Chapter 2
Drought Hazard in Bihar

2.1 Introduction

Drought occurs when a region faces a deficiency in its water supply either surface or underground for an extended period of months or years, due to consistent low precipitation. Drought is one of the major natural hazards affecting the environment and economy of the regions worldwide. There are certain conflicts in defining drought. In general sense, drought originates from a deficiency of precipitation over an extended period of time, usually a season or more resulting in a water shortage for some activity, group, or environmental sector. Its impacts range from the interplay between the natural event (less precipitation than expected) and the demand people place on water supply. Human activities can exacerbate the impacts of drought. *Drought is a protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield.* No single operational definition of drought works in all circumstances, and this is a big reason why policy makers, resource planners, and others have more trouble recognizing and planning for drought than for other natural disasters. In fact, most drought planners now rely on mathematical indices to decide when to start implementing water conservation or drought response measures.

Drought zonation is a difficult task as drought spreads up in a very slow and silent process. Augmenting weather data with satellite images to identify the location and severity of droughts is a must for complete, up-to-date, and comprehensive coverage of current drought conditions. To monitor drought situation, the AVHRR-based Vegetation Condition Index (VCI) and Temperature Condition Index (TCI) have been successfully used. Seiler et al. (1998) proposed various indices to apply and validate drought detection and impact assessment. The VCI and TCI were useful to assess the spatial characteristics, the duration and severity of drought, and were in a good agreement with the precipitation patterns. Normalized Difference Vegetation Index (NDVI) is also used to enhance drought monitoring techniques (Peters et al. 2002). They used Standardized Vegetation Index to describe the vegetation condition deviation from normal situation on the basis of calculations from weekly NDVI values. Bhuiyan et al. (2006) worked on

T. Ghosh and A. Mukhopadhyay, *Natural Hazard Zonation of Bihar (India) Using Geoinformatics*, SpringerBriefs in Earth Sciences,
DOI: 10.1007/978-3-319-04438-5_2, © The Author(s) 2014

Table 2.1 Occurrence of monsoon in Bihar during 2009–2011 (% deviation from normal)

Year	June	July	August	September	June–Sept
2009	−62	−32	8	−41	−29
2010	−32	−18	−22	−22	−22
2011	38	−25	1	19	3

Aravalli region of Rajasthan province of India to quantify the agricultural drought using Vegetation Health Index (VHI). Prasad et al. (2006) developed various indices such as normalized difference NDVI, VCI and TCI for mapping and monitoring of drought and assessment of vegetation health and productivity.

Bihar is the 12th largest state in India with an area of 94163 sq km. The topography of Bihar is a vast stretch of fertile alluvial plain occupying the Gangetic Valley. Bihar is a definite disaster prone state, especially with floods and droughts. Like flood, drought is also a recurring phenomenon in Bihar. The area of north Bihar (north to river Ganga) is of mainly flood prone while south Bihar (south of river Ganga) is under the influence of drought. Analysis shows that in recent years, the frequency of occurrence of these disasters has increased. Based on the observed IMD rainfall data for the period of 2009–2011 (Table 2.1) for the districts of Bihar, it is found that Kishanganj (−31 %) and Katihar (−29 %) districts of north Bihar experience a remarkable deficit of summer monsoon rainfall in 2009. The southern part of Bihar especially Bhojpur (−28 %), Buxar (−12 %), Gaya (−17 %), Rohtas (−12 %) and Kaimur show a remarkable deficit of rainfall in 2009–2011. The estimated rainfall of the state is 1205 mm with considering an average of 53 rainy days each year.

In the present study, main emphasis was given on the comprehensive assessment and monitoring of agricultural drought situation, in Bihar state of India, using satellite datasets during the Kharif season (June to October) for the years 2009 to 2012.

2.2 Satellite Datasets for Agricultural Monitoring

Space based remote sensing data have been used for monitoring the drought scenario of Bihar. NOAA AVHRR based Vegetation Health Index of 16 km resolution was used for assessment of drought. Vegetation Health Index represents overall vegetation health which was used by Kogan (2001). It is a combination of vegetation condition index and temperature condition index. Vegetation condition index indicates the short-term weather-related NDVI fluctuations from the long-term ecosystem changes (Kogan 1995). NDVI depicts the seasonal vegetation dynamics but VCI reflect relative changes in the vegetation condition from extremely bad to optimal. The range of VCI varies from 0 to 100. Temperature Condition Index reflects the relative change in thermal condition in terms of brightness temperature.

$$NDVI = 100\frac{Ch2 - Ch1}{Ch2 + Ch1}$$
$$VCI = 100\frac{NDVI_{Max} - NDVI}{NDVI_{Max} + NDVI_{Min}}$$
$$TCI = 100\frac{BT_{Max} - BT}{BT_{Max} + BT_{Min}}$$
$$VHI = 0.5(VCI) + 0.5(TCI)$$

MODIS global monthly vegetation index product (MOD13A3) at 1 km spatial resolution has been considered. Vegetation indices are widely used for monitoring of vegetation conditions, environmental monitoring, assessment of regional climate, monitoring hydrological process modeling; land use and land cover changes. In this study, vegetation growth is delineated using NDVI, which is also an important indicator of drought.

