

## Drought monitoring over India through Normalized Difference Vegetation Index (NDVI)

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**सार** – वनस्पति (प्रतिबल/अप्रतिबल) की स्थिति का मानीटरन करने के लिए प्रसामान्यीकृत अन्तर वनस्पति सूचकांक (एन. डी. वी. आई.) एक सरल सूचकांक है जिसे उपग्रह के आँकड़ों से प्राप्त किया जा सकता है। अतः इस क्षेत्र में किए जा रहे अध्ययनों से एन. डी. वी. आई. के माध्यम से वर्षा के समय वनस्पति की प्रतिक्रियाओं का पता लगाने का प्रयास किया गया है। वर्ष 1982–2003 की अवधि के एन. डी. वी. आई. और वर्षा के आँकड़ों का उपयोग करते हुए सूखे का मानीटरन करने के लिए एन. डी. वी. आई. की उपयोगिता पर विचार-विमर्श किया गया है। एन. डी. वी. आई. की विसंगति की तुलना अनुकूल वर्षों के वर्षा के प्रतिशत प्रत्यंतर के साथ की गई है। इनसे प्राप्त परिणामों से वर्षा के प्रतिशत प्रत्यंतर सहित एन. डी. वी. आई. के मध्य उल्लेखनीय संबंध का पता चला है। पिछले दो दशकों के दौरान भारत में वनस्पति पैटर्न में आए परिवर्तनों का विश्लेषण करने के लिए 1982–2003 की अवधि में उत्तर पश्चिमी भारत (21° उ. – 31° उ., 68° पू. – 78° पू.) और मध्य भारत (22° उ. – 27° उ., 70° पू. – 77° पू.) और प्रायद्वीपीय भारत (16° उ. – 21° उ., 74° पू. – 79° पू.) के लिए औसतन एन. डी. वी. आई. और मौसमी वर्षा (जून–सितंबर) की समय श्रृंखलाओं के पाल्ट तैयार किए गए। इनसे प्राप्त परिणामों से उत्तर पश्चिम और मध्य भारत में रेखीय संबंध का स्पष्ट रूप से पता चलता है। एन. डी. वी. आई. की विसंगतियाँ और अनुवर्ती संवहनी वर्षा से उत्तर पश्चिम भारत में 0.69 और मध्य भारत में 0.57 के उल्लेखनीय रेखीय संबंध का पता चलता है जो 1% स्तर पर महत्वपूर्ण है किन्तु प्रायद्वीपीय भारत में यह संबंध उल्लेखनीय नहीं पाया गया है जो मात्र 0.04 है। भारत में औसतन एन. डी. वी. आई. के प्रवृत्ति विश्लेषण से यह पता चला है कि पिछले दो दशकों में भारत के शुष्क कृषि पथों में वनस्पति की स्थिति में काफी सुधार हुआ है।

**ABSTRACT.** Normalized Difference Vegetation Index (NDVI) is a simple index to monitor the state of vegetation (stressed/unstressed) which can be derived from satellite data. Hence an attempt is made to find out the vegetation responses to rainfall through NDVI over the study area. Applicability of NDVI in drought monitoring is discussed using the NDVI and rainfall data for the period 1982-2003. The anomaly of NDVI is compared with the percentage departure of rainfall of corresponding years. Results showed a significant relation between the NDVI with the percentage departure of rainfall. The time series plots of averaged NDVI and seasonal rainfall (June-September) are done for NW India (21° N - 31° N, 68° E - 78° E), Central India (22° N - 27° N, 70° E - 77° E) and Peninsular India (16° N - 21° N, 74° E - 79° E) over the period 1982-2003 to analyze changes in vegetation pattern of India during the last two decades. Results indicated a clear linear relationship over NW and Central India. NDVI anomalies and the corresponding cumulative rainfall showed significantly linear correlation of 0.69 over NW India and 0.57 over Central India significant at 1% level but the correlation is found to be insignificant over Peninsular India which was only 0.04. Trend analysis of averaged NDVI over India showed that during last two decades the vegetation status had quite improved over the dry farming tracts of India.

