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Impact of Climate Change on *Kharif* Paddy Crop in Odisha

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ABSTRACT

Climate change is one of the leading challenges for agrarian economy. Variability associated with weather parameters like temperature and rainfall largely affect agricultural productivity as well as yield. Odisha is predominantly a rain fed rice ecosystem with 71% rain fed and 29% canal irrigated area. Extremity of climate variability across all scales is the growing concern as it directly affects agricultural production. In the view of increasing sporadic rainfall patterns and mean temperature associated in the current scenario, an attempt has been made to evaluate the potential impact of climatic variations on production and productivity of *kharif* paddy. Present study has been carried out by considering meteorological data of rainfall, temperature and crop productivity from the year 2006-2022. The meteorological and vegetation data is collected from *in-situ* sources. The analysis shows that there is a decreasing trend in rainfall (–16.5 mm/season) and an increasing trend in temperature (0.05°C/season) for yearly estimation. The temperature shows the weekly average of 30°C with 0.03°C/week trend, whereas rainfall shows 0.0008 mm/week which shows that the rainfall is having more impact on *kharif* paddy productivity and health as compare to temperature. Similarly, the area, production and productivity of paddy crop has shown a substantial change reveals that climate has a significant influence on the agricultural production of Odisha. The possible future climate scenarios are found to have a negative impact on the net revenue from agricultural production of Odisha towards the end of the twenty-first century, which call for some policy attention.

Keywords Rainfall, Temperature, Climate change, Climate variability, Vegetation indices.

INTRODUCTION

A threat of climate change emerges large over the worldwide food security, particularly susceptible for the rice production (Ansari *et al.* 2023). Moreover, a change in climate lead to the global warming which disrupt the weather pattern, which cause events like

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flood and droughts (Seneviratne *et al.* 2021). Such change including the rise in the temperature significantly affects the rice production. The probable consequences are awful as rice is the primary food for billions. To ensure food safety despite the climate change globally. It is difficult to understand how different varieties of rice are going to be affected with this change. Since, rice is the India's primary gain, thus to understand the climate change which is affecting the rice yield is a crucial aspect to raise the production. In this context, Odisha, which is an India eastern state, is particularly vulnerable to the effects of climate change, including heatwaves, cyclones, floods, and droughts (Patel *et al.* 2019). The state has a tropical climate with a monsoon season from June to September months, and a dry season from October to May months. Cyclones from the Bay of Bengal frequently hit Odisha, wreaking havoc on the state's agriculture, infrastructure, and way of life (Singh and Jeffries 2013). Variations in rainfall patterns have resulted in problems related to flooding and scarcity of water. The *kharif* season is extremely important in Odisha, particularly for agriculture and the growing of paddy or rice. Pasupalak reviewed a climate change and agriculture in Orissa (Pasupalak 2009). Odisha is a mainly agrarian economy with a GSDP (Gross State Domestic Product) value of Rs 3.74 trillion at current prices contributing about 26.5% (Sahu and Gartia 2022). A study using meteorological data and satellites found that climate change significantly affects agricultural output, with potential future scenarios negatively affecting net revenue from agricultural production by the end of the century (Das and Mishra 2017). Rice accounts for 42% of total food grains and 45% of total cereal production in India (Nikitha and Natarajan 2020). In *kharif* season 2021, acreage in India increased by 0.20% from 41.33 M ha to 41.41 M ha (Snigdha 2022). Rice is a major cereal grown in the state, with nearly 5 million hectares of area (884,282 ha of *kharif*-autumn rice, 3,401,572 ha *kharif*-winter rice, and 884,282 ha of *rabi*-summer rice) and 71% of the total rice crop is rainfed (Gumma *et al.* 2015). Moreover, a vegetation index demonstrated for derivation of land surface temperature using satellite imagery and its relationship (Parmar and Gontia 2019). The climate change and cropping pattern in Keonjhar district of Odisha, India investigated recently by Parida *et al.* (2023).