Tropical Rainfall Monitoring Mission (TRMM) data provides accurate measurements of rainfall from space. TRMM also provides improved estimate of precipitation in the tropics, where Earth's major rainfall occurs. TRMM started operating and recording data since December 1997 and is placed in a (46-day) processing orbit at a 35° inclination with a period of about 91.5 min. This orbit allows TRMM to build up a complete view of the climatological diurnal cycle. Accumulated rain (3B43) product has been applied in this project. The data set currently contains monthly combined microwave-IR-gauge estimates of precipitation computed on quasi-global grids.

2.3 Drought Scenario in Bihar

The study examines the agricultural drought scenario of Bihar. This occurs when the soil is devoid of enough moisture to support crop production. Though this generally happens during the periods of low rainfall, it has a probability to recur even during periods of average precipitation when the soil conditions or agricultural practices require more water. Drought condition from the years 2009 to 2012 has been analysed and presented during June to October, considering the agricultural growing season (Kharif season). The analysis has been made considering the three major parameters:

(a) Rainfall distribution
(b) Vegetation vigor/growth
(c) Vegetation health index

Table 2.2 Rainfall statistics calculated from TRMM data (year 2009–2012)

Month	Rainfall statistics (in mm)			
	Min	Max	Mean	Standard deviation
June	89.41	461.34	160.65	50.54
July	138.78	602.29	239.69	71.82
August	254.92	758.98	347.56	68.37
September	135.77	414.36	219.33	43.86
October	28.71	179.19	67.93	29.01