**Key words** – NDVI, Drought monitoring.

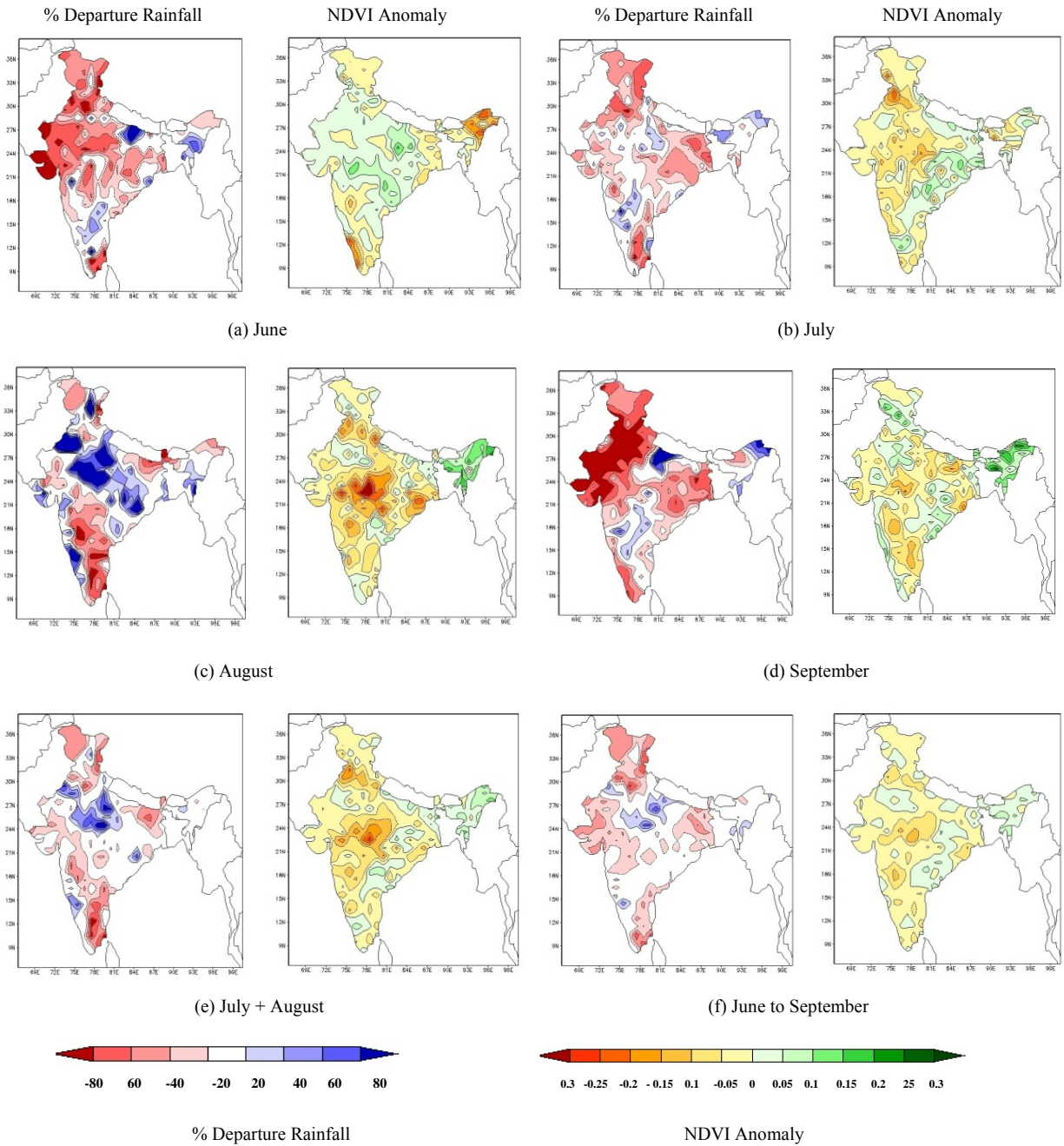
### 1. Introduction

Indian economy is largely based on agriculture as nearly 70% of the total population depends on it for their livelihood. Owing to both spatial and temporal abnormalities in monsoon precipitation, drought is a frequent phenomenon over many parts of the country. Out of net sown area of about 140 Mha, 68% of the area is

reported to be vulnerable to drought and 50% of the drought prone area is classified as severe.

The synoptic view and the repetitive cover afforded by satellite data allow multi-temporal observation of seasonal changes. Spectral vegetation indices derived from the near infra-red and red spectral bands are intermediate parameters from which various plant canopy

Year 1982



**Figs. 1(a-f).** Distribution of rainfall and NDVI anomaly over the country during monsoon season in 1982

characteristics such as biomass, leaf area index, photosynthetic capacity, net primary productivity and estimates of the seasonality characteristics of the canopy can be derived.

Among the various satellite derived vegetation indices, the Normalized Difference Vegetation Index (NDVI) has evolved over a period of time as a primary tool for monitoring vegetation changes. Green and healthy

vegetation reflects much less radiation in the visible (CH1) compared to those in near-infrared (CH2). More importantly, when vegetation is under stress, CH1 values may increase and CH2 values may decrease. The Normalized Difference Vegetation Index (NDVI) is defined as

$$\text{NDVI} = \frac{\text{CH2} - \text{CH1}}{\text{CH2} + \text{CH1}}$$

where CH2(0.73-1.10  $\mu\text{m}$ ) and CH1(0.58-0.68 $\mu\text{m}$ ) are the radiation measured in channels 2 and 1 respectively.

