Chapter 5
Mapping Agriculture Dynamics and Associated Flood Impacts in Bihar using Time-series Satellite Data

C. Jeganathan and P. Kumar

Abstract Agriculture is the prime requirement for sustaining human life on earth, and agriculture sustainability depends on soil health and suitable climatic variations. Human have adopted many local-weather-dependent crop types and its cultivation patterns based on knowledge about long term climatic and environmental conditions. Any anomaly in these factors would result in unforeseen reduction in the food production and associated socio-economic chaos at local/regional to global scale. Due to anthropogenic activities like expansion of urban area, industrialization, deforestation etc. have increased the greenhouse gases (GHGs) level and hence the mean earth surface temperature has increased by 0.74 °C during 1900 to 2000 AD and it is anticipated to rise by 1.4–5.8 °C during 2000 to 2100 AD with notable local differences which would result in increase in the frequency of drought, flood, sea level rise etc. and will drastically affect the crop production. Bihar is one of the fertile regions in India, gifted with numerous water resources like Ganga, Gandak and Kosi and many more rivers. But these rivers are both boon and bane to Bihar because most of the rivers flood during monsoon season. Hence it would be interesting to know the Agriculture cropping pattern over a decade, its changing scenario and the impact of flood on agriculture area in Bihar. In this regard, current study attempted to use time-series remote sensing data from 2001 to 2012 in deriving spatio-temporal, seasonal and annual cropping pattern, and as well as flood scenario purely based on space based observation.

Keywords MODIS EVI time series · Cropping system · Flood impact · Climate change · Bihar · India

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5.1 Introduction

Agriculture is one of the primary activity for maintaining economic and social well-being of Indian population. Although the contribution of agriculture in the employment and Gross Domestic Product (GDP) has declined over time. The contribution of agriculture in GDP has declined from 39% in 1983 to 24% in 2000–01 and its contribution in total employment from 63% to 57% during the same period (Mall et al. 2006). Indian cropping system is widely reliant on monsoon from the ancient times and hence it will be severely affected in case of any drastic anomaly in the monsoon trend. Climate change is influencing the rainfall and temperatures conditions across India. The number of rainy days may decrease but the intensity is anticipated to increase, and the availability of gross per capita water will decline from 1820 m^3/ year in 2001 to as low as 1140 m^3/year in 2050 in India (Mahato 2014). Increasing concentrations of CO2 and temperature may affect the crop yield both positively and negatively at different regions, however the rain-fed/un-irrigated crops cultivated over 60% of cropland of India is more venerable to climate change. As per Kalra et al. (2003) the rise in winter temperature by 0.5 °C is likely to reduce rain-fed wheat yield by 0.45 tonnes per hectare in India. The economy of Bihar is mainly based on agriculture with 88.70% of its population living in villages (Census of India 2011) and 81% of the population is associated with agro based work and contributing 42% of GDP of the state (2004–05) (including forestry and fishing) (GOB 2012). Bihar's population in 1951, 1971 and 1991 were 29.08, 42.12 and 64.53 Million, respectively, and has crossed 104 Million in 2011 (Census of India 2011).

To analyse and understand climate change and its impact on agriculture has been recognised as an important first step to strategize adaptation (Turner II et al. 2003; Parry et al. 2007; UNDP. 2010; USAID. 2013). The Space-borne remote sensing technology has been extensively used to map cropping scenario, intensity and change (Xiao et al. 2003; Galford et al. 2008; Wardlow and Egbert 2008). In this study, Moderate Resolution Imaging Spectro radiometer (MODIS) Terra sensor derived vegetation index data (1 km spatial resolution and 16 days temporal resolution) has been used to study the cropping scenario and flood impact in Bihar during 2001 to 2012. Advantage of having high temporal resolution and coarse spatial resolution covering large area using MODIS data helps in monitoring agriculture situation in a continuous manner which otherwise would not be possible using high spatial resolution data due to coarse revisit period and cloud coverage issues.

