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SEASONAL VARIABILITY AND SPATIO-TEMPORAL TRENDS OF NDVI FOR VEGETATION MONITORING IN SANGLI DISTRICT OF WESTERN MAHARASHTRA INDIA

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ABSTRACT

This study investigates vegetation dynamics in Sangli district of Maharashtra using the Normalized Difference Vegetation Index (NDVI) derived from Landsat 8 Collection 2 Level-2 satellite data for the period 2014–2023. Seasonal NDVI values were analyzed for *kharif*, *rabi*, and summer to assess spatial and inter-annual variability in vegetation cover and its relationship with rainfall. Results showed that NDVI was highest in the *kharif* season, with the maximum mean value of 0.53 recorded in 2021, reflecting the influence of monsoon rainfall on crop growth. In *rabi*, the maximum mean NDVI reached 0.41 (2021), largely supported by residual soil moisture and irrigation. Summer exhibited the lowest vegetation activity, with the highest seasonal mean NDVI of 0.30 (2020 and 2021), due to water stress and high temperatures. Spatial analysis indicated that eastern talukas consistently showed lower NDVI, particularly in summer, highlighting their drought-prone nature. Inter-annual variation revealed poor vegetation conditions in 2015, 2016, and 2019, while 2020 and 2021 showed improved vegetation health under favourable rainfall and irrigation. Correlation analysis demonstrated a positive association between NDVI and rainfall in all seasons, with the strongest relationship in *kharif* (r = 0.74), followed by summer (r = 0.51) and *rabi* (r = 0.44). These results highlight NDVI as an effective indicator of vegetation response to rainfall and a useful tool for drought monitoring in semi-arid regions.

***Key words*:** NDVI, Vegetation Monitoring, Rainfall Correlation, Seasonal Variation, Sangli District

Introduction

Remote sensing technology has emerged as a vital tool for monitoring Earth surface, particularly vegetation dynamics, by utilizing electromagnetic radiation and its interaction with land cover (Richards and Jia, 2006). It provides timely, spatially comprehensive information for analyzing vegetation health, crop conditions, drought stress, and land-use changes. Among various satellite-derived indicators, vegetation indices are widely employed to assess vegetation cover, growth patterns, and stress conditions.

The Normalized Difference Vegetation Index (NDVI) is one of the most commonly used vegetation indices for evaluating vegetation health and productivity (Bannari *et al*., 1995). NDVI is calculated from red and near-infrared (NIR) reflectance, where healthy vegetation strongly absorbs visible red light and reflects NIR, yielding higher NDVI values (close to +1), while sparse vegetation, barren land, or water bodies result in lower or negative values. This makes NDVI highly sensitive to variations in greenness and photosynthetic activity, enabling effective monitoring of drought and crop stress (Wardlow *et al*., 2007).

Out of the several vegetation indices that have been formulated, the Normalized Difference Vegetation Index (NDVI) is the most commonly used because it is simple to compute, highly reliable, and closely linked with vegetation condition (Sahebjalal and Dashtekian, 2013).

First introduced by Deering (1978) and Tucker (1979), NDVI is derived from the contrast between red and near-infrared reflectance and produces values between –1 and +1. Higher values approaching +1 indicate healthy and dense vegetation, values near zero correspond to bare soil or urban surfaces, while negative values generally represent water bodies or non-vegetated land.

In semi-arid regions, such as Sangli district of Western Maharashtra, agriculture is heavily dependent on monsoon rainfall, with average annual precipitation around 692 mm (Anonymous, 2015). The district exhibits strong spatial variability: western talukas such as Shirala and Walwa receive relatively high rainfall (>1200 mm), while eastern talukas like Jat and Atpadi experience recurrent droughts with <600 mm. These climatic contrasts make NDVI a suitable indicator for studying spatial and temporal vegetation dynamics.

Several studies across India have highlighted the effectiveness of NDVI in detecting drought onset, severity, and spatial spread (Aswathi *et al*., 2018). By analyzing seasonal NDVI variations, it is possible to evaluate vegetation response to rainfall distribution, identify drought-prone regions, and support agricultural decision-making. Given Sangli's agro-climatic diversity and recurring drought conditions, NDVI-based monitoring provides valuable insights for sustainable water resource management and crop planning.