In this paper, *kharif* paddy, being a water-intensive crop, heavily relies on adequate water supply throughout its growth stages, especially during the *kharif* season. To address such issues, the study aims to contribute valuable insights into the nexus between rainfall variability and paddy cultivation in Odisha, with the overarching goal of informing evidence-based policies and strategies for enhancing agricultural resilience and ensuring food security in the face of climate change. The following objectives: (a) To study the impact of monsoon rainfall on *kharif* rice production in Odisha. (b) Relationships of various indices with rainfall have been studied.

MATERIALS AND METHODS

General description of the study area: Odisha lies between the latitudes 17.78ºN and 22.73ºN, and between longitudes 81.37ºE and 87.53ºE (Fig. 1). The state has a geographical area of 15.571 mha lying just south of the Tropic of Cancer. Odisha State is highly humid with medium-to-high rainfall, tropical and short winter with mild temperature. The annual long-term rainfall of the state varies between 961 and 1872 mm. Out of this southwest monsoon contributes 79% i.e. 1152 mm. Long Period Average (LPA) of rainfall is the rainfall recorded over a particular region for a given interval (like month or season) averaged over a long period like 30-years, 50 years. Long Period Average (LPA) of southwest monsoon rainfall over Odisha for the months June, July, August and September are 216.5 mm, 339 mm, 356 mm and 231.9 mm respectively. Odisha is predominantly a rainfed rice ecosystem *kharif* having 10 agro-climatic zones with various types of soil like red, yellow, red-loamy, alluvial and coastal alluvial, laterite and black soil, with a low and medium texture. Impact of climate variables such as temperature and rainfall on the productivity of paddy crops in Odisha during the period 2006-2019 using district level secondary data were evaluated.

Meteorological data: Rainfall data is collected from India Meteorological Department (IMD) and SRC, Odisha as yearly and weekly normal from the year 2006-2022. Temperature data is collected from the Nasa POWER project which uses MERRA-2 (Modern-Era Retrospective Analysis for Research