5.2 Materials and Methods

5.2.1 Study Area

Bihar, the land of Buddha, has been a cradle of knowledge in Indian history. Patna is the capital of the state, which is located on the bank of the holy river Ganga. The river divides the state into two unequal halves from west to east. The northern part

of the state is mostly affected by flooding and the southern part usually by drought. The state falls in the sub-tropical climatic zone. The state's average annual rainfall is about 1200 mm (Chowdary et al. 2008). The spatial extent of the state is between 83° 19.83′ to 88° 17.67′ E longitude and 24° 20.17′ to 27° 31.25' N latitude. It comprises of 38 districts and total area of the state is 94,163 km^2 (GOB 2014).

5.2.2 Satellite Data

Moderate Resolution Imaging Spectro radiometer Enhanced Vegetation Index (MODIS EVI) (MOD13A2, 1 km, 16 days composite) Terra's time series data over 12 years (2001 to 2012) were used to analyse cropping pattern of the state, and detailed results were given in this paper for the years 2001, 2006 and 2011. The satellite data were downloaded from USGS website (source: https://lpdaac.usgs.gov/). The flood map from IWMI were used in this study. These maps were derived using MODIS Data (MOD09A1, 500 m, 8 day composites) with validation based on Landsat TM and ALOS AVINIR / PALSAR data (Amarnath et al. 2012).

5.2.3 Research Methods

The methodology used to analyse the spatio-temporal change in cropping pattern and flood impact assessment on agriculture growing areas of Bihar is provided in the Fig. 5.1.

Smoothing based on Fourier technique and phenology detection algorithms were used to identify the starting of greening phase in annual EVI data. Based on these annual data horizontal expansion as well as vertical intensification (net sown area, Rabi, Zaid and Kharif Area) of the cropping pattern using were quantified spatially and temporally in this region. The detailed procedure can be seen in Kumar and Jeganathan (2016). The flood impact has been assessd only for the Kharif crop (monsoon crop). Since the actual loss of crop cannot be accurately quantified, Potential Kharif crop loss map for different years have been prepared based on Kharif frequency information along with Annual Net Sown area and flood maps (see Fig. 5.1 for details).

5.3 Results and Discussion

Seasonal cropping system (Rabi, Zaid & Kharif) based on MODIS EVI (MOD13A2) time series data seems well distributed all over the state (Fig. 5.2). The Tables 5.1 to 5.3 provides district wise percentage area under different cropping pattern of the state for the yeras 2001, 2006 and 2011 respectively. It can be seen that most of the