Materials and Methods

Study Area

Sangli District is geographically positioned between 16° 46' N and 17° 10' N latitude and 73° 42' E and 75° 41' E longitude, encompassing an area of approximately 8,610 square kilometers. Located on the Deccan Plateau, the district has an average elevation of about 553 meters above sea level. According to the Planning Commission of India and Maharashtra's Gazetteers Department, Sangli falls under the Hot Semi-Arid Agro-Climatic Zone, characterized by moderate rainfall and a tropical wet-dry climate. Receiving average rainfall 692 mm (IMD). According Rajmane *et al.*, more frequent drought events in Jat, Shirala, Tasgaon, Walwa, with comparatively fewer in Atpadi, Kavathe mahankal, Miraj, and the least in Khanapur, Kadegaon, Palus. Wale *et al.*, also reported that Eastern tehsils of Sangli are drought-prone.

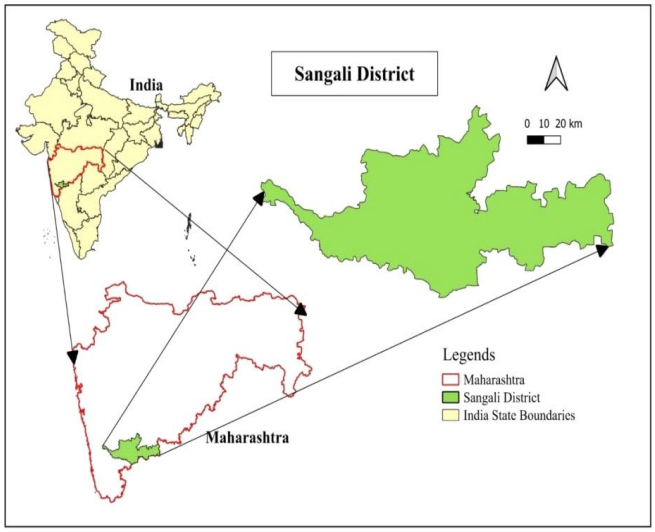

Fig. 1: Study Area.

In the present study, Landsat 8 Collection 2 Level-2 satellite data for the period 2014 to 2023 were acquired from the USGS Earth Explorer platform and processed using QGIS software to generate the Normalized Difference Vegetation Index (NDVI). NDVI serves as a reliable indicator of vegetation condition, as it reflects the degree of water availability or stress experienced by crops and natural vegetation. The index is computed from the red and near-infrared (NIR) spectral bands, using the ratio of their difference to their sum. Formula of NDVI is expressed as

$$\mathbf{NDVI} = \frac{\mathbf{(NIR + RED)}}{\mathbf{(NIR - RED)}} \quad \cdots\cdots$$ [Deering (1978), Tucker (1979)]

Where

NIR and RED represent the surface reflectance values in the near-infrared and red bands, respectively. In the case of Landsat 8 imagery, NDVI is calculated using Band 5 (NIR) and Band 4 (Red), expressed as:

$$\text{For Landsat 8, NDVI} = \frac{(\text{Band 5} - \text{Band 4})}{(\text{Band 5} + \text{Band 4})}$$

Chlorophyll in plant leaves absorbs strongly in the red region of the spectrum while the internal structure of leaves reflects a large portion of near-infrared radiation. This unique spectral contrast forms the basis of the Normalized Difference Vegetation Index (NDVI), which has been widely applied for vegetation monitoring (Tucker, 1979; Jensen, 2007).

The NDVI values range from -1 to +1 and are typically divided into five classes based on vegetation health and density, as described by Maher., *et al* (2015) and Sahebjalal., *et al* (2013). These classes are as follows;

Table 1: Classification of NDVI.

Class	NDVI Values
Non Vegetation	< 0.1
Sparse vegetation	0.1 to 0.2
Moderate vegetation	0.2 to 0.3
High vegetation	0.3 to 0.4
Dense vegetation	> 0.4

Table 2: Seasonal Variation in NDVI Mean for Sagli District during (2014–2023).