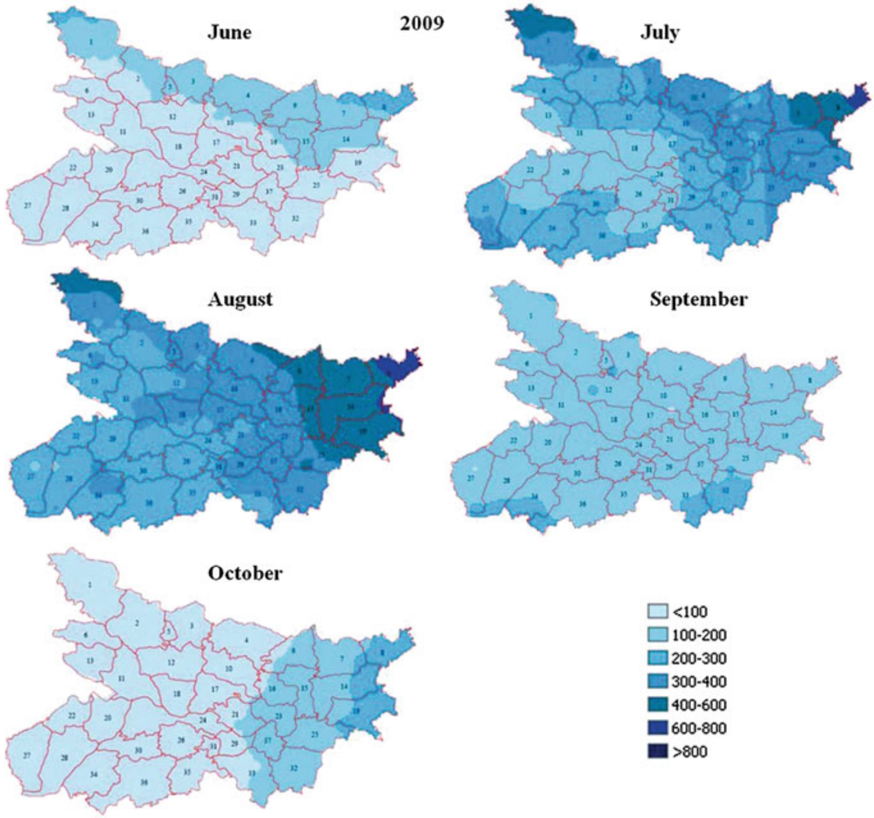

Fig. 2.1 Spatial distribution of rainfall from TRMM data, 2009

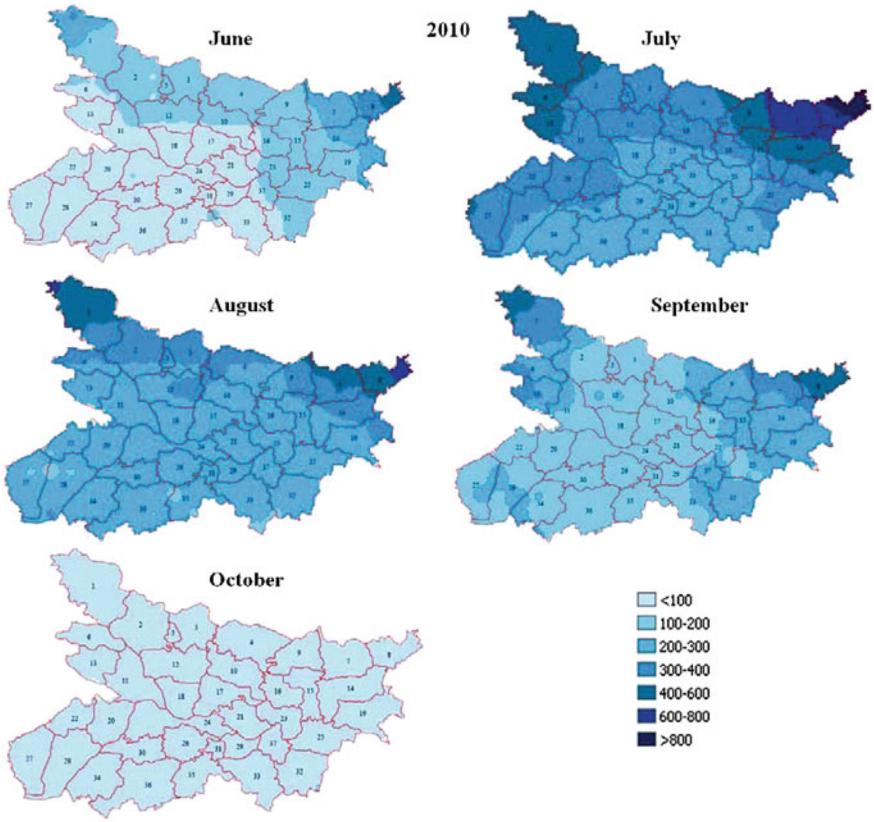

Fig. 2.2 Spatial distribution of rainfall from TRMM data, 2010

2.4 Rainfall Distribution

The average monthly rainfall for entire Bihar has been calculated (2009–2012) from TRMM accumulated rainfall data and has been shown in the Table 2.2. It has been found that the mean rainfall for the month of June is 160.65 mm and 67.93 mm for October. The difference in rainfall (maximum and minimum) and rainfall variation (standard deviation) is very large which signifies the uneven spatial distribution. July, August and September months receive maximum rainfall due to the monsoon effect. Generally, monsoon rain commences in Bihar around mid of June to first or second week of July (depending on the time of onset of monsoon) and continues up to the last week of September.

The spatial distribution pattern of the rainfall has been shown in Figs. 2.1, 2.2, 2.3, 2.4. This figure also shows that the occurrence of rainfall is not same for every year. The area received less rainfall in the year 2009, paradoxically got higher rainfall in the year of 2011. It is also observed that the northern part of Bihar