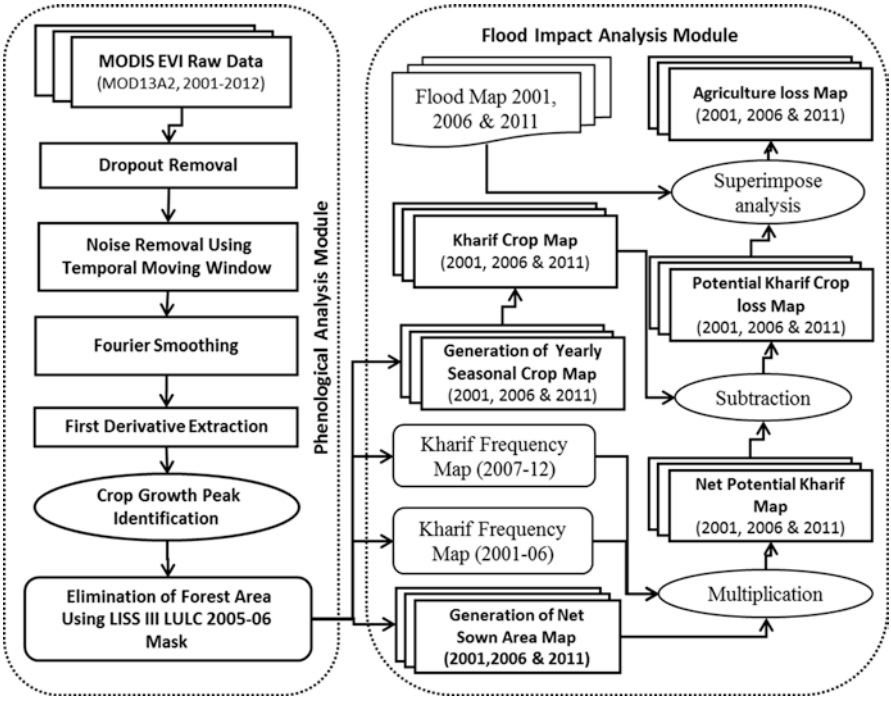

Fig. 5.1 Methodology of Research

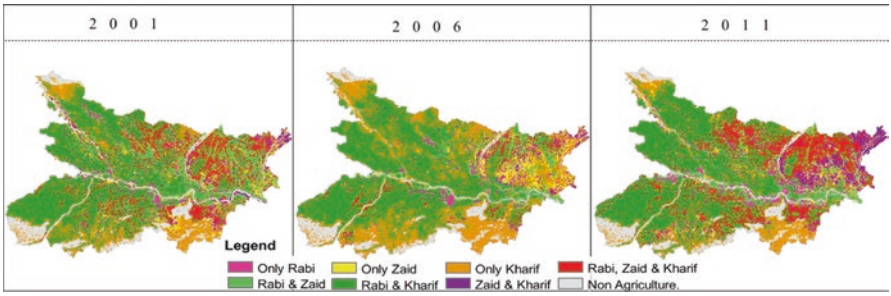

Fig. 5.2 MODIS EVI based cropping system dynamics of Bihar (2001, 2006 & 2011)

area in Bihar has double cropping pattern (*Rabi and Kharif* - dark green colour in Fig. 5.2) covering 43.66, 48.56 and 44.85% of the state during 2001, 2006 and 2011 respectively. The districts Araria and Supaul had more than 50% of area having triple cropping system in 2011. The year 2011 found to be having more area under triple cropping pattern (crop in all the 3 seasons - *Rabi, Zaid and Kharif*) (13.47%) than 2001 and 2006 in the state and this may be because of good rainfall throughout the year (DSV 2014). In the year 2001, Rabi and Zaid cropping area was more (11.77%) in comparison to 2006 and 2011. The second maximum area seems in the

Table 5.1 District-wise agriculture area (%) distribution of seasonal crops in the Bihar during 2001

Districts	Non Agriculture	Only Rabi	Only Zaid	Only Kharif	Rabi & Zaid	Rabi & Kharif	Zaid & Kharif	Rabi, Zaid & Kharif
W. Champaran	20.63	1.54	5.65	27.70	2.87	38.58	2.44	0.59
E. Champaran	2.34	4.76	2.38	7.47	4.76	75.95	1.22	1.12
Sitamarhi	0.25	4.97	0.71	2.09	7.27	72.40	0.29	12.03
Madhubani	0.65	5.16	2.83	19.93	8.66	35.37	2.71	24.70
Gopalganj	3.25	4.18	5.53	5.49	12.08	64.60	1.94	2.92
Sheohar	1.04	4.63	2.69	3.73	11.49	63.88	1.94	10.60
Araria	0.00	7.18	4.81	2.80	37.92	21.58	1.40	24.32
Supaul	11.04	3.63	2.26	4.21	23.44	11.65	2.55	41.23
Kishanganj	4.81	1.33	13.09	17.21	4.12	5.97	32.66	20.82
Darbhanga	0.15	5.79	4.75	5.34	24.22	36.43	2.17	21.15
Muzaffarpur	2.12	5.22	4.89	11.54	16.59	47.70	1.43	10.51
Siwan	2.25	2.68	2.33	5.01	6.06	80.72	0.08	0.86
Saran	8.61	9.09	3.33	3.14	11.03	62.99	0.23	1.59
Purnia	1.66	6.04	6.89	4.75	30.03	24.73	4.22	21.67
Madhepura	0.47	4.38	4.71	2.98	25.96	18.27	5.50	37.74
Samastipur	2.19	7.71	3.78	2.87	26.74	49.59	0.35	6.77
Saharsa	5.53	3.55	9.13	2.89	26.59	20.14	7.26	24.91
Vaishali	9.00	7.17	4.52	7.00	7.81	62.24	0.13	2.13
Katihar	7.98	4.44	18.39	8.96	27.48	16.04	9.15	7.56
Begusarai	7.88	5.80	3.50	4.12	19.74	58.34	0.13	0.49
Buxar	2.39	1.62	0.30	5.69	1.02	86.19	0.00	2.79
Bhojpur	3.51	3.83	0.61	6.54	1.05	80.01	0.04	4.41
Patna	9.28	8.71	1.98	3.48	7.06	64.82	0.00	4.68
Khagaria	4.37	7.25	6.38	1.32	42.90	29.50	2.01	6.27
Bhagalpur	8.59	5.59	7.73	10.82	26.91	17.15	10.26	12.95
Munger	34.98	5.76	8.39	6.70	10.64	7.13	3.94	22.47
Nalanda	2.31	6.60	0.59	1.50	11.14	60.35	0.07	17.44
Kaimur	33.46	0.31	0.10	13.08	0.05	52.89	0.03	0.08
Rohtas	23.40	0.18	0.33	8.29	0.42	66.05	0.04	1.28
Lakhisarai	14.34	16.01	5.89	7.17	7.81	29.45	2.18	17.16
Jehanabad	0.51	6.57	4.65	5.97	17.19	42.77	0.20	22.14
Sheikhpura	0.72	7.16	2.87	8.60	13.75	61.03	0.14	5.73
Jamui	20.79	0.86	11.74	55.15	1.50	2.96	3.35	3.65
Aurangabad	9.61	1.72	0.55	26.83	0.76	59.06	0.08	1.38
Banka	10.74	0.25	5.34	53.17	0.59	7.46	7.46	14.98
Nawada	20.18	3.25	2.06	19.73	3.25	44.81	0.38	6.34
Gaya	16.89	3.27	2.43	33.68	3.48	37.68	0.14	2.43
Arwal	6.31	1.69	0.56	6.99	1.92	79.71	0.11	2.71
Bihar	9.46	4.34	4.42	13.62	11.77	43.66	2.73	10.00