Year	Mean NDVI		
	Rabi	**Summer**	***Kharif***
2014	0.31	0.21	0.31
2015	0.26	0.22	0.35
2016	0.29	0.2	0.37
2017	0.31	0.19	0.38
2018	0.33	0.25	0.36
2019	0.35	0.23	0.49
2020	0.35	0.25	0.47
2021	0.41	0.30	0.53
2022	0.29	0.26	0.51
2023	0.26	0.27	0.41

Results and Discussion

Season-wise Temporal Analysis of Mean NDVI (2014-2023)

The analysis of NDVI values for the Sangli district during *rabi*, summer and *kharif* season from 2014 to 2023 shows a clear variation in vegetation cover as shown in Table 2 and Fig. 2

During the *rabi* season (2014–2023), NDVI in Sangli district ranged from 0.26 (2015, 2023) to 0.41 (2021), reflecting variations in vegetation vigour due to rainfall and temperature. The highest value in 2021 indicated dense vegetation supported by favourable rainfall, while 2015, 2016, 2022, and 2023 showed moderate growth under reduced rainfall, and 2014, 2017–2020 had healthy but less vigorous vegetation. Maximum temperatures generally corresponded to lower NDVI, whereas minimum temperatures had inconsistent effects. Overall, *rabi* NDVI demonstrates that vegetation performance in Sangli is primarily governed by rainfall, consistent with Dwivedi *et al*., (2024), who reported declines in vegetation indices during dry *rabi* seasons and improvements under favourable rainfall conditions.

During summer (2014–2023), NDVI in Sangli district showed minor variations, generally indicating sparse to moderate vegetation. The lowest value of 0.19 in 2017 reflected drought stress and low soil moisture, while the highest of 0.30 in 2021 suggested better vegetation health due to favourable early summer rainfall. Years 2016–2017 experienced the lowest NDVI, whereas 2014, 2015, and 2018–2023 mostly maintained moderate vegetation. Overall, summer NDVI indicates vegetation is moderately stressed, influenced by low rainfall and high temperatures. These trends align with Revadekar *et al*. (2012) the role of moisture and heat in controlling vegetation health.

Kharif NDVI in Sangli district (2014–2023) ranged from 0.31 to 0.53, showing healthier and denser vegetation during the monsoon. Between 2014 and 2018, NDVI stayed in the high vegetation range (0.31–0.38), while from 2019 onwards it exceeded 0.40, reaching a peak of

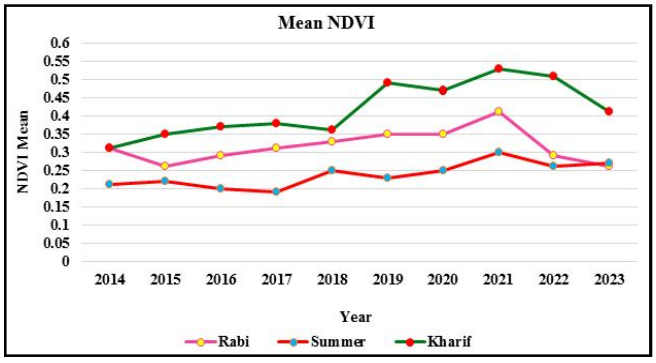

Fig. 2: Mean NDVI for *rabi*, and summer *kharif* season in Sangli district from 2014-2023.