NDVI is a good indicator of photosynthetic productivity and of large scale ecosystem distribution (Kidwell, 1990). It can be used not only for reasonably accurate description of continental land and vegetation cover, vegetation classification and vegetation phenology (Tarpley *et al.*, 1984; Hielkema *et al.*, 1986; Justice *et al.*, 1985) but it is also effective for estimating net primary production of vegetation, crop growth and yields, detecting weather impacts and other events important for agriculture, ecology and economics (Kogan, 1987a; Darbrowska-Zielinska *et al.*, 2002).

Chandrasekar *et al.* (2006) studied the lagged response of NDVI to rainfall in forewarning of the vegetation condition, particularly in low NDVI cases. He correlated the seasonal cumulative NDVI with yield to forecast the yield where a strong relation is established. Therefore, there is a scope to analyze the NDVI data along with the precipitation data to detect the trend of NDVI over the country. The objectives of the present study are:

- (i) To analyze the variation of NDVI values in response to precipitation over the NW, Central and Peninsular India.
- (ii) To detect the trend of NDVI over the country for the years 1982-2003.

## 2. Data and methodology

The India Meteorological Department have reported the development of a high resolution ( $1^\circ \times 1^\circ$  Lat./Long.) gridded daily rainfall dataset for the Indian region using 2140 stations (Rajeevan *et al.*, 2006). For analysis the interpolation method proposed by Shepard (1968) was followed.

The NDVI data set is produced as part of the NOAA (National Oceanic and Atmospheric Administration)/NASA (National Aeronautics and Space Administration)

Pathfinder AVHRR Land program. In this study, the bimonthly NDVI data of (300 datasets) at 8 km resolution is collected from the IRI (International Research Institute)/LDEO (Lamont-Doherty Earth Observatory) Climate Data Library. The GLCF (Global Land Cover Facility) GIMMS (Global Inventory Modeling and Mapping Studies) NDVI data is collected from the University of Maryland (UMD). Monthly composite data of NDVI is prepared from the original bimonthly data. The  $0.072727 \times 0.072727$  *i.e.*, 8 km spatial resolution is converted into  $1^\circ \times 1^\circ$ . For the present study, we have considered the drought years like 1982, 1986, 1987 and 2002. The anomaly maps of NDVI as well as rainfall for the months of June, July, August, September, July + August and June to September are prepared for these years.

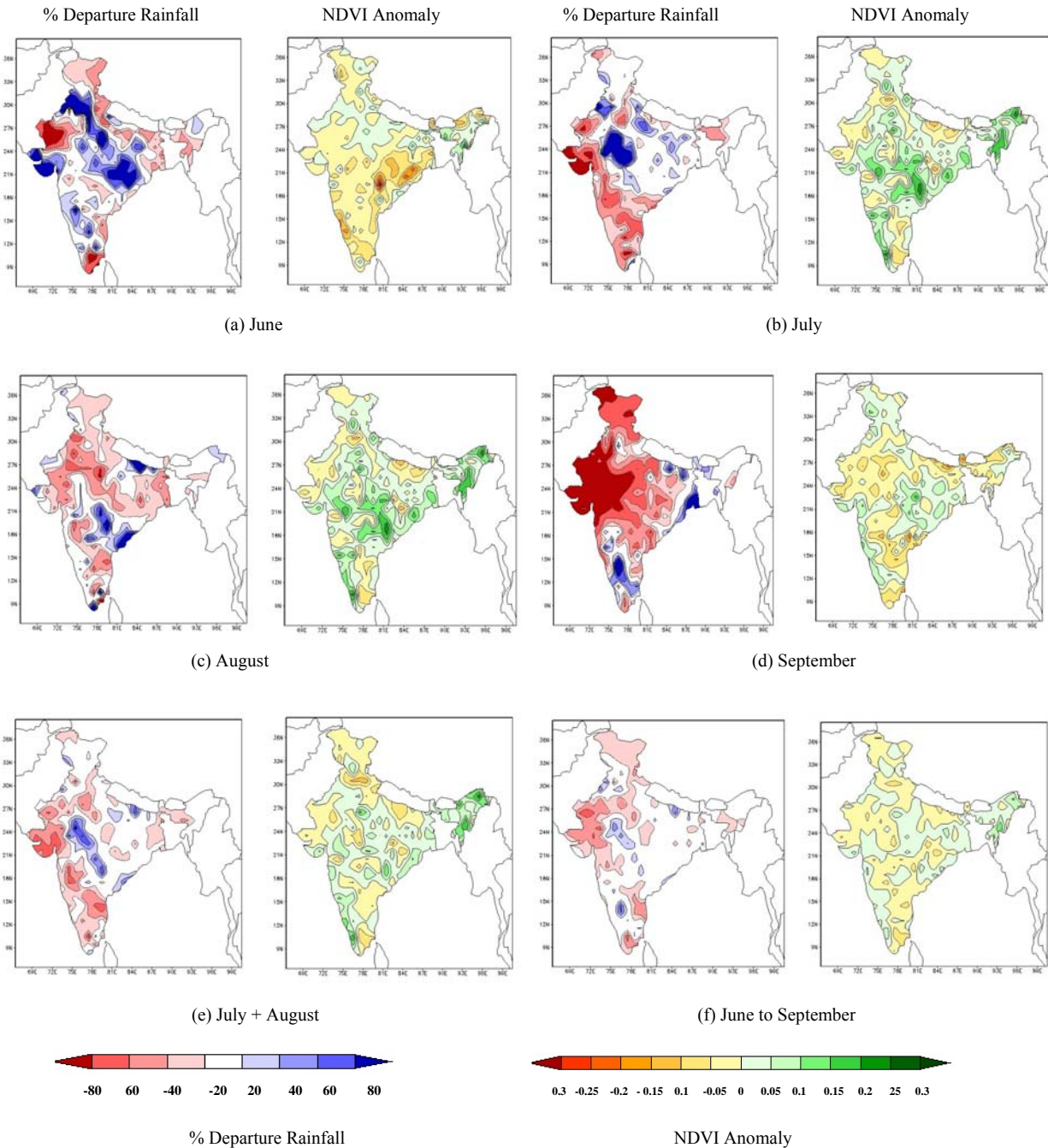
The time series of averaged NDVI for Central India, NW India and Peninsular India along with the cumulative rainfall of June to September during the period 1982-2003 are plotted to examine the variation between rainfall and NDVI. A trend analysis of NDVI and seasonal rainfall for the years 1982-2003 was made to examine the trends of NDVI and rainfall over the country.

