year relatively lower than all other years recorded

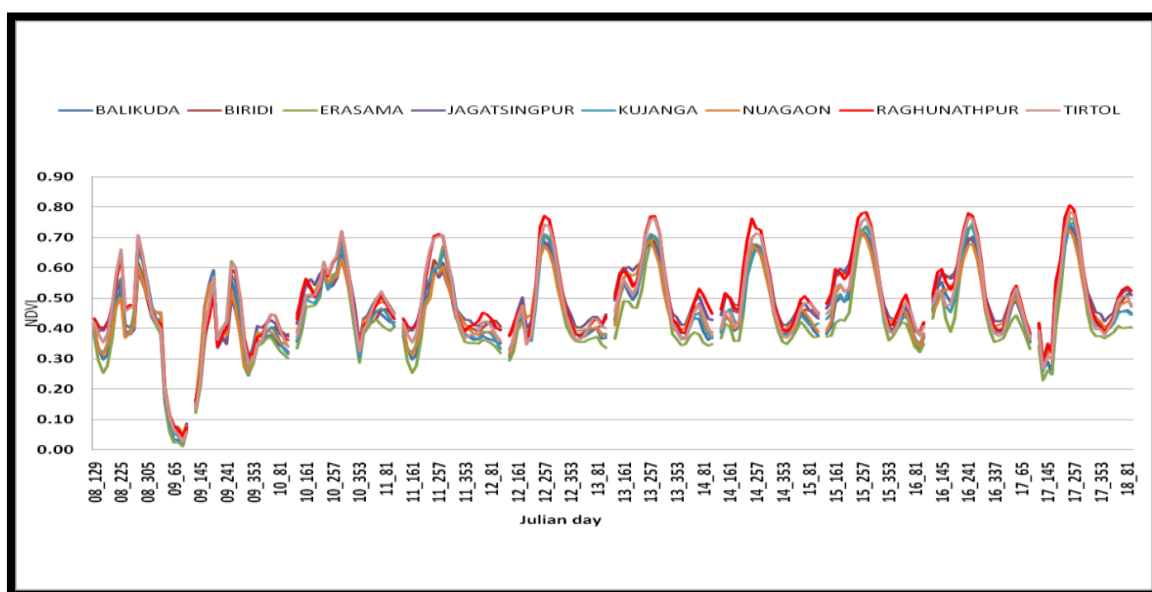


Fig. 3. Graphical representation of NDVI by using MODIS data JAGATSINGHPUR district