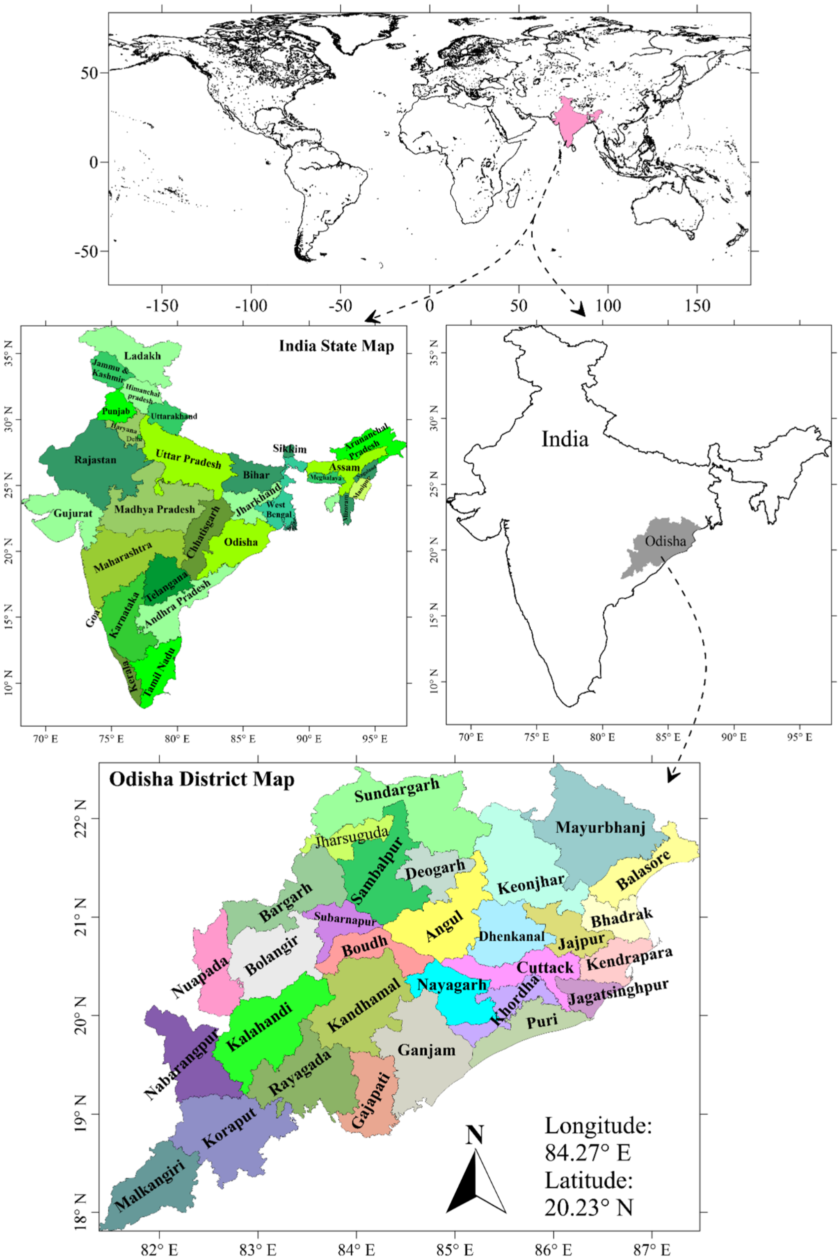

Fig. 1. Study area (Odisha).

and Application). MERRA-2 is a version of NASA's Goddard Earth Observing System (GEOS) Data Assimilation System (Bosilovic *et al.* 2016).

Crop data : Area, production and productivity reports of paddy crop during the year 2006-2019 for *kharif* season obtained from the State Government Site of the Agricultural Department in Odisha. By employing a combination of data collection methods and techniques such as Weather Stations, Sensor-Based

Technologies, Remote Sensing, Historical Data Analysis, researchers and agricultural practitioners can gather comprehensive and accurate information on *kharif* rice crops, leading to better-informed decision-making, improved crop management practices, and enhanced agricultural productivity.

Geospatial data using QGIS 3.22, ArcGIS 10.7.1 & Google Earth Engine Platform: Software used for digital processing of satellite images and Map processing are QGIS 3.22 (Open source geospatial application) & Google Earth Engine, ArcGIS online (public). QGIS is a tool for focusing on spatial data, overlay modeling and visualizing climate, habitat, geographic, and species occurrence data. ESRI ®ArcMap is the application for creating and altering geographic and tabular data, in addition to map making and map-based analysis. Google Earth Engine (GEE) is a computing platform that allows users to run geospatial analysis on Google's infrastructure. Data from Landsat 4, 5, 7 and 8 processed by the US Geological Survey (USGS), many MODIS products, including global composites, recent imagery from Sentinel 1, 2 and three satellites, and much more may be found in the GEE.

Satellite data: Various indices data is collected from STAR- Global Vegetation Health Products: Browse archived image of selected administrative region (noaa.gov), https://www.star.nesdis.noaa.gov. Normalized difference vegetation index (NDVI) were used for classification and an NDVI 8-day data set was used for identifying and labeling seasonal rice classes. Facing the worldwide usage of AVHRR (Advanced Very-High-Resolution Radiometer), NDVI (Normalized difference vegetation index), the stratification resulted in the Vegetation Condition Index (VCI), which could be simply illustrated as:

$$VCI=100\times(NDVI-NDVI\ min)/(NDVI\ max-NDVI\ min)$$

Where, NDVI max, and NDVI min are the multi-year absolute maximum and minimum values of NDVI. As VCI is more sensitive to rainfall dynamics compared to NDVI, so it is a better indicator of vegetation response to precipitation impact. VCI is a proxy for moisture conditions.

VCI could be augmented by the introduction of the Temperature Condition Index (TCI), for determining temperature-related vegetation stress and also stress caused by excessive wetness. TCI is a proxy for thermal conditions. TCI is defined as:

$$TCI=100\times(BT\ max-BT)/(BT\ max - BT\ min)$$

Where, BT, BT max and BT min are the Brightness Temperature, originally derived from AVHRR's fourth channel (10–11.5 μm), its multi-year absolute maximum and minimum, respectively. By combining VCI and TCI through weighted averaging, one can obtain the Vegetation Health Index (VHI) as:

$$VHI= \alpha\times VCI+(1-\alpha)\times TCI$$

Where, α is a coefficient determining contribution of the two indices. VHI is a proxy characterizing vegetation health or a combined estimation of moisture and thermal conditions. VH (VHI, VCI, TCI) is used often to estimate crop condition and anticipated yield.