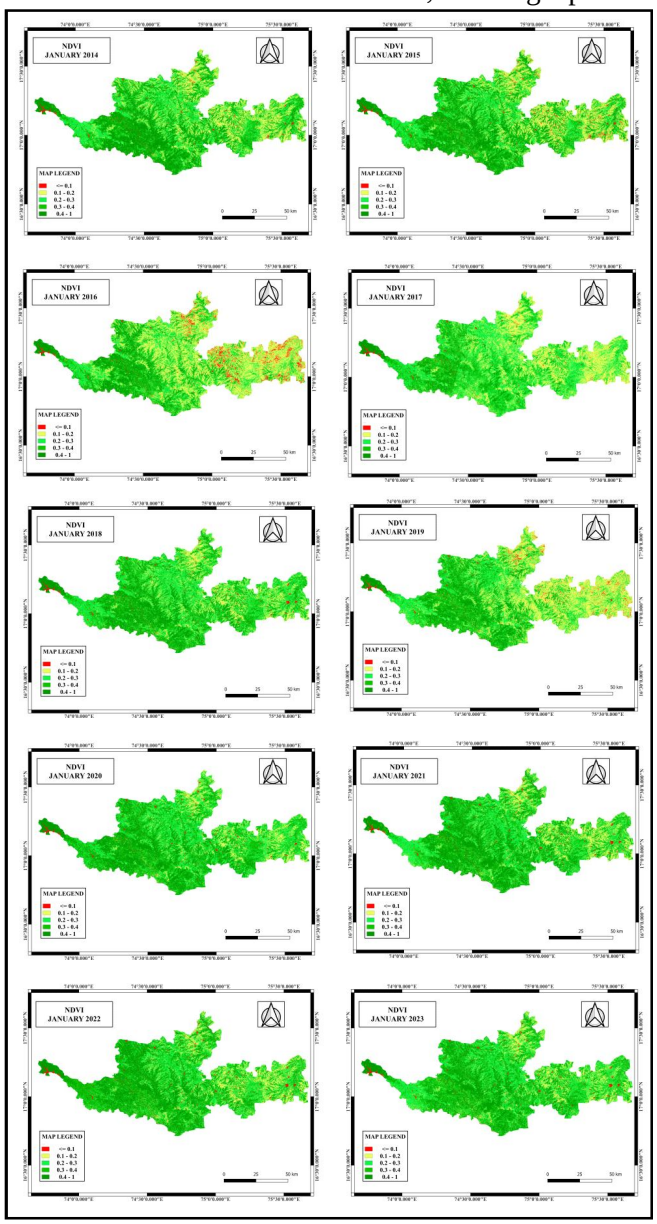

Fig. 3: Thematic Maps of Sangli district NDVI for *Rabi* season (January) during (2014- 2023).

0.53 in 2021 due to favourable rainfall and improved soil moisture. The shift from high to dense vegetation reflects better monsoon performance and suitable temperatures, supporting both crops and natural vegetation. Overall, NDVI trends demonstrate its reliability for monitoring seasonal vegetation changes, consistent with findings from Gandhi *et al.*, (2017) in semi-arid Maharashtra.

Seasonal Spatial Analysis of NDVI in Sangli District (2014–2023) Using Thematic Maps

Fig. 3 to 5 represents the spatial variability of vegetation condition in Sangli district evaluated using NDVI thematic maps across *rabi*, *kharif*, and summer seasons from 2014 to 2023.