Table 5.2 District-wise agriculture area (%) distribution of seasonal crops in the Bihar during 2006

Districts	Non Agriculture	Only Rabi	Only Zaid	Only Kharif	Rabi & Zaid	Rabi & Kharif	Zaid & Kharif	Rabi, Zaid & Kharif
W. Champaran	19.36	0.16	1.79	43.55	0.18	34.42	0.29	0.25
E. Champaran	0.88	0.54	0.39	15.32	0.24	81.98	0.30	0.36
Sitamarhi	0.08	0.92	0.33	33.74	1.17	63.34	0.25	0.17
Madhubani	0.55	3.23	4.07	43.36	6.83	39.09	0.97	1.91
Gopalganj	2.03	0.34	1.27	17.74	0.38	77.95	0.21	0.08
Sheohar	0.45	0.30	0.60	20.90	1.04	75.97	0.60	0.15
Araria	0.00	3.47	8.40	18.78	21.70	25.47	8.40	13.79
Supaul	10.21	4.24	9.63	10.68	21.96	17.07	5.64	20.56
Kishanganj	1.93	0.64	14.59	47.81	1.63	4.76	22.66	5.97
Darbhanga	0.04	4.19	4.97	22.38	14.31	53.03	0.52	0.56
Muzaffarpur	0.86	4.46	1.16	21.35	3.07	67.65	0.51	0.94
Siwan	1.48	0.16	0.12	8.32	0.08	89.51	0.31	0.04
Saran	5.89	2.59	2.07	8.31	3.62	77.42	0.06	0.03
Purnia	0.61	1.27	22.80	42.54	11.30	11.96	7.65	1.87
Madhepura	0.47	2.19	21.02	18.69	6.62	34.39	9.04	7.60
Samastipur	1.95	6.09	1.63	20.33	7.74	61.94	0.24	0.09
Saharsa	4.72	1.47	15.07	28.97	1.62	32.57	12.18	3.40
Vaishali	6.70	1.45	1.71	12.93	3.07	73.72	0.26	0.17
Katihar	5.66	0.92	21.99	38.95	13.98	7.20	8.93	2.37
Begusarai	7.53	1.81	0.80	12.04	2.08	75.70	0.04	0.00
Buxar	1.88	2.34	0.46	5.38	3.10	84.87	0.05	1.93
Bhojpur	2.31	2.93	1.45	6.62	4.05	75.81	0.33	6.51
Patna	7.46	9.01	1.71	5.16	2.57	69.98	0.24	3.88
Khagaria	2.42	5.75	1.50	6.04	5.69	75.96	2.59	0.06
Bhagalpur	7.23	5.69	4.43	22.78	18.41	37.70	1.30	2.46
Munger	32.60	4.38	1.88	20.15	3.82	31.85	0.44	4.88
Nalanda	3.00	4.36	0.22	9.53	0.37	81.35	0.00	1.17
Kaimur	33.44	0.47	0.16	15.60	0.42	49.51	0.05	0.36
Rohtas	22.98	0.46	0.58	9.75	0.55	63.61	0.04	2.01
Lakhisarai	13.12	8.64	0.77	29.96	1.15	45.01	0.38	0.96
Jehanabad	0.40	1.01	0.30	26.29	0.20	70.88	0.10	0.81
Sheikhpura	1.43	2.29	0.14	35.10	0.00	60.74	0.00	0.29
Jamui	20.38	0.08	0.14	73.39	0.00	4.57	0.69	0.75
Aurangabad	8.96	0.94	2.17	45.30	0.57	37.02	1.52	3.53
Banka	10.23	0.08	0.62	60.58	0.00	20.30	2.94	5.26
Nawada	20.14	0.10	0.00	29.12	0.00	50.33	0.03	0.27
Gaya	16.46	0.34	0.22	52.98	0.05	29.68	0.02	0.24
Arwal	5.41	0.56	2.59	6.88	1.01	76.44	0.34	6.76
Bihar	8.57	2.22	4.07	27.32	4.44	48.56	2.24	2.58