In this study the anomaly maps of NDVI and percentage departure of rainfall for the period 1982-2003 are compared to monitor and analyze the vegetation pattern of India during drought years.

## 3. Results and discussion

Figs. 1(a-f) depict the effect of rainfall on vegetation for the year 1982 which was a drought year. It is noticed that during the month of June, most parts of the country received scanty to deficient rainfall. Some parts of central and most parts of Peninsular and NE India received normal to excess rainfall. The near normal values in NDVI anomaly map suggested that agricultural activity have already been started over those regions. In July, poor vegetation was observed over NW and Peninsular India due to scanty rainfall. In August, some parts of NW India received normal to excess rainfall which considerably recovered crop health over these areas. NE India and some parts of peninsular India also received normal to excess rainfall during August which provided favourable condition for growth of the crops. In September also, there was dry spell resulting in poor crop growth over the country except NE India which received normal to excess rainfall. The cumulative rainfall for July-August and June-September was scanty to normal, which caused poor vegetation cover over most parts of the country. Therefore the NDVI anomaly maps duly reflected the prevailing drought conditions in 1982.

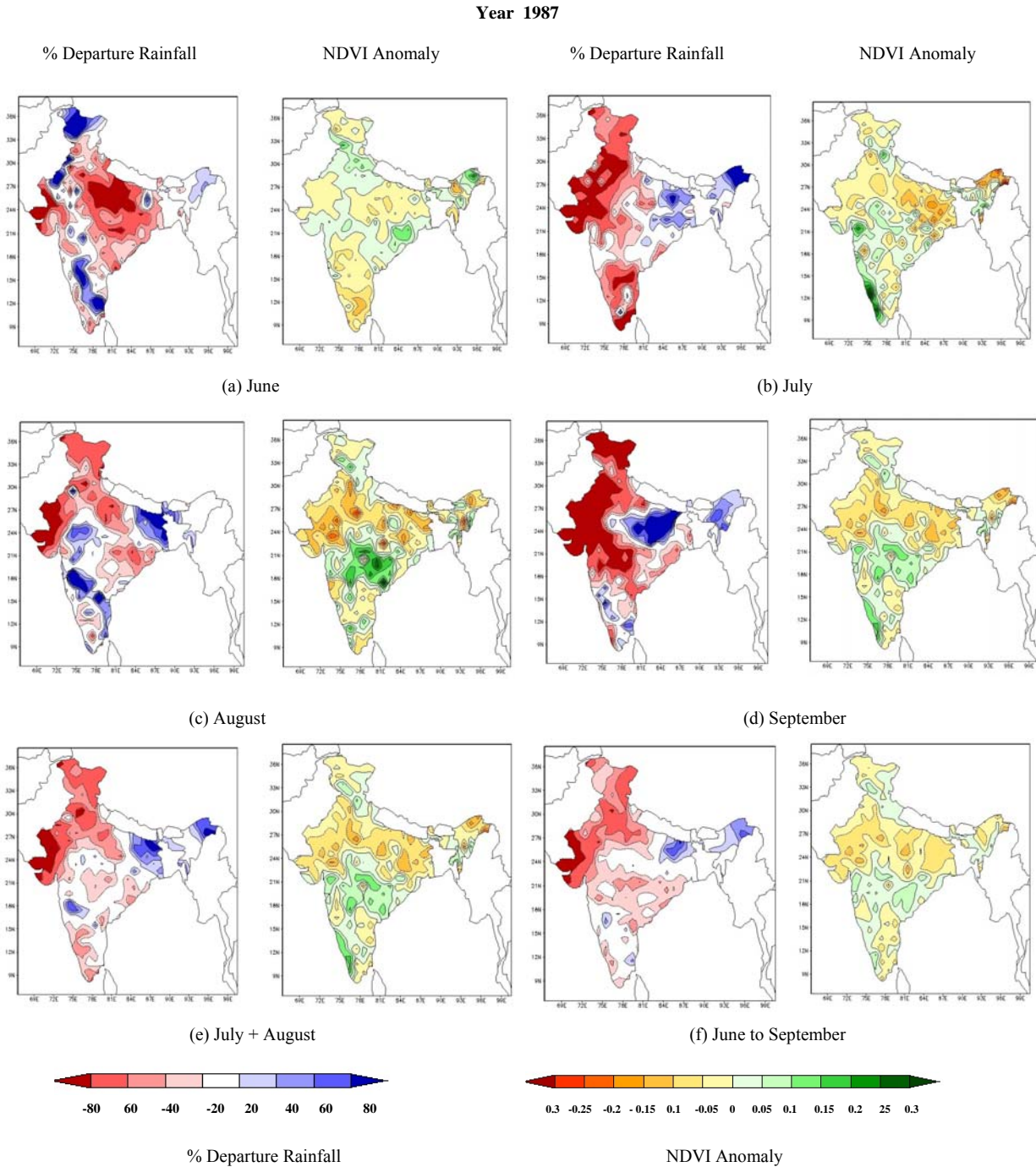
Year 1986



**Figs. 2(a-f).** Distribution of rainfall and NDVI anomaly over the country during monsoon season in 1986

Figs. 2(a-f) depict the relationship of rainfall with NDVI in 1986, which was a moderate drought year. Poor vegetation was observed over Rajasthan, central India and peninsular India due to scanty to deficient rainfall over these parts. Gujarat, Maharashtra, Karnataka, Punjab, Haryana and NE India received normal to excess rainfall in June. Healthier vegetation was thus observed in those

states indicating higher values of NDVI in June. On the contrary, Andhra Pradesh showed very poor vegetation. July showed good agricultural situation as indicated by NDVI anomaly values ranging from 0.05 to 0.1. Since the onset of monsoon was in time, the development of crops up to August and was near normal and the same was reflected in more vegetation cover in August. In