The Normalized Difference Vegetation Index (NDVI) measures the greenness and the density of the vegetation captured in a satellite image. Healthy vegetation has a very characteristic spectral reflectance curve which we can benefit from by calculating the difference between two bands-visible red and near-infrared. NDVI is that difference expressed as a number ranging from -1 to 1. NDVI is calculated with the following expression:

$$NDVI = (NIR-Red) / (NIR+Red)$$

Where NIR is near-infrared light and Red is visible red light.

RESULTS AND DISCUSSION

Climate variability has drawn a lot of interest from throughout the globe, especially that related to weekly and yearly rainfall and temperature. The degree of the component variations or variability varies depending on the locale. Therefore, in order to evaluate climate-induced changes and provide workable adaptation measures, so it is essential to look at the spatio-temporal dynamics of meteorological variables in the context of changing climate, especially under

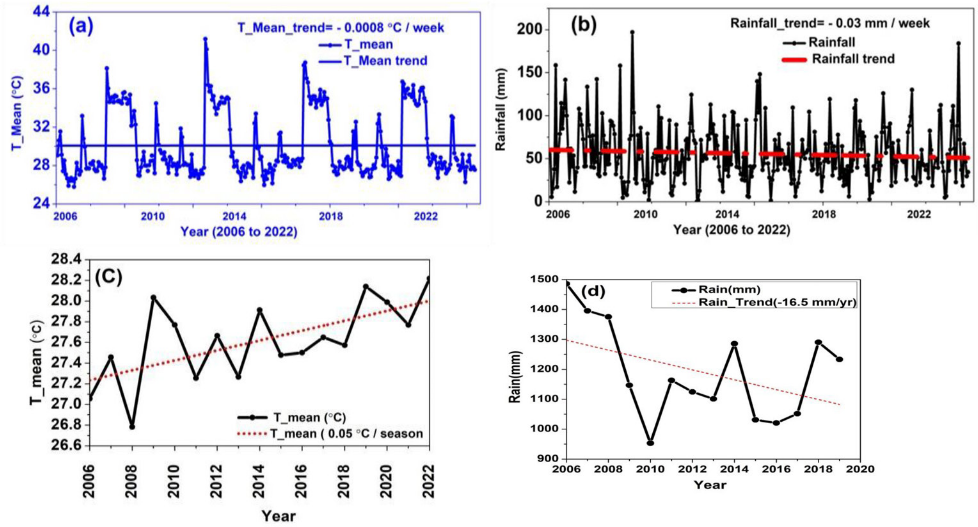

Fig. 2. (a) Weekly mean temperature (T_Mean in°C), (b) Weekly rainfall (mm), (c) Yearly mean temperature (T_Mean in °C) and (d) Weekly rainfall (mm) from 2006 to 2022 over the Odisha region.

rainfed conditions where this practice is prevalent. In order to do this, the current study looks at both short- and long-term variations in the temperature and monsoonal rainfall all the districts of Odisha. This research investigated temperature and rainfall data for the years 2006–2022. The issues were analyzed by using slope estimators and trend analysis approaches. From 2006 to 2022, the weekly average temperature analysis shown in Fig. 2 (a) revealed a tendency toward cooling (Slope: -0.0008ºC/week). The rainfall pattern for given study period is shown in Fig. 2 (b). A systematic examination of the data spanning for a given study period shown in Fig. 2 (c), depicts a rising trend in yearly temperature with a slope of 0.05ºC/season, whereas Fig. 2 (d) shows a declining trend in rainfall with a slope of -16.5 mm/year, whereas negative trend was observed i.e. -0.03 mm/week. It implies that rainfall has a greater impact on *kharif* paddy production as compared to temperature on yearly analysis which is contradicting for weekly analysis. The above weather parameters shown significant relationship in variation of area, production and productivity of paddy crop during the study period (2006-2019).

