

## **Assessment of spatial-temporal changes in Wetlands (2013-2022): A case study of Madhubani district**

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### **Abstract:**

Wetlands are one of the richest ecosystems on the Earth. It is rich in many species of amphibians, small mammals, fishes, birds and aquatic plants. According to the Ramsar Convention, "Wetlands are areas of marsh, fen, peatland, or water whether formed naturally or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water which at low tide does not exceed 6m." They provide important services such as water supply, recreational opportunities, flood control and climate regulation. These are more likely to be eroded due to climate change processes. This study is to evaluate the impact of climate change on the wetlands of Madhubani district. The study area is characterized by high environmental and agricultural pressure. In this paper, two important indices NDVI and NDWI have been used to assess the current status of wetlands. Also, the Mann-Kendall test and Sen's slope estimator have been used to assess the main component of climate, namely rainfall. Using both these methods, an attempt has been made to explain the status of wetlands and the trend of average annual rainfall in this region during the last decade (2013-2022). Through this paper, it can be understood that what is the impact of climate change and human activities on wetlands. Based on the importance of wetlands and their characteristics, it is essential for their future to have a quick assessment and adopt remedial measures without any delay