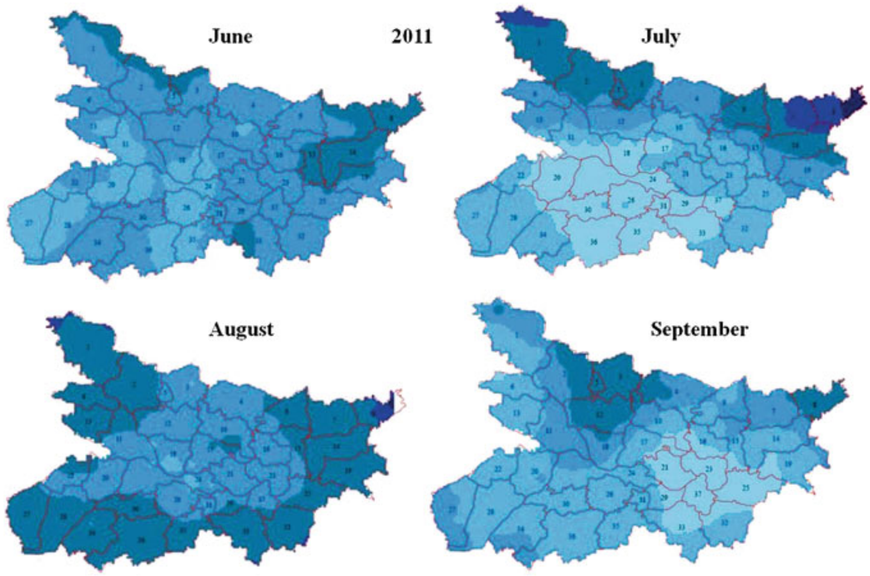

Fig. 2.3 Spatial distribution of rainfall from TRMM data, 2011

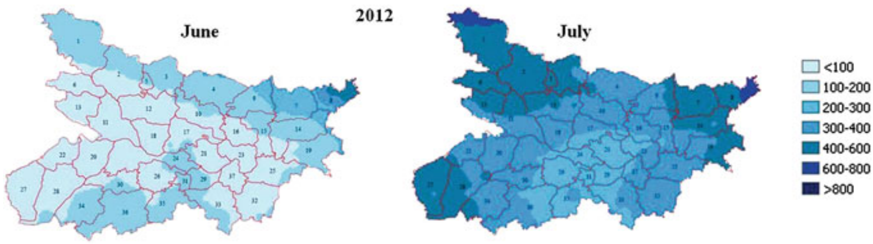

Fig. 2.4 Spatial distribution of rainfall from TRMM data, 2012

received higher rainfall due to its location on the foothill of Himalaya. Moreover, the amount of rainfall occurrence was higher in the eastern part of Bihar. The occurrence of rainfall is the lowest in the southern and south-western part of Bihar. The occurrence of low rainfall and its spatial variability is the major concern for the occurrence of drought in Bihar.

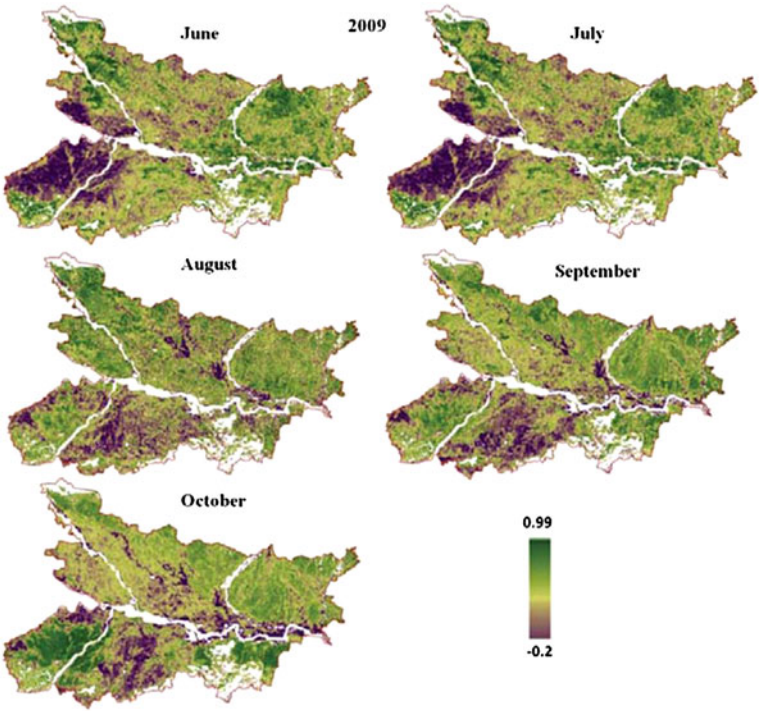

Fig. 2.5 Normalized difference vegetation index for the year 2009

2.4.1 Vegetation Vigor/Growth

Vegetation vigor is one of the important parameters to be considered for monitoring of drought. The amount of soil moisture gets reduced due to the low occurrence of rainfall and it seriously affects the vegetation growth. Vegetation vigor was estimated in terms of NDVI shown in Figs. 2.5, 2.6, 2.7, 2.8. Here, the NDVI value ranges from -0.2 to 0.99, while the usual range is between -1 and 1. NDVI value <0.2 indicates the poor growth of vegetation (more towards violet shade in map) and NDVI value >0.5 indicates higher growth of vegetation (more towards green shade in map). As the vegetation growth is directly linked with rainfall and temperature, the lower value of NDVI indicates the higher possibility of drought.

The analysis output in Figs. 2.5, 2.6, 2.7, 2.8. depicts that the vegetation growth is minimum in southern and south western part of Bihar. The western part of Bihar was also affected in the month of June during the years 2009, 2010 and 2012. The northern and eastern part of the state was not at all affected. This pattern matches with the spatial distribution pattern of rainfall, which supports the authenticity of the situation report.