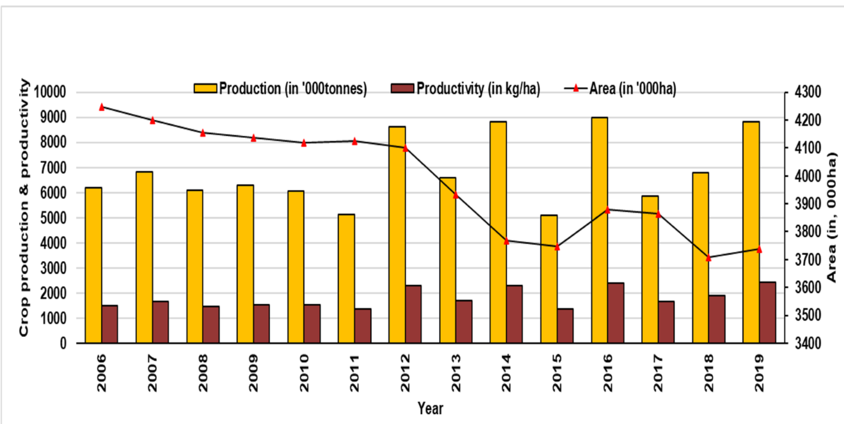

Fig. 3. Area, production & productivity of paddy in *kharif* during 2006-2020.

Table 1. Area, production & productivity of paddy in *kharif* during 2006-2019.

Year	Area (in'000 ha)	Productivity (in kg/ha)	Production (in '000 tons)	Rainfall amount (mm)
2006	4136	1498	6196	371.52
2007	4118	1658	6826	348.88
2008	4124	1477	6092	343.86
2009	4100	1535	6293	286.68
2010	3933	1539	6051	238.25
2011	3769	1360	5127	290.78
2012	3749	2302	8629	281.11
2013	3880	1697	6585	275.27
2014	3865	2287	8838	321.44
2015	3708	1373	5092	257.78
2016	3738	2408	9001	260.68
2017	3544	1652	5856	257.28
2018	3585	1899	6808	322.94
2019	3648	2418	8822	314.35

Table 2. Different vegetation products during the year 2006-2022.

	Indices				
Year	SMN	SMT	VCI	TCI	VHI
2006	0.227	289.617	59.419	24.24	41.83
2007	0.218	288.556	54.199	31.21	42.71
2008	0.204	286.49	45.756	36.299	41.03
2009	0.207	287.333	47.004	31.589	39.29
2010	0.234	291.373	62.693	18.689	40.69
2011	0.216	287.572	54.231	35.328	44.78
2012	0.191	287.241	39.441	34.561	37
2013	0.233	289.352	62.749	27.95	45.33
2014	0.222	290.039	56.627	23.213	39.89
2015	0.237	290.082	65.01	23.234	44.1
2016	0.216	287.457	53.243	34.864	44.04
2017	0.216	286.365	53.044	38.371	45.68
2018	0.205	287.904	47.637	31.744	39.67
2019	0.228	290.389	60.874	22.501	41.66
2020	0.249	289.399	72.593	27.689	50.12
2021	0.241	289.202	68.109	28.602	48.33
2022	0.22	288.58	55.821	29.546	42.67

The possible impacts of climate change by using the climate response function in the 'best' guess climate change scenario of 2ºC temperature increase and 7% increase in precipitation (Kumar and Parikh 2001). Another investigation described that if temperature rises by 2ºC with an 8% increase in precipitation, agricultural net revenue may fall 12% in India (Sanghi and Mendelsohn 2008).