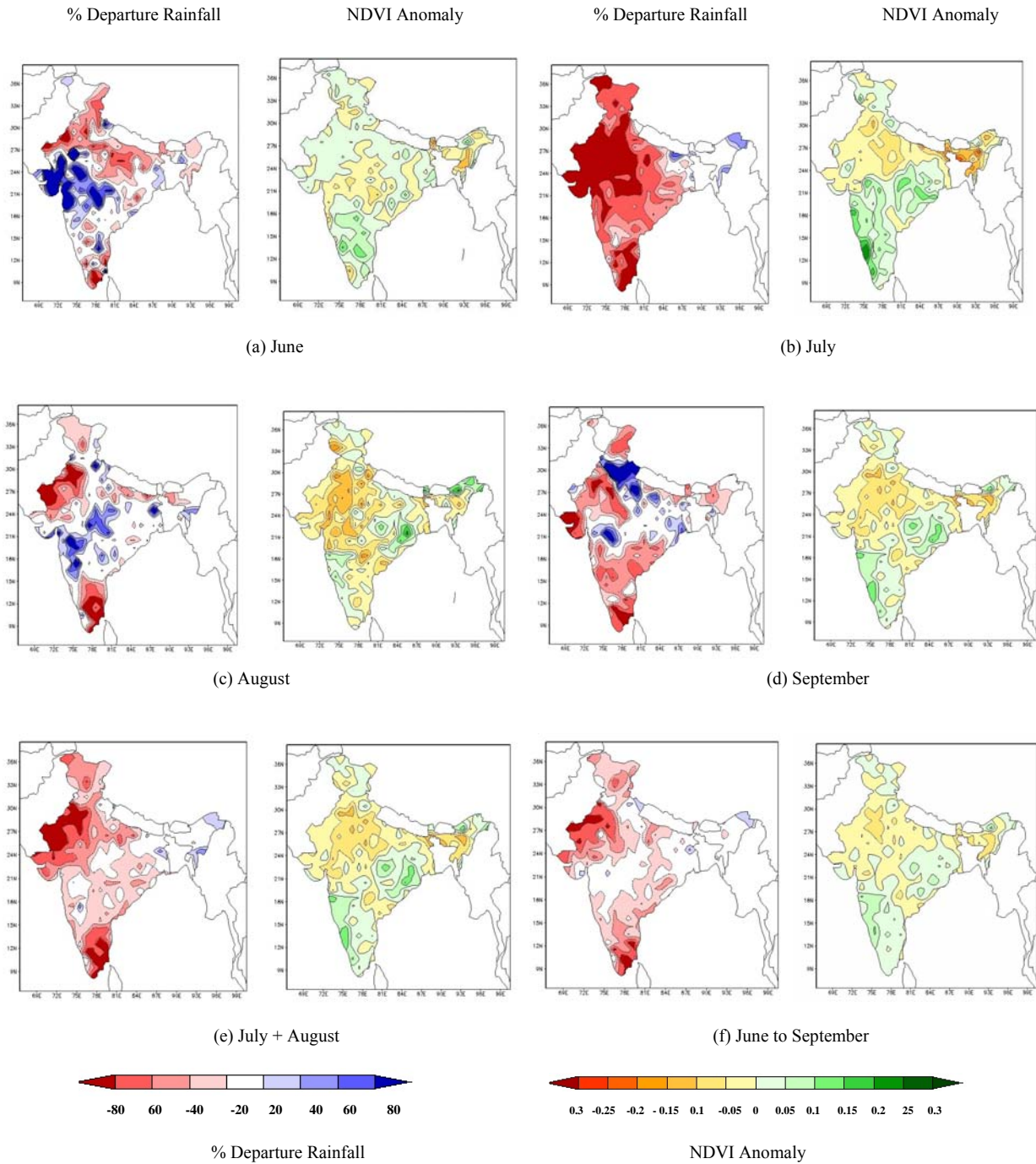


**Figs. 3(a-f).** Distribution of rainfall and NDVI anomaly over the country during monsoon season in 1987

September, the whole country experienced dry spell. NW and peninsular India received deficient rainfall and showed lower anomaly values of NDVI (-0.01 to 0). Parts of Peninsular India and NE India showed good vegetation due to excess rainfall. Cumulative rainfall of June to September which was scanty to deficient in many parts of India resulted in a drought situation.

Figs. 3(a-f) show the agricultural situation over the country in 1987, which was a major drought year. In June, Gujarat, parts of Rajasthan and Central India and NE India received scanty to deficient rainfall. Southern parts of Maharashtra, Karnataka and Tamil Nadu received excess rainfall. Parts of Rajasthan and central India, which received normal rainfall, reflected good vegetation