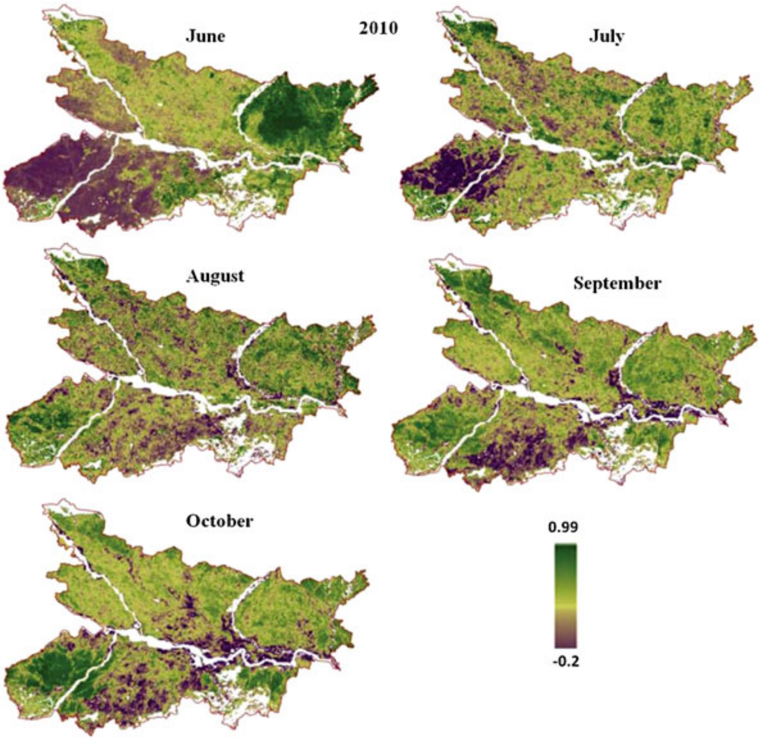

Fig. 2.6 Normalized difference vegetation index for the year 2010

2.4.2 Vegetation Health Index

Vegetation Health Index (VHI) is widely used for drought monitoring and mapping, and it takes into account the vegetation and temperature condition of a region considering the deviation since longer time. The VHI value ranges from 0 to 100 and can be classified into 5 classes to delineate drought (Kogan 2002; Bhuiyan et al. 2006). The classification scheme is given below:

Drought class	VHI value
Extreme drought	<10
Severe drought	<20
Moderate drought	<30
Mild drought	<40
No drought	>40