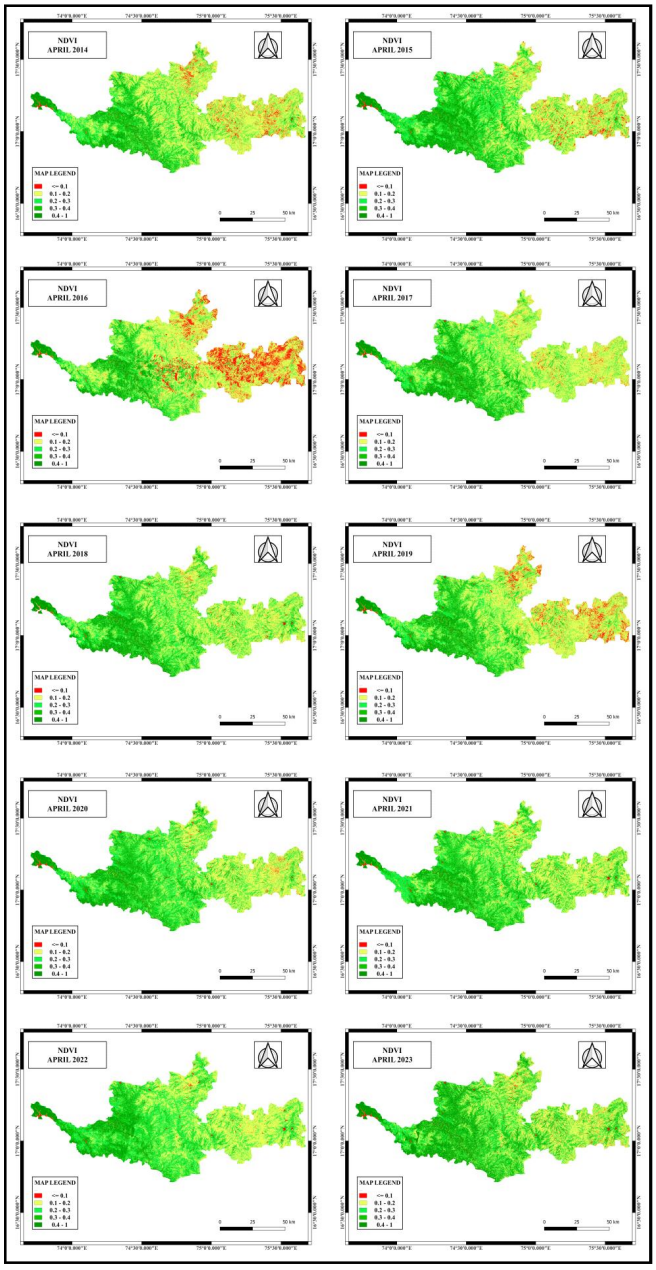

Fig. 4 : Thematic Maps of Sangli district NDVI for Summer season (April) during (2014- 2023).

NDVI maps showed that the eastern parts of Sangli consistently had lower vegetation cover, highlighting areas vulnerable to drought stress. Summer seasons particularly revealed the lowest NDVI in this region, suggesting recurring water scarcity. The NDVI-based area classification further emphasized inter-annual differences, with *rabi* 2015 and 2016 showing minimal vegetation, while 2021 recorded the highest growth. Summer 2017 reflected low vegetation, whereas 2021 indicated improved growth. During *kharif*, 2016 had moderate vegetation, while 2021 exhibited strong growth due to favourable rainfall. The observed spatial patterns support the utility of NDVI and related indices (NDWI, NDDI) for assessing drought vulnerability and vegetation response in semi-arid districts (Patil *et al.*, 2024)

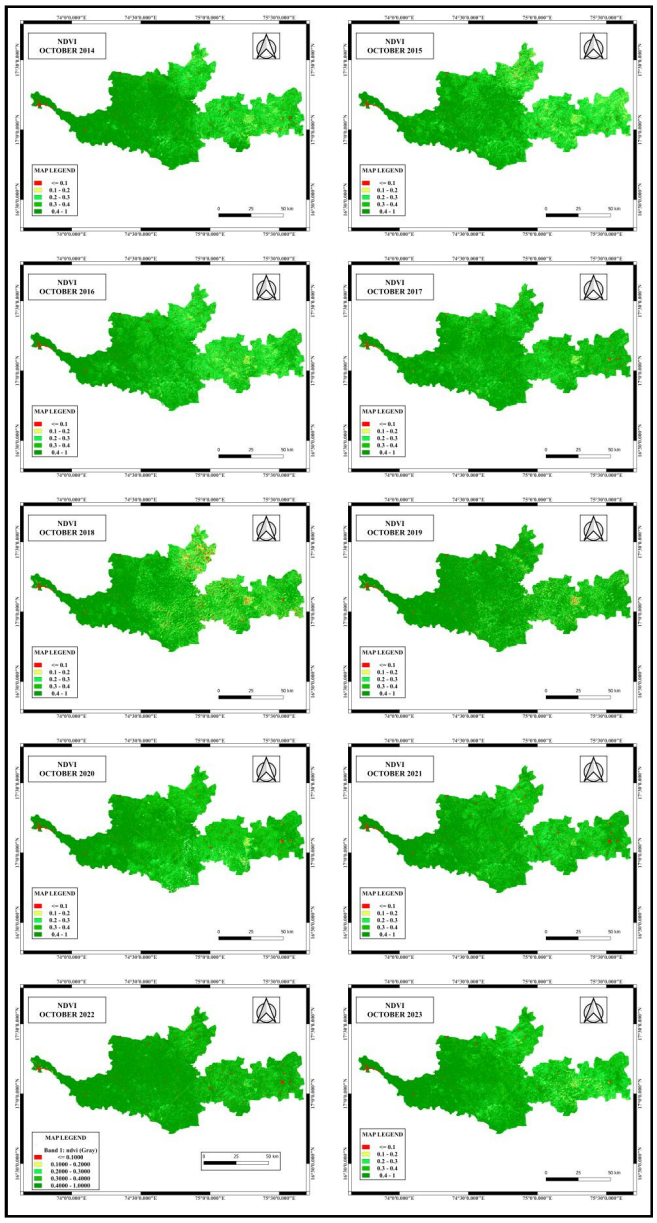

Fig. 5 : Thematic Maps of Sangli district NDVI for Kharif season (October) during (2014- 2023).