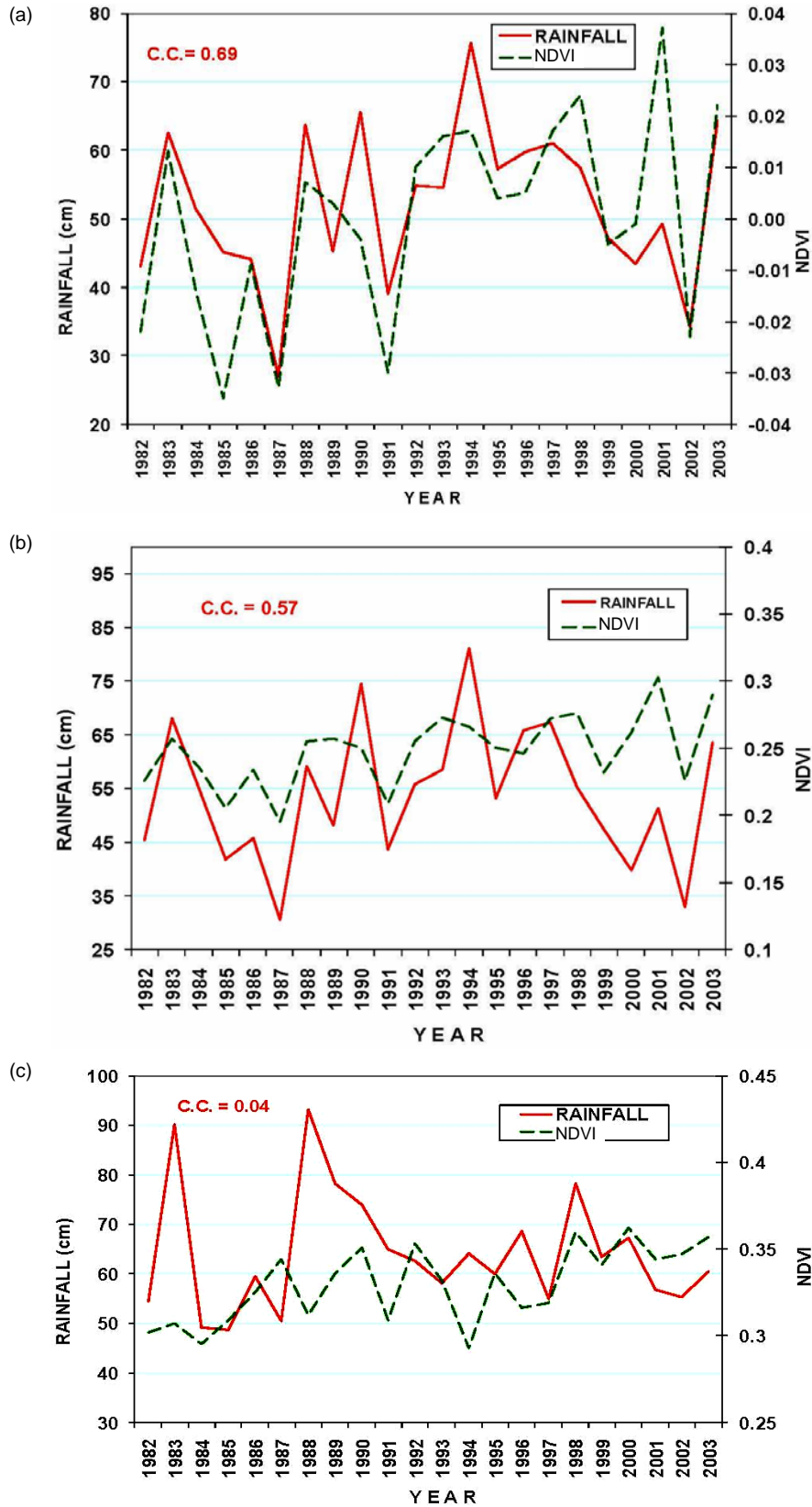
Year 2002



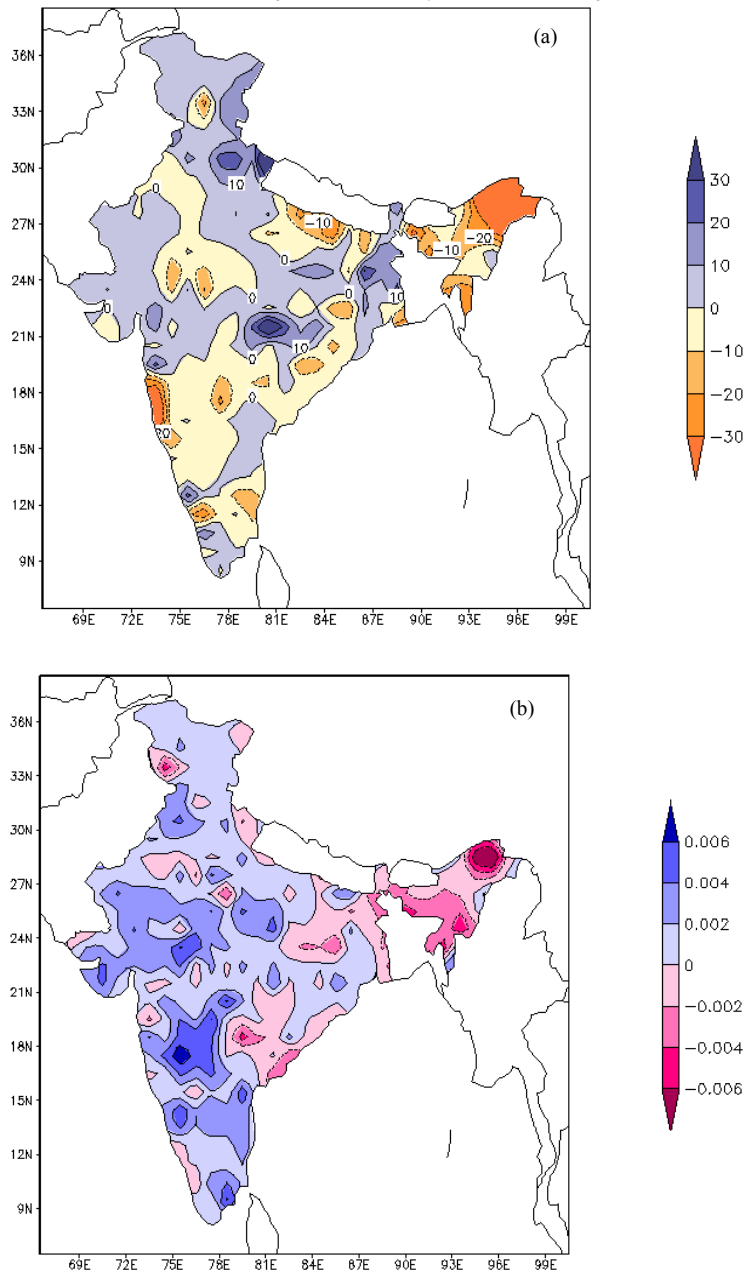
**Figs. 4(a-f).** Distribution of rainfall and NDVI anomaly over the country during monsoon season in 2002

cover in those parts. In July, there was a dry spell over the country except over NE India and some parts of Central India resulting in poor vegetation over NW India due to deficient rainfall in Andhra Pradesh also resulted in poor vegetation. August indicated still less rainfall causing very poor vegetation in many parts of the country. Only few parts of central India showed higher

vegetation status due to receipt of normal rainfall either in June or July. Deficient rainfall in Andhra Pradesh also resulted in poor vegetation. August indicated still less rainfall causing very poor vegetation in many parts of the country. Only few parts of central India showed higher



Figs. 5(a-c). Time Series of Rainfall and NDVI (Jun-Sept) for (a) NW India, (b) Central India and (c) Peninsular India



**Figs. 6(a&b).** Trend of (a) rainfall and (b) NDVI for June-September over the period 1982-2003

degree of vegetation as it received normal rainfall. The cumulative rainfall analysis in 1987 showed drought situation over NW India and parts of central India.