Table 5.3 District-wise agriculture area (%) distribution of seasonal crops in the Bihar during 2011

Districts	Non Agriculture	Only Rabi	Only Zaid	Only Kharif	Rabi & Zaid	Rabi & Kharif	Zaid & Kharif	Rabi, Zaid & Kharif
W. Champaran	19.86	1.72	4.31	25.57	0.88	46.76	0.48	0.43
E. Champaran	1.54	1.59	0.64	4.14	1.14	89.70	0.15	1.09
Sitamarhi	0.08	2.38	2.59	7.52	5.14	48.60	2.05	31.65
Madhubani	0.22	2.33	1.74	10.03	5.14	46.89	4.39	29.26
Gopalganj	4.06	2.24	1.18	3.46	1.14	87.03	0.34	0.55
Sheohar	0.00	2.84	1.64	5.37	3.28	68.51	1.49	16.87
Araria	0.00	0.85	2.62	3.20	7.91	12.17	12.02	61.23
Supaul	10.50	2.77	2.91	2.52	12.47	8.81	5.46	54.57
Kishanganj	2.79	0.17	4.98	9.83	0.09	3.56	62.40	16.18
Darbhanga	0.15	4.67	2.95	4.11	14.46	39.95	2.80	30.90
Muzaffarpur	1.24	7.34	2.20	5.19	9.90	58.32	1.13	14.68
Siwan	1.59	2.25	0.58	0.82	1.83	92.15	0.19	0.58
Saran	6.57	7.41	1.39	1.49	10.81	69.07	0.26	3.01
Purnia	0.77	2.16	12.01	14.23	12.93	7.50	31.91	18.50
Madhepura	0.61	6.24	4.85	5.17	9.74	20.13	19.48	33.78
Samastipur	1.74	9.90	2.98	12.65	17.70	47.84	0.56	6.62
Saharsa	5.43	4.26	4.16	8.78	5.02	29.22	20.95	22.17
Vaishali	7.21	5.42	2.52	5.59	19.37	59.09	0.09	0.73
Katihar	6.47	3.60	12.30	12.56	23.44	9.26	22.24	10.13
Begusarai	8.63	9.61	1.11	8.54	15.32	56.71	0.04	0.04
Buxar	2.03	3.20	0.30	1.68	5.03	80.76	0.20	6.80
Bhojpur	2.42	10.20	0.69	2.21	8.46	65.76	0.18	10.09
Patna	8.85	9.65	2.81	3.37	14.54	47.53	0.27	12.99
Khagaria	2.47	23.06	1.38	1.55	18.80	46.58	3.39	2.76
Bhagalpur	8.59	11.29	4.90	9.16	31.37	18.25	3.23	13.22
Munger	34.61	15.64	1.25	10.89	6.38	16.71	1.31	13.20
Nalanda	2.53	4.91	0.55	3.22	3.70	68.52	0.37	16.20
Kaimur	33.44	1.59	0.13	10.40	1.98	50.81	0.00	1.66
Rohtas	22.87	0.84	0.73	6.53	0.91	66.25	0.00	1.88
Lakhisarai	13.25	12.10	2.75	9.22	11.72	32.71	1.66	16.58
Jehanabad	0.71	2.83	1.21	16.89	0.40	72.90	0.30	4.75
Sheikhpura	0.00	3.30	0.57	6.16	4.58	48.71	1.29	35.39
Jamui	20.40	0.72	2.13	57.86	0.17	9.44	2.38	6.89
Aurangabad	8.28	2.77	3.68	15.78	3.24	57.13	3.13	5.98
Banka	9.98	0.14	3.27	49.40	0.14	14.03	6.51	16.52
Nawada	20.01	2.91	3.05	9.22	4.56	38.40	1.10	20.76
Gaya	16.56	4.64	2.64	25.21	4.32	40.78	0.63	5.21
Arwal	5.41	3.27	1.01	3.16	2.82	67.87	0.68	15.78
Bihar	8.87	4.54	2.96	12.11	7.73	44.85	5.48	13.47