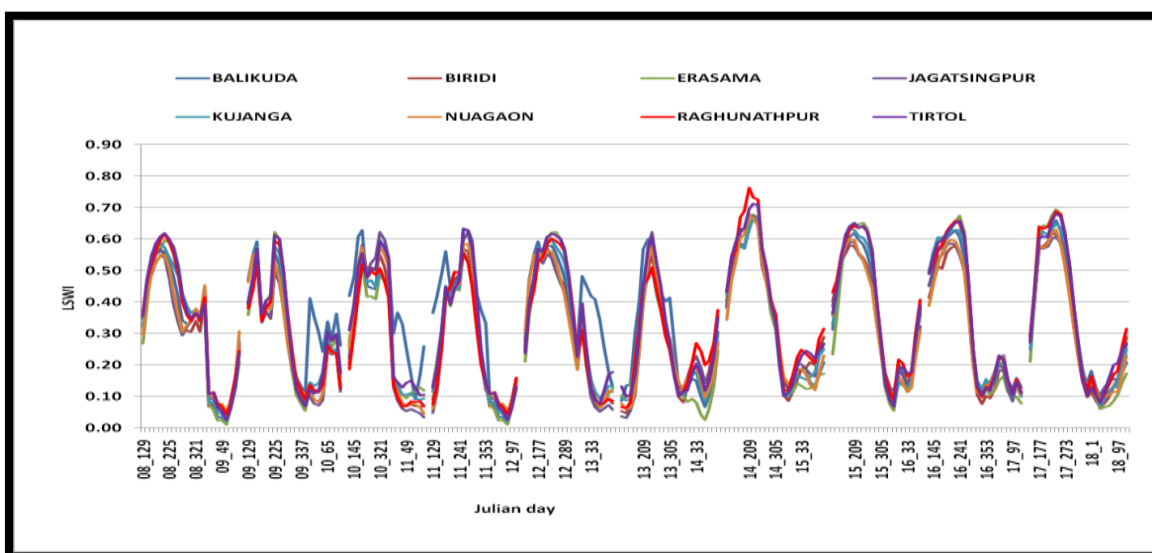


Fig. 4. Graphical representation of LSWI by using MODIS data JAGATSINGHPUR district