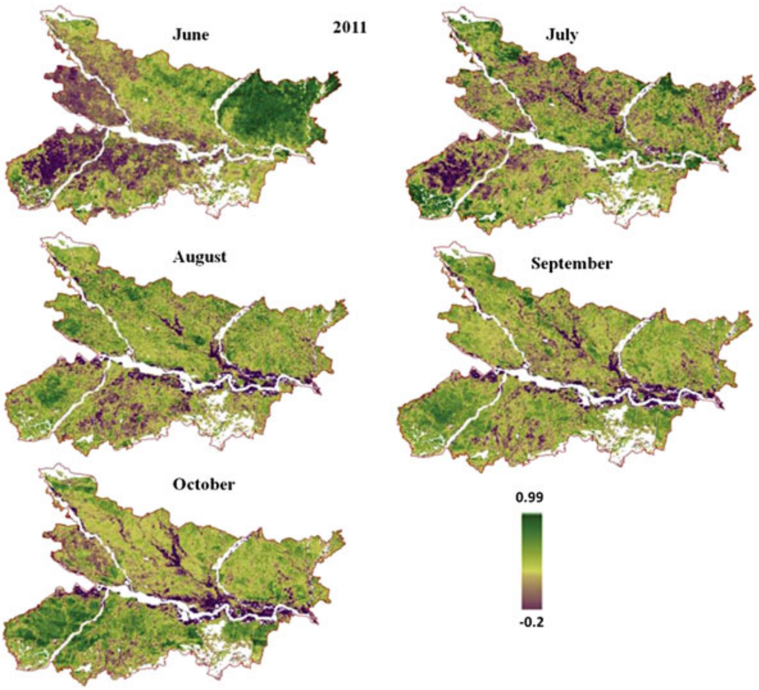

Fig. 2.7 Normalized difference vegetation index for the year 2011

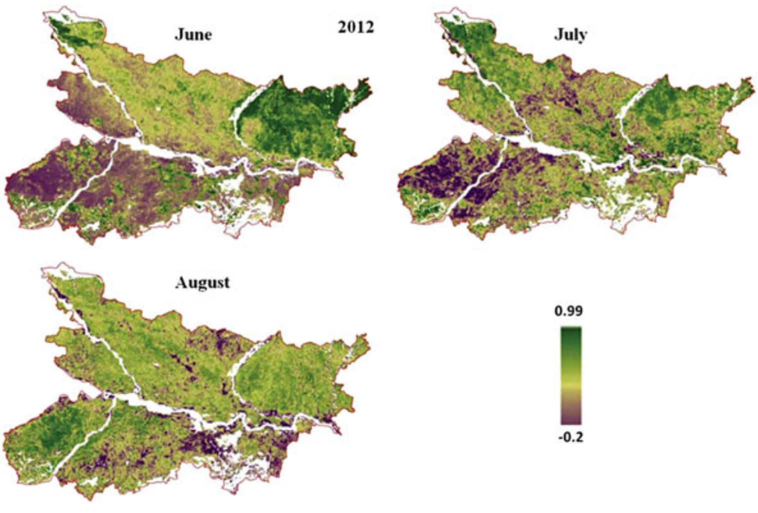

Fig. 2.8 Normalized difference vegetation index for the year 2012

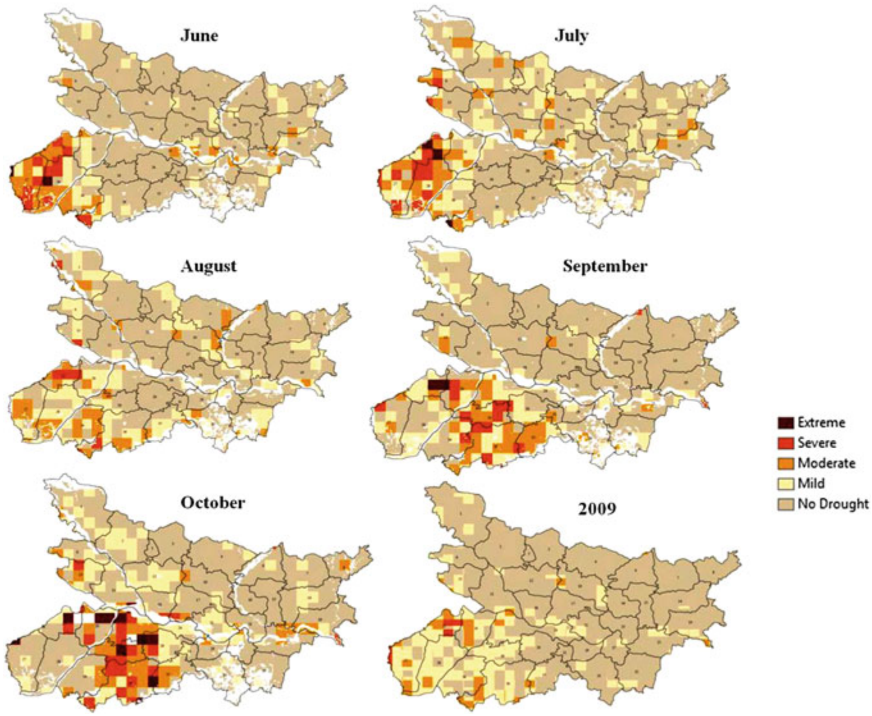

Fig. 2.9 Vegetation health index (2009)

The VHI images for the entire state have been classified as per above mentioned scheme and has been shown above. The economy of Bihar is exclusively dependent on the agricultural practice and in this study agricultural drought has been considered and assessed. So, for analysis of agriculture drought, only agricultural area is extracted from the generated land use/land cover map. Figures 2.9, 2.10, 2.11, 2.12 shows that mainly southern, south-western and western part of the state became drought affected in every year which also coincides with the rainfall and NDVI based analysis. The central and eastern part of the state sometimes face mild drought. The intensity of drought is not same for every month. June is the most drought affected month followed by July and October. A shifting pattern (towards east in October) has been observed in the pre-monsoon (June) and post monsoon (October) drought. The drought condition also varies year wise. June and July month of the year 2009 and 2010 get highly drought affected. June 2012 was found to be extremely affected by drought due to the extremely low rainfall. As per the Times of India news on 5th June 2012, “The pre-monsoon rainfall in Bihar during this year has been the scantiest in the past six years”. According to the meteorological department, the state has recorded 46.5 mm rainfall between March and

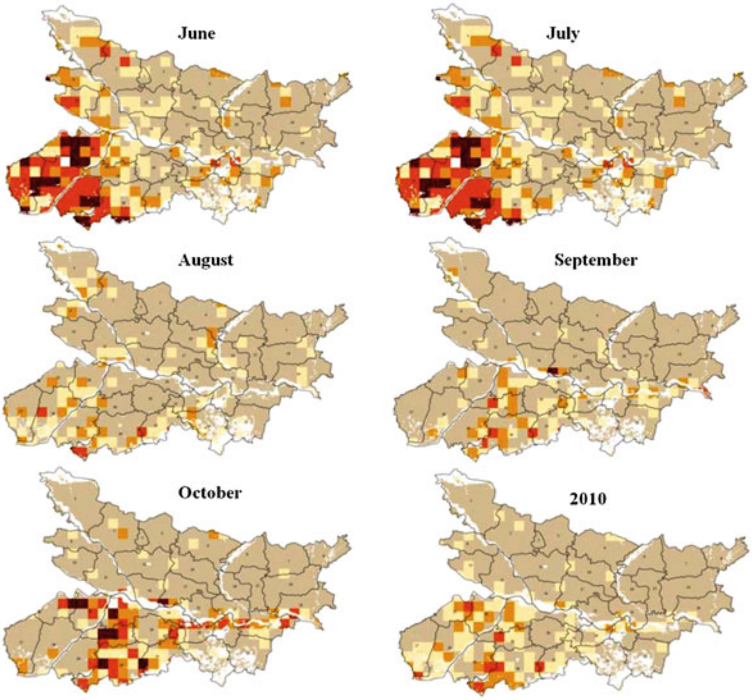

Fig. 2.10 Vegetation health index (2010)

May against the normal 77.5 mm during the same period. It is a drop of 40 per cent from the normal pre-monsoon rainfall in the state. The situation has been worse in the state capital, which has received no rainfall for the past 57 days. To add to this, the maximum temperature in Patna that touched 44.1 °C on Monday is expected to soar even higher in the coming few days." (Source: http://www.telegraphindia.com/1120605/jsp/bihar/story_15569416.jsp#.ULkAiuSAAgE).