Figs. 4(a-f) elucidate the relation between rainfall and NDVI in the year 2002, which was also a major drought year. In June, except for some parts of NW India

and central India, most parts of the country received normal to excess rainfall causing higher NDVI values indicating good vegetation cover over the country except over some parts of central and NE India. Scanty to deficient rainfall all over the country in July, and over many parts of the country in August and September caused reduction in the vegetation cover over NW and



many parts of central India. The poor vegetation over NW India might be due to reduced sown area, delayed sowing or poor condition of the already sown crops. These areas experienced scanty to deficient rainfall for longer period in July. The impact of dry spell prevailing during July on the early sown rainfed crops had also contributed to the poor vegetation.

Thus, the results clearly brought out the relation of NDVI with rainfall and how this relation can be used in drought-monitoring and assessment. The results thus provided insight into the spatial and temporal agricultural growth anomalies and can form the basis for the detailed analysis to determine the agricultural drought.

### 3.1. *Inter-annual variation and long-term trends of NDVI*

The time series plot helps to find the exact variance of the index with the degree of rainfall over a certain period. In this study, the time series of NDVI and rainfall is computed for the period 1982 to 2003. The anomaly values of NDVI are plotted against the cumulative seasonal rainfall (June to September) for the said period and time series for NW India, Central India and Peninsular India are prepared.

Fig. 5(a) represents the time series for the NW India. NDVI showed linear relationship with the rainfall. The years receiving higher rainfall showed higher NDVI values reflecting better vegetation growth, whereas, lower values of NDVI in low rainfall years represented poor condition of vegetation. The anomaly values of NDVI and the corresponding cumulative rainfall gave a linear correlation of 0.69 significant at 1% level.

Similar pattern of relationship between NDVI and amount of rainfall received has also been observed over Central India [Fig. 5(b)]. The anomaly values of NDVI and the corresponding cumulative rainfall have a correlation of 0.57 which is significant at 1% level. The results revealed that corresponding variation in NDVI values in response of rainfall indicate the condition of vegetation over any region and therefore, establish the possibility of its use in monitoring vegetation health for rainfed crops during monsoon season.

But in case of Peninsular India [Fig. 5(c)] the relationship between NDVI and corresponding cumulative rainfall is not well established. The correlation was found to be 0.04 which is not significant. Peninsular India has a heterogeneous topography and rainfall variability which may be the reason for not having a good correlation between NDVI and rainfall.

### 3.2. *Long Term Trend Analysis of NDVI over Dry Farming Tracts of India*

Fig. 6(a&b) depict the trend analysis of NDVI and rainfall for the months June to September over two decades respectively. As irrigation facilities are not available over large parts of the country, the crops are mainly depending on the rainfall. Hence, in many parts of the country, the crop season is restricted to the monsoon months. The intra-seasonal as well as inter-seasonal variation of rainfall reflects in the growth of the crop which can be understood from their NDVI anomaly values.

It may be seen from Fig. 6(a) that NE India, East Uttar Pradesh, parts of Bihar, Coastal Orissa and some parts of Kerala have decreasing trend of rainfall which is clearly reflected by the decreasing trend of NDVI values due to moisture stress on the crop growth over these regions. Over most of the other parts of the country the rainfall pattern shows increasing trend which is the reason for better crop condition causing the increase in NDVI values. It is observed that over Punjab and Haryana, though the rainfall trend is decreasing, the NDVI trend is mostly increasing. This may be due to increase in irrigation facilities in these states. From 1980 onwards, the state of Haryana was having 65% or more of net sown area under irrigation which has reached nearly 80% during recent past. During the same period Punjab has reported more than 85% irrigated area (Bhattarai and Narayanamoorthy, 2003).

## 4. Conclusion

There are several indices in use for identifying the occurrence, spatial extent and severity of a drought. The most commonly used space-based index to describe drought is the NDVI. This study has focused on the NDVI in relation to rainfall. The study confirmed the relation between the density of vegetation and the pattern of rainfall anomalies in different regions of India in the southwest monsoon months.

The study showed that the intra-seasonal as well as inter-seasonal variation of rainfall alongwith variation of growth of the crop could be explained from their NDVI anomaly values. The change of NDVI values in response of rainfall is a good indicator to understand the condition of vegetation and thereby establish the possibility of its use in monitoring drought during monsoon season. This study indicates that NDVI can be used to delineate the drought prone areas of the country.

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