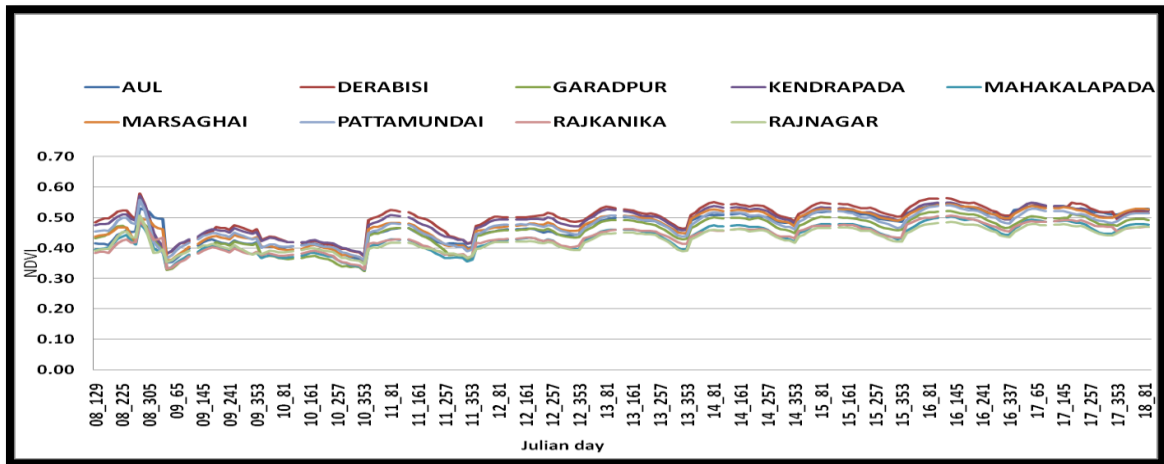


Fig. 5. Graphical representation of NDVI by using MODIS data KENDRAPARA district

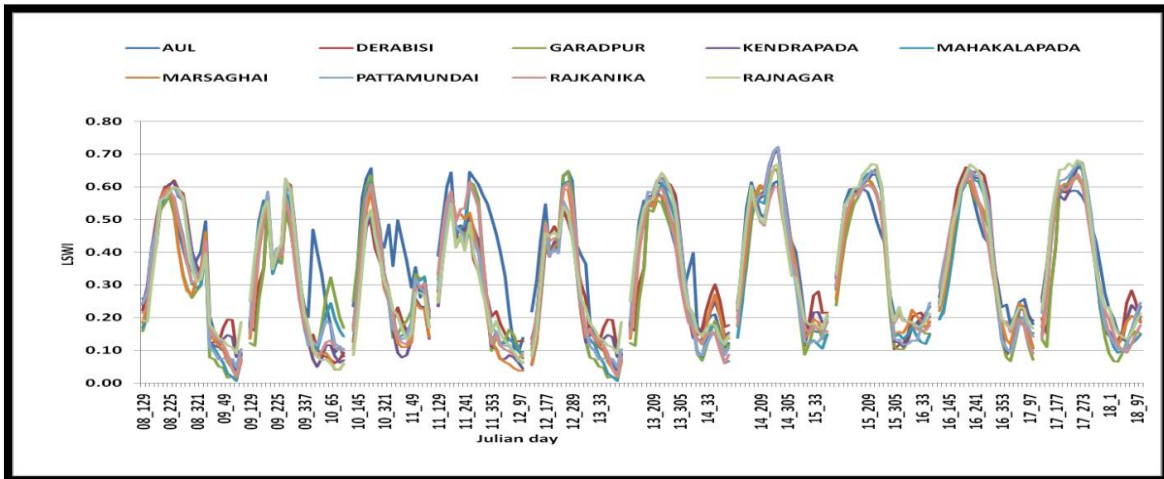


Fig. 6. Graphical representation of NDVI by using MODIS data KENDRAPARA district

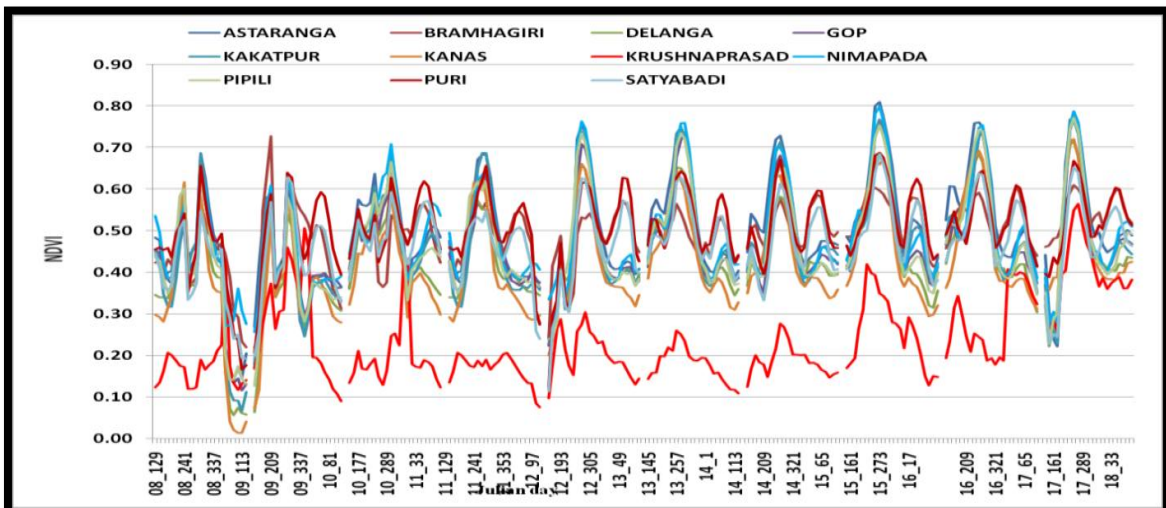


Fig. 7. Graphical representation of NDVI by using MODIS data PURI district

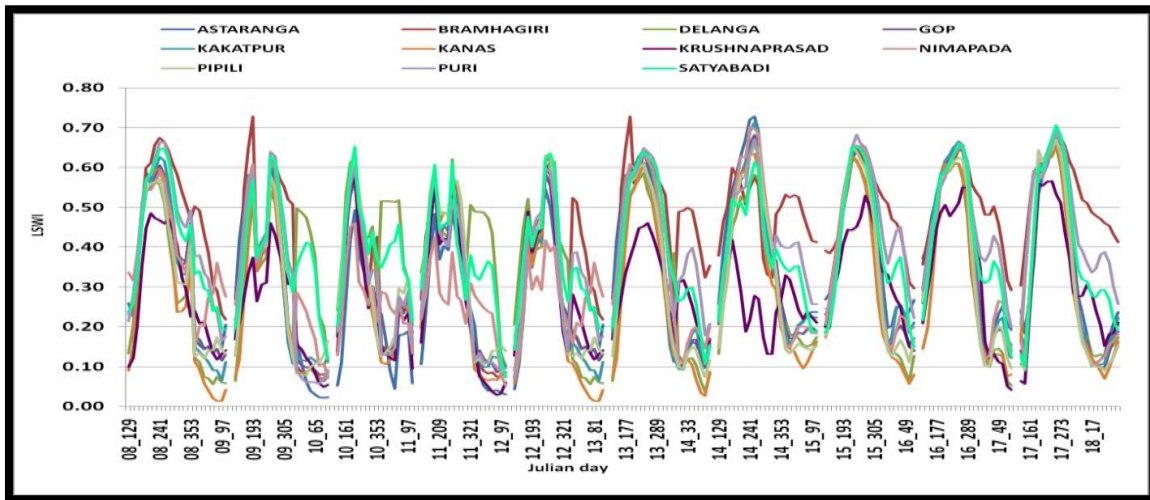


Fig. 8. Graphical representation of LSWI by using MODIS data PURI district

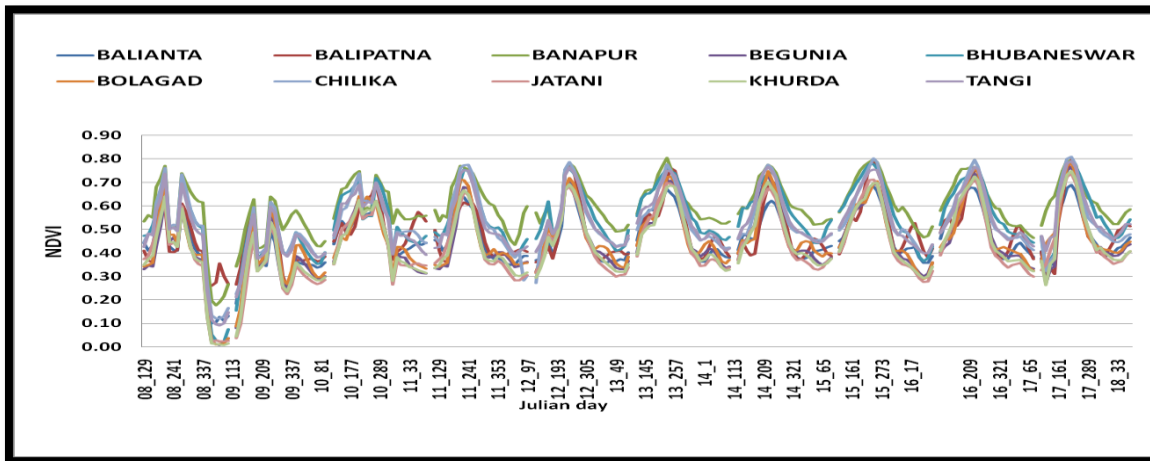


Fig. 9. Graphical representation of NDVI by using MODIS data KHURDA district

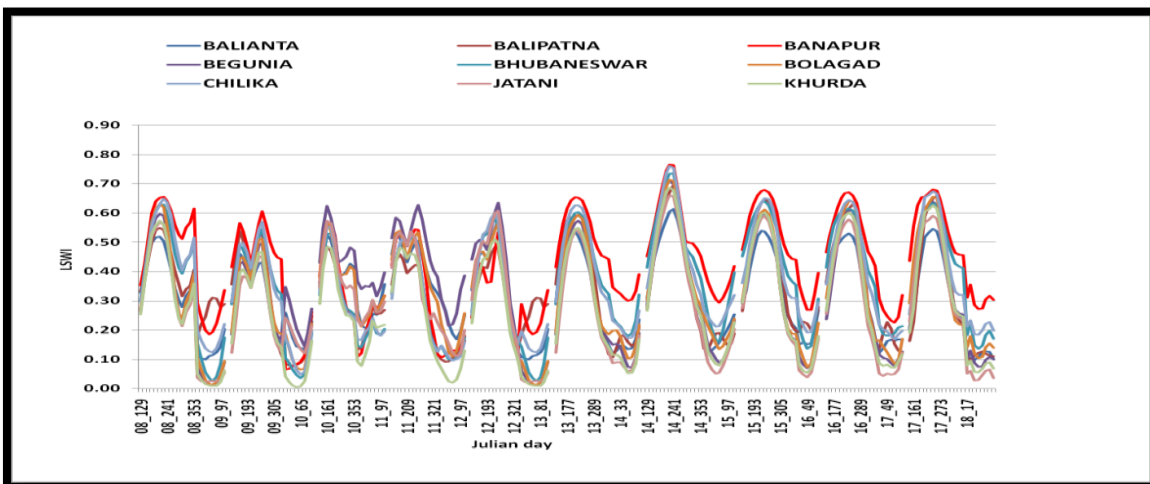


Fig. 10. Graphical representation of NDVI by using MODIS data KHURDA district