The drought affected areas of each year has been identified and shown in the Table 2.3 as well as in Fig. 2.13. It implies that drought intensity was higher in 2009 and 2010.

2.4.3 Summary and Conclusion

Analysis of drought in Bihar suggests that the southern part of river Ganga is facing severe drought every year during Kharif season. The main reason for this drought is monsoon onset and uneven spatial distribution. The pre-monsoon

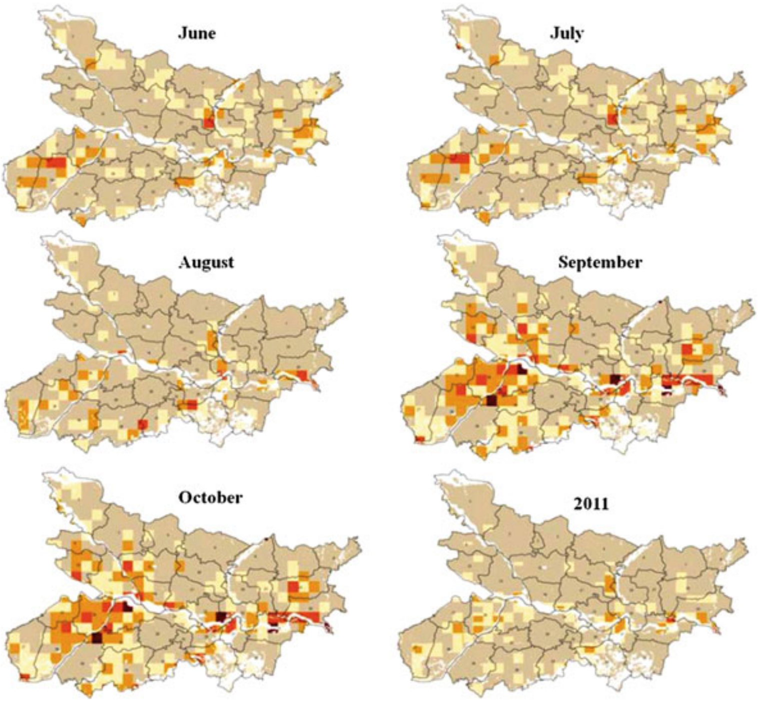

Fig. 2.11 Vegetation health index (2011)

drought is more severe as compared to post monsoon season. A shifting pattern of pre-monsoon and post-monsoon drought has been observed. June, July and October are the drought prone months. Ten districts of Bihar that are affected by drought the most are:-

(1) Kaimur
(2) Rohtas
(3) Aurangabad
(4) Buxar
(5) Bhojpur
(6) Gaya
(7) Jahanabad
(8) Patna
(9) Siwan
(10) Gopalganj

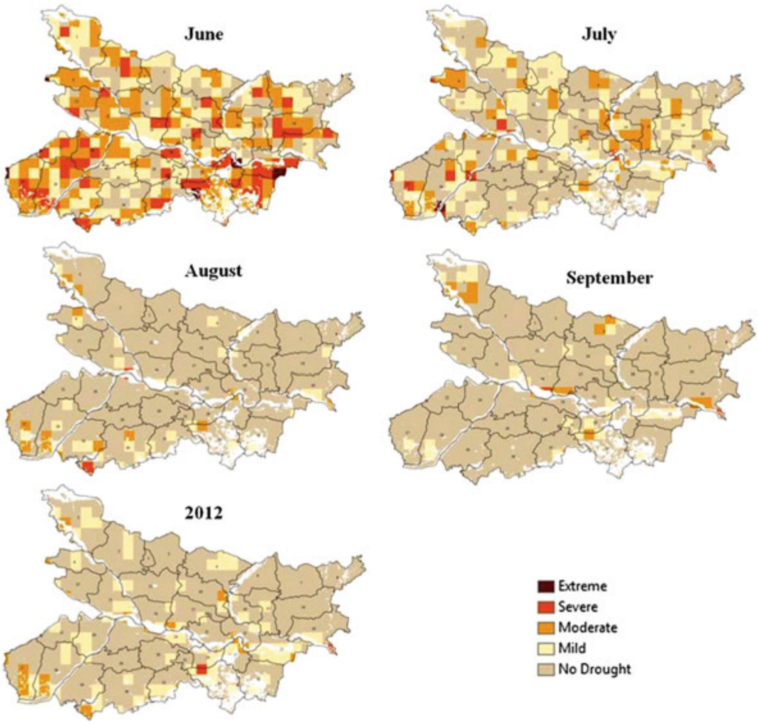

Fig. 2.12 Vegetation health index (2012)