A number of these variables contribute to the

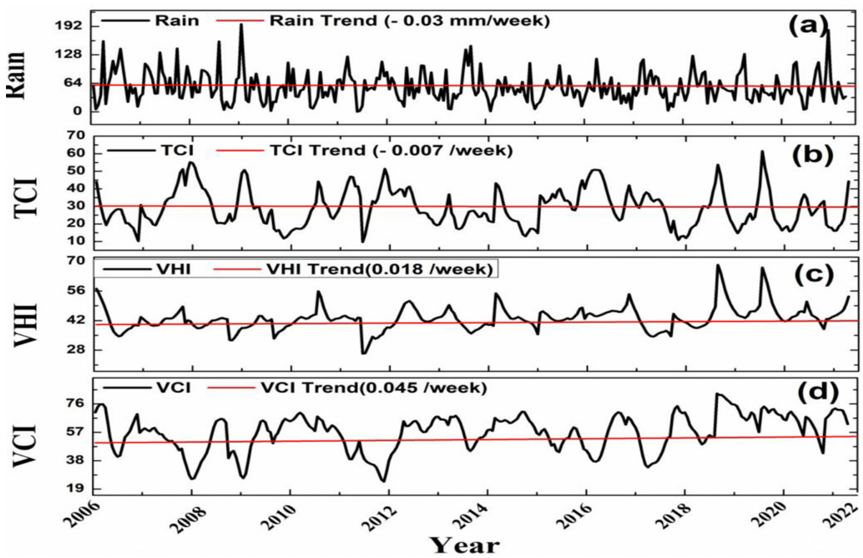

Fig. 4. Different vegetation products and its relation with rainfall during 2006-2022.