### 3.7 Nayagarh

**NDVI, LSWI:** As shown in fig no. 11 the range of NDVI is from 0.28-0.78 and range of LSWI is from 0.15-0.75. The highest values of NDVI are observed in Gania block and lowest values is observed in Bhapur block. The highest value of LSWI observed in Ranpur block and lowest value is observed in Bhapur block.

Both indices values are observed during 2<sup>nd</sup> fortnight of September shows highest peak and gradually start decreasing from the month of November up to January as shown in fig no.12 for all the years from 2008-2018 but the NDVI values in 2009-2010 year relatively lower than all other years recorded.

### 4. SEASONAL AND INTERANNUAL ANALYSIS OF NDVI, LSWI

Changing trends in ecology can be quantified using satellite observation of spectral indices.

however the estimation of trends from the time series indices differs substantially depending on analysed satellite dataset with corresponding spectrotemporal resolution .Here we compare the performance of wide range of trend estimation methods and demonstrates that performance decreases with increasing inter annual variability in spectral indices time series.

Temporal profiles of NDVI,LSWI for each season, for each year demonstrates that kharif rice crop phenology well presented. Temporal profile of seasonal NDVI represents well greenness condition of rice crop and the values gradually increases from mid-July to mid-September represents the peak vegetative growth of rice.

Table 1. We can see the highest and lowest peaks of NDVI, LSWI of different blocks under east and southern east odisha.