Table 2.3 Drought affected area for the year 2009 to 2012

	Drought affected area (Sq.Km)				
	Extreme	Severe	Moderate	Mild	No drought
2009					
June	257	2349	5409	9103	58389
July	435	2245	7077	17727	48023
August	0	1016	6477	17057	50825
September	406	2511	6266	11918	54274
October	1729	3558	6464	15048	48106
2010					
June	1641	4173	10393	13149	46151
July	3153	7365	8474	16368	39951
August	0	657	3985	11256	59603
September	131	821	3687	8932	61936
October	1597	3780	5365	4818	5616
2011					
June	0	647	5046	13967	55715
July	0	651	5001	14311	55544
August	0	792	3586	8287	62842
September	0	1077	4383	6380	63667
October	726	3254	10887	16852	43788
2012					
June	574	10316	23105	22712	18800
July	118	1090	8494	22064	43741
August	0	251	1966	4812	68478
September	0	109	1908	4330	69160

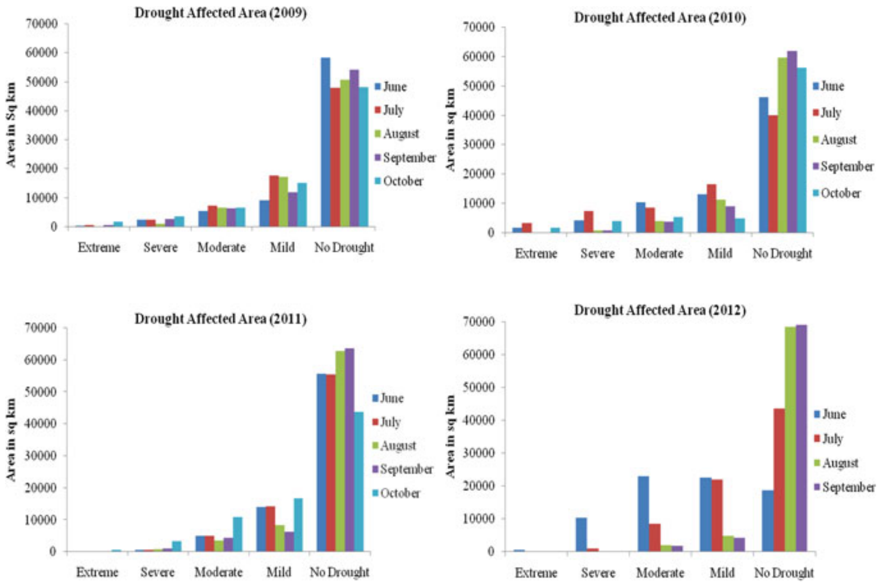

Fig. 2.13 Drought affected area for the year 2009, 2010, 2011, 2012

References

Bhuiyan C, Singh RP, Kogan FN (2006) Monitoring drought dynamics in the Aravalli region (India) using different indices based on ground and remote sensing data. Int J Appl Earth Obs Geoinf 8:289–302

Kogan FN (1995) Droughts of the Late 1980s in the United States as derived from NOAA polar orbiting satellite data. Bull Amer Meteor Soc 76:655–668

Kogan FN (2001) Operational space technology for global vegetation assessments. Bull Amer Meteor Soc 82(9):1949–1964

Kogan FN (2002) World droughts in the new millennium from AVHRR-based vegetation health indices. Eos Trans Amer Geophys Union 83:557–564

Peters AJ, Elizabeth A, Walter-Shea ji L, Viña A, Hayes M, Svoboda MD (2002) Drought monitoring with NDVI-based standardized vegetation index, Photogram Eng Remote Sens 68(1):71–75

Prasad AK, Chai L, Singh RP, Kafatos M (2006) Crop yield estimation for Iowa using remote sensing and surface parameters. Int J Appl Earth Obs Geoinf 8:26–33

Seiler RA, Kogan F, Sullivan J (1998) AVHRR-based vegetation and temperature condition indices for drought detection in Argentina. Adv Space Res 21(3):481–484

Springer

http://www.springer.com/978-3-319-04437-8

Natural Hazard Zonation of Bihar (India) Using Geoinformatics
A Schematic Approach
Ghosh, T.; Mukhopadhyay, A.
2014, XIII, 93 p. 67 illus. in color., Softcover
ISBN: 978-3-319-04437-8