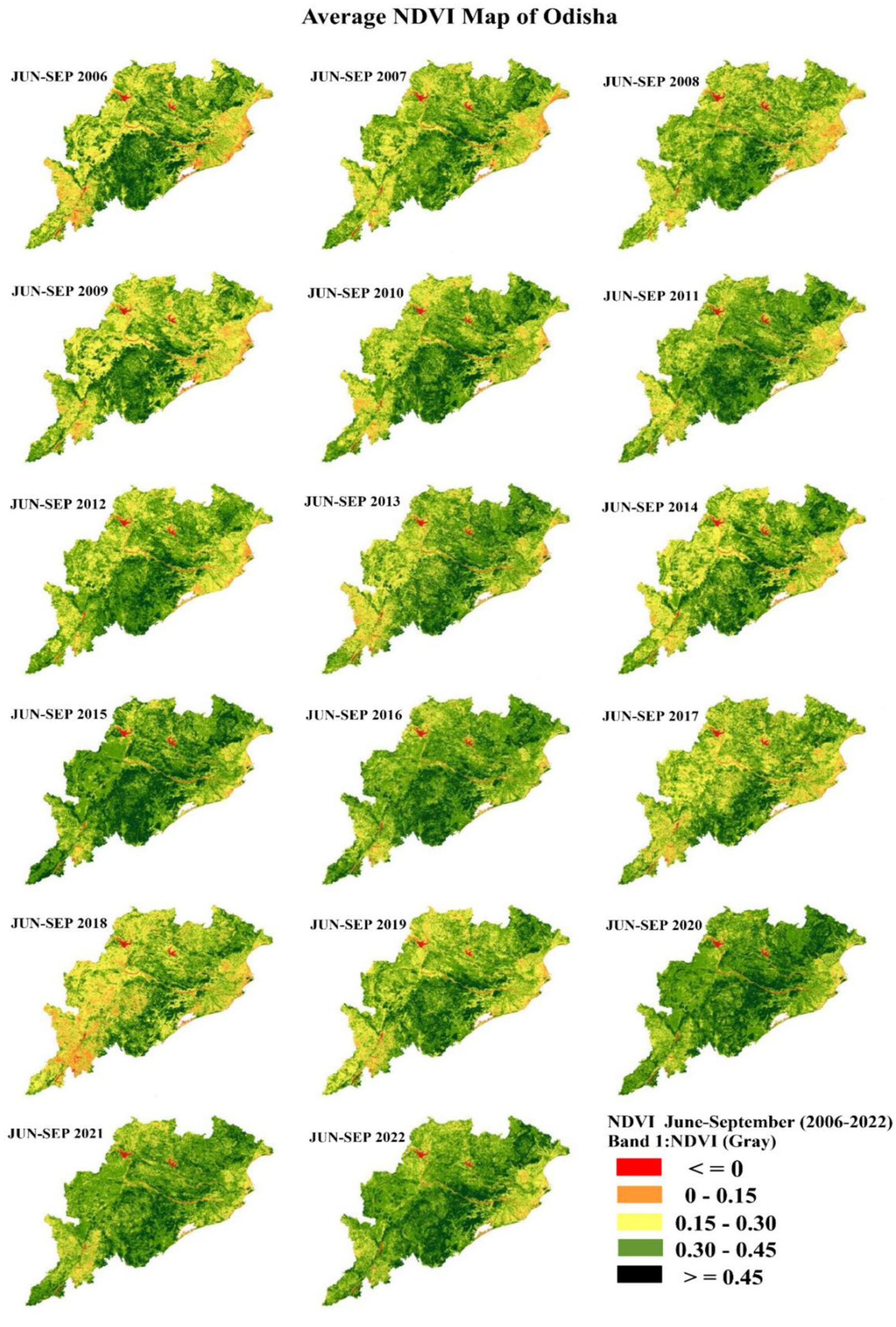

Fig. 5. NDVI mapping of monsoon (JJAS) during the year 2006-2022.

decrease in the area under agricultural cultivation, their relative importance varies based on the location and local conditions. It is essential to track and comprehend these processes in order to practice sustainable land management and endeavors to ensure food security. Rice output may be impacted by reduced cropping area (Table 1). A 4.32 lakh tonne paddy shortage, or almost 3 lakh tons of rice, might arise from the deficiency in the growing area. Severe weather conditions have a bigger impact on the area's departure and yield from long-term patterns compared to the typical seasonal environment, temperature and precipitation during the *kharif* seasons' sowing phase have a bigger impact on the overall yearly area's fluctuation than during the growth season.

Since the state's rice crop covers a larger area during the *kharif* season and climate fluctuations are influencing *kharif* paddy yields (Fig. 3). The combined impacts of temperature and precipitation had an impact on the growth of the plant, according to the correlation study between SMN and SMT with precipitation (Table 2). The relationship of rainfall analysis with different vegetation indexes i.e. Vegetation Health Index (VHI), Vegetation Condition Index (VCI), Temperature Condition Index (TCI) and Normalized Difference Vegetation Index (NDVI) (Zuhro *et al.* 2020). The positive trend was predominated in the VCI during the growing season, and the same was found true for the TCI. Identification and measurement of drought intensity are made feasible by the correlations between VHI ranges with drought, length of time and impacted region. In (Figs. 4–5) displayed weekly fluctuations of the various indicators examined during the period 2007-2022 trends. The slope displayed a strong positive elevation of VCI and VHI i.e. 0.045 and 0.018 per week, respectively. Amongst indices, the TCI trend indicates a negative trend of -0.007/week. It concludes that the vegetation condition index was very low in high rainfall years as compared to low rainfall years because the rainfall deficit was overcome through irrigation, whereas excess rainfall caused water stagnation due to poor drainage in crops field. Rainfall is decreasing and temperature is increasing constantly. High temperature and humidity of the state keep the temperature condition index within the range of 40 to 60 during most of the year, which shows evapotranspiration plays a vital role in crop production even if sufficient irrigation is provided. Vegetation health index (VHI) lies around 35 to 45% which denotes moderate health vegetative condition prevails throughout the growing period which is due to temperature and rainfall. *Kharif* paddy in Odisha was under moderate stress, where it may further intensify due to dry and wet spell of erratic pattern of rainfall.

CONCLUSION

The agricultural practices in Odisha studied here are mainly rain-fed and are highly dependent on rainfall patterns. Among two climatic parameters (rainfall and temperature), rainfall is shown high significant impact on the yield of paddy crops. The prevailing humid climate of Odisha state impacts crop growth with moderate stress in normal years and it is further intensified due to rainfall variation. Satellite-derived indices was found better tools to study the crop stress, development and yield, which will be helpful in the yield forecasts for the policy makers and stakeholders. Based on different indices viz. VCI, TCI, VHI and NDVI farmers can be suggested to proper management of agriculture resources to attain better growth, development and higher yield of *kharif* Paddy. These indices will also helpful for management of pest and diseases.

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