Table 3: Percentage Area of classified NDVI for Sangli district for *rabi* season.

Year	NV	SV	MV	HV	DV	Total (%)
2014	1.15	21.33	30.52	18.43	28.57	100
2015	1.76	21.36	29.09	19.83	27.96	100
2016	4.13	37.25	26.75	15.57	16.3	100
2017	0.83	28.81	41.17	18.98	10.21	100
2018	1.13	16.05	36.22	22.25	24.35	100
2019	2.09	32.02	30.36	18.22	17.31	100
2020	1.14	11.78	35.01	25.07	27	100
2021	1.31	13.39	33.53	22.62	29.15	100
2022	1.42	14.52	29.25	24.2	30.61	100
2023	2.13	36.02	27.02	15.24	19.59	100

NV: Non Vegetation (%); **SV:** Sparse Vegetation (%); **MV:** Moderate Vegetation (%); **HV:** High Vegetation (%); **DV:** Dense Vegetation (%)

Seasonal Vegetation Classification by Area Using NDVI in Sangli District (2014–2023)

Table 3 and Fig. 6 present the area-wise classification of vegetation using NDVI during the *rabi* season (2014–2023).

Analysis of Table 3 and Fig. 6 indicates that non-vegetated areas remained low, ranging from 0.83% in 2017 to 4.13% in 2016, showing minimal changes in barren land. Sparse vegetation fluctuated between 11.78% in 2020 and 37.25% in 2016, reflecting the influence of climatic and agronomic conditions. Moderate vegetation ranged from 26.75% (2016) to 41.17% (2017), while high-density vegetation increased in later years, reaching 25.07% in 2020 and 22.62% in 2021. Dense vegetation showed the widest variation, from 10.21% in 2017 to 30.61% in 2022, highlighting inter-annual changes in healthy, biomass-rich vegetation across the decade. These patterns align with observations by Deshmukh *et al.*, (2020), who reported similar fluctuations in sparse and dense vegetation in semi-arid regions of Maharashtra influenced by annual rainfall and temperature variability.

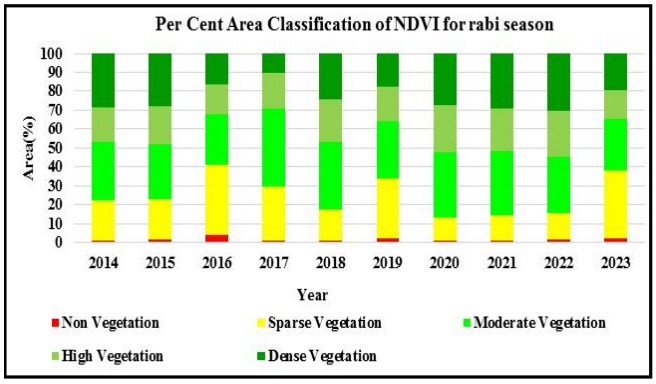

Fig. 6: Classification of per cent area of NDVI for *rabi* season in Sangli district from 2014-2023.

Table 4: Percentage Area of classified NDVI for Sangli district for summer season.

Year	NV	SV	MV	HV	DV	Total (%)
2014	4.12	50.11	25.05	12.02	8.71	100
2015	3.53	38.52	30.13	16	11.82	100
2016	14.17	52.9	18.72	7.68	6.53	100
2017	2.08	46.87	27.71	11.85	11.49	100
2018	1.38	42.32	30.79	13.68	11.83	100
2019	5.43	48.33	24.45	10.99	10.8	100
2020	1.53	36.99	34.74	15.44	11.3	100
2021	1.26	38.67	31.91	16.04	12.12	100
2022	1.05	38.94	35.9	15.08	9.03	100
2023	1.31	12.78	35.1	24.77	26.04	100

NV: Non Vegetation (%); **SV:** Sparse Vegetation (%); **MV:** Moderate Vegetation (%); **HV:** High Vegetation (%); **DV:** Dense Vegetation (%)

Table 4 and Fig. 7 present the area-wise classification of vegetation using NDVI during the summer season (2014–2023).