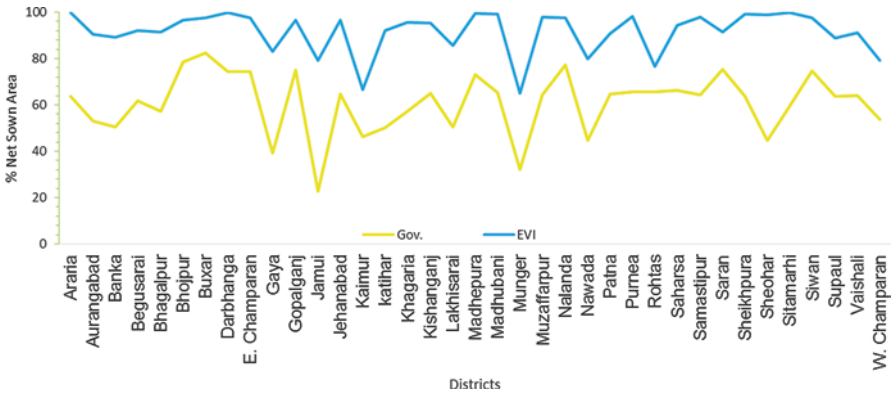

Fig. 5.3 Percentage net sown area comparison between Bihar Government report 2001–02 and MODIS EVI 2001

only Kharif cropping system 13.62, 27.32 and 12.11% respectively 2001, 2006 and 2011 (Table 5.1 to 5.3). These results would help in understanding cropping system and its dependency on monsoon season. It can be seen that few districts like West Champaran in the North -West and Jamui and Banka districts of South -East of the state, have *only kharif* crop (see orange colour in Fig. 5.2) which could be because of gaps in irrigation facility and they depend only on monsoon rain.

The net sown area of the state for the years 2001, 2006 and 2011 is 90.54, 91.42 and 91.13% respectively. Fig. 5.3 provides comparison of net sown area extracted using Government of Bihar report (2001–02) and MODIS EVI (2001). The Bihar Government report 2001–02 (DES 2016) and the district wise result of net sown area based on MODIS EVI 2001 found some difference but the pattern seems same. This trend reflects strong inter-relation of these statistics (Fig. 5.3). The major drawback of MODIS data is its coarse spatial resolution however the trend is found to be similar. It is also noticed that there were contradictions about net-sown area amongst the government departments.

For example, Government of Bihar report (GOB 2007) revealed the net sown area in Gopalganj, Saran and Siwan as 98%, in Seohar, Muzaffarpur, Vaishali and Sitamarhi districts as 95%, in Darbhanga, Samastipur and Madhubani as 87%, in Jehanabad, Aurangabad and Gaya as 86.7%. These government statistics are closely related to MODIS EVI results.