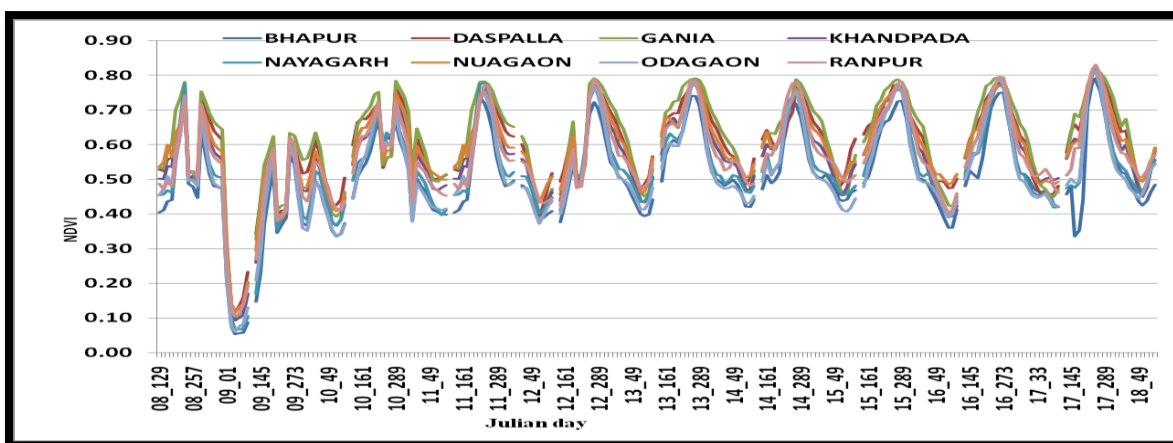


Fig. 11. Graphical representation of NDVI by using MODIS data NAYAGARH district

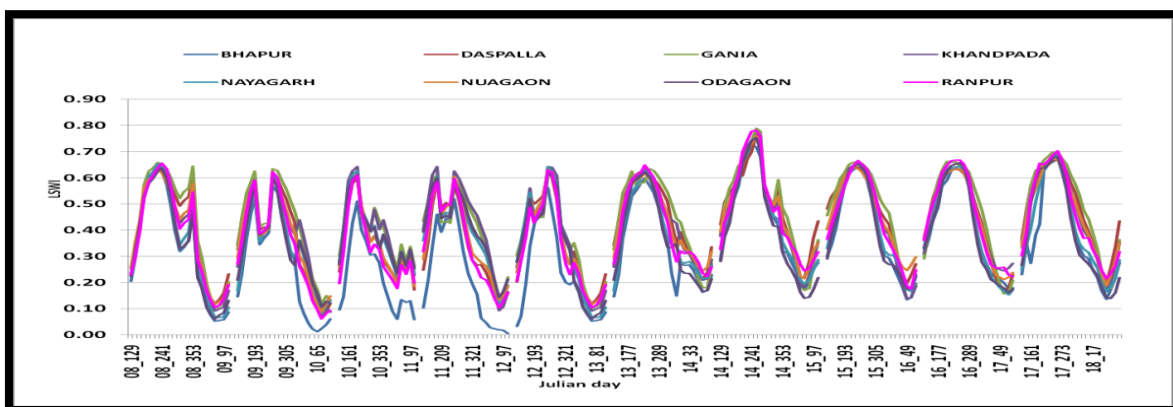


Fig. 12. Graphical representation of LSWI by using MODIS data NAYAGARH district

**Table1. Representation of NDVI, LSWI values of East and Southern Plateau Zone of Odisha**

<b>East and South Eastern Plateau zone of ODISHA</b>				
<b>Block level NDVI , LSWI values of respective districts</b>				
<b>District</b>	<b>NDVI Highest peak</b>	<b>NDVI Lowest peak</b>	<b>LSWI Highest peak</b>	<b>LSWI Lowest peak</b>
Cuttack	Tigra	Salepur	Banki	Salepur
Jagatsinghpur	Parapan	Rasulpur	Jagatsinghpur	Tirtol
Kendrapara	Derabisi	Rajnagar	Rajnagar	Mahakalapada
Puri	Nimapada	Krushnapada	Satyabadi	Nimapada
Khurda	Banapur	Balianta	Banapur	Balipatna
Nayagarh	Gania	Bhapur	Ranpur	Bhapur

## 5. CONCLUSION

The present study demonstrates methodology of extracting kharif rice condition and phenology information from temporal images from MODIS 250m,500m of 16 day and 8-day composite respectively, as these MODIS data are daily products can be used for kharif crop growth and condition monitoring. In present study it is observed that rice crop phenology matches with temporal profile of ndvi lswi and following are the concluded points:

- Greenness condition of kharif rice is well represented through temporal profile of ndvi
- The NDVI profile is a representation of crop phenology with minimum value of showing senescence and maximum value at peak vegetative growth.
- Wetness condition of kharif rice is well represented through temporal profile of LSWI .
- The LSWI profile is a representation of crop phenology with minimum value of showing senescence and maximum value at peak water content in the crop growth.
- The intra annual comparison of all these conditions represents weather condition particularly onset and receding of monsoon.
- Though cloud is a limiting factor in optimal remote sensing time composite of daily index minimizes the cloud effect.
- These mod09a1(500m) 8day composite, mod13q1(2580m) 16-day composite products are well suited for monitoring kharif rice crop growth and condition monitoring at district level.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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