Analysis of Table 4 and Fig. 7 shows that non-vegetated areas varied between 1.05% in 2022 and 14.17% in 2016, indicating occasional expansion of barren land but generally low coverage. Sparse vegetation ranged from 12.78% in 2023 to 52.90% in 2016, reflecting variability in climatic conditions and land management practices. Moderate vegetation fluctuated from 18.72% in 2016 to 35.90% in 2022, showing periods of favorable growth. High vegetation gradually increased in later years, reaching 24.77% in 2023, while dense vegetation exhibited notable inter-annual variation, peaking at 26.04% in 2023. These trends suggest dynamic shifts in vegetation structure over the decade.

Table 5 and Fig. 8 present the area-wise classification of vegetation using NDVI during the summer season (2014–2023).

Analysis of Table 5 and Figure 8 shows that non-vegetated areas remained low, ranging from 0.83% in

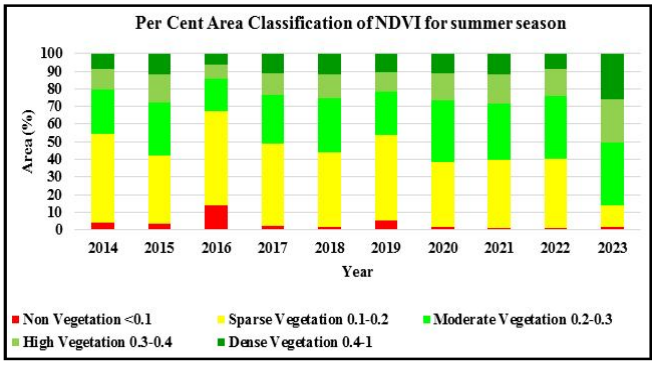

Fig. 7: Classification of per cent area of NDVI for Summer season in Sangli district from 2014-2023.

Table 5: Percentage Area of classified NDVI for Sangli district for *kharif* season.

Year	NV	SV	MV	HV	DV	Total (%)
2014	1.15	21.33	30.52	18.43	28.57	100
2015	1.76	21.36	29.09	19.83	27.96	100
2016	4.13	37.25	26.75	15.57	16.3	100
2017	0.83	28.81	41.17	18.98	10.21	100
2018	1.13	16.05	36.22	22.25	24.35	100
2019	2.09	32.02	30.36	18.22	17.31	100
2020	1.14	11.78	35.01	25.07	27	100
2021	1.31	13.39	33.53	22.62	29.15	100
2022	1.42	14.52	29.25	24.2	30.61	100
2023	2.13	36.02	27.02	15.24	19.59	100

NV: Non Vegetation (%); **SV:** Sparse Vegetation (%); **MV:** Moderate Vegetation (%); **HV:** High Vegetation (%); **DV:** Dense Vegetation (%)

2017 to 4.13% in 2016. Sparse vegetation varied from 11.78% in 2020 to 37.25% in 2016, while moderate vegetation ranged between 26.75% in 2016 and 41.17% in 2017. High vegetation increased in some years, reaching 25.07% in 2020 and 24.2% in 2022, whereas dense vegetation showed substantial variation, peaking at 30.61% in 2022 and lowest at 10.21% in 2017. In individual years, moderate and dense vegetation were 30.52% and 28.57% in 2014, 29.09% and 27.96% in 2015, and 22.25% and 24.35% in 2018. Sparse vegetation peaked again at 36.02% in 2023, with high and dense vegetation at 15.24% and 19.59%, respectively. These trends indicate dynamic shifts in vegetation cover across Sangli district.