The Fig. 5.4 shows flood impact on Kharif crop during 2001, 2006 and 2011 in the state. The flood has affected crops mainly in the northern districts from Ganges closer to the rivers like Gandak, Burhi, Bagmati, Gandak, Kosi and Mahananda. In the southern part it has affected mainly in the Sheikhpura and Lakhisarai districts (Fig. 5.4). In the year 2001, the kharif crop area lost due to flood is 8.22%. The least impact of flood was observed in the year 2006 (only 3.56%) in comparison to 2001 and 2011. In the year 2011, flood impact (5.87% loss) was mainly seen along the banks of Ganges and lower part of Kosi River.

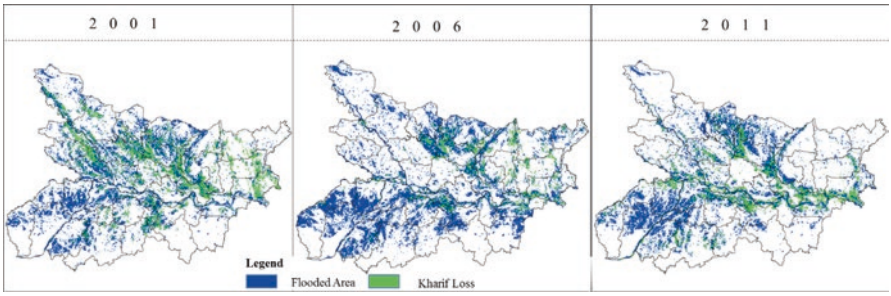

Fig. 5.4 Flood impact assessment on Kharif crop in Bihar (2001, 2006 & 2011)

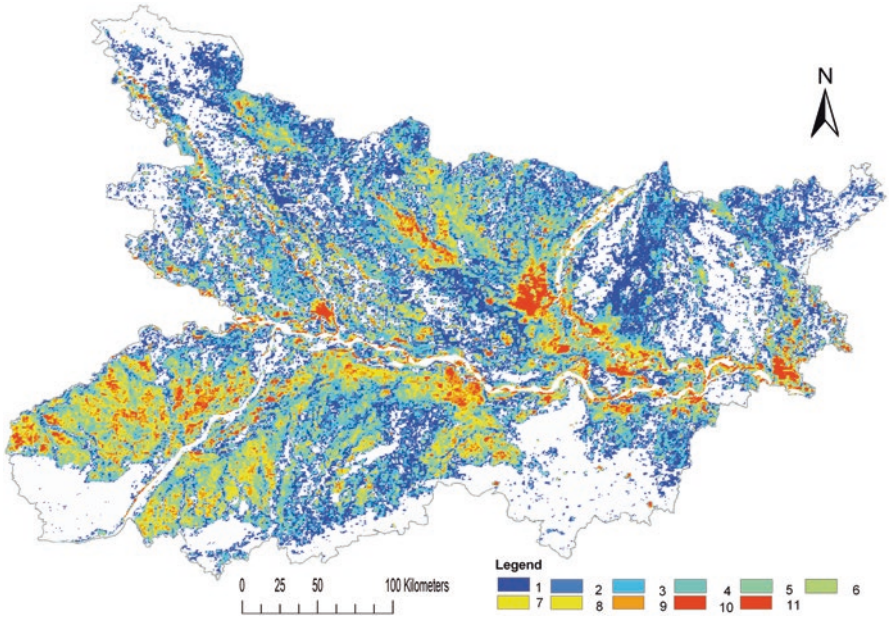

Fig. 5.5 Flood frequency of Bihar during 2001–11

In the Fig. 5.5 has shown flood frequency in Bihar during 2001 to 2011. The maximum concentration of flood frequency is seen at the junction of Burhi Gandak, Kamla and Balan near the embankment of Kosi River. It has also revealed concentrations of flood freqancy at the junction of Mahananda and Ganga rivers.

5.4 Conclusion

The study has successfully used the MODIS EVI time series data for seasonal cropping system assessment as well as the flood impact on agriculture in Bihar. The study has revealed spatio-temporal variations in the cropping pattern during 2001,

2006 and 2011. There are contradictions between results from our study and the government reports which requires further scrutiny. Due to varying rainfall scenario in different years the agriculture pattern in Bihar is highly dynamic and only Satellite based observation can provide a reliable estimates. Any loss estimate based on previous year cropping situation should not be used as the current study has revealed high inter-annual variation in the cropping pattern in this State. The changing climatic condition and its impact on agriculture pattern need to be further quantified with more authentic ground information.

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