Rainfall and NDVI showed a positive association across all three seasons (Table 7), with the strongest correlation during *kharif* ($r = 0.74$, $p < 0.05$, significant at 5%), followed by summer ($r = 0.51$, not significant even at 10%) and *rabi* ($r = 0.44$, not significant even at 10%). This pattern highlights the critical role of monsoonal precipitation in vegetation development. Similar findings

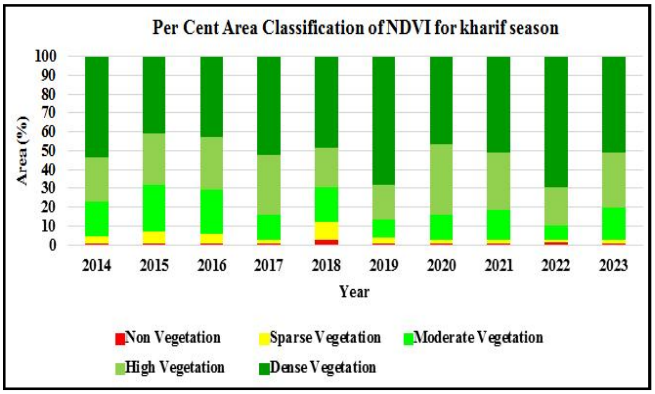

Fig. 8 : Classification of per cent area of NDVI for *kharif* season in Sangli district from 2014-2023.

Table 6: Year-Wise Trends in Vegetation Indices and Rainfall During Rabi, Summer, and Kharif Seasons in Sangli District (2014–2023).

Year	Rabi		Summer		Kharif	
	NDVI Mean	Rainfall (mm)	NDVI Mean	Rainfall (mm)	NDVI Mean	Rainfall (mm)
2014	0.31	14.4	0.21	27.5	0.31	281
2015	0.26	12.4	0.22	57.5	0.35	456.7
2016	0.29	17.6	0.20	0	0.37	534.3
2017	0.31	0	0.19	0	0.38	509.6
2018	0.33	0.7	0.25	2	0.36	442.5
2019	0.35	29.7	0.23	9.5	0.49	695
2020	0.35	4.7	0.25	40.5	0.47	481.7
2021	0.41	165.5	0.30	73.7	0.53	698.2
2022	0.29	2.2	0.26	44.5	0.51	553.2
2023	0.26	96	0.27	3.2	0.41	212.7

were reported by Kamble *et al.*, (2010), who observed significant correlations between NDVI anomalies and cumulative rainfall in different regions of India, demonstrating that seasonal rainfall strongly influences vegetation growth and health.

Conclusion

The evaluation of mean NDVI across *rabi*, summer, and *kharif* seasons over 2014–2023 highlights the seasonal variations in vegetation health in Sangli district. The *kharif* season consistently recorded the highest NDVI values, reflecting dense and vigorous vegetation supported by sufficient monsoon rainfall. Conversely, the summer season showed the lowest NDVI values, indicating limited vegetation growth and water-stressed soils.

Spatial analysis of NDVI maps indicated that the eastern region of Sangli district consistently had lower vegetation cover and was more prone to drought throughout the study period. This trend was especially evident during summer, emphasizing the vulnerability of this area to seasonal water deficits and the need for targeted irrigation and land management practices. According to the NDVI maps and area-wise classification, *rabi* seasons of 2015 and 2016 experienced the lowest vegetation, whereas 2021 recorded the highest growth. In summer, 2017 reflected poor vegetation, while 2021 showed improved cover. During *kharif*, 2016 had moderate vegetation, while 2021 exhibited strong growth due to favourable rainfall distribution.

Table 7: Rainfall-NDVI correlation by season.

Season	Correlation Coefficient (r)
Rabi	0.44(P= 0.2)
Summer	0.51(p=0.1)
Kharif	0.74(P=0.01**)
Note: *p < 0.1, **p < 0.05.	

Correlation analysis showed a positive relationship between NDVI and rainfall across all seasons, with the strongest correlation during *kharif* ($r = 0.74$, $p < 0.05$), followed by summer ($r = 0.51$, $p = 0.1$) and *rabi* ($r = 0.44$, $p = 0.2$). These results demonstrate that vegetation in Sangli district is highly responsive to precipitation, particularly during the monsoon, underlining the importance of rainfall in shaping seasonal vegetation dynamics and informing drought monitoring and agricultural planning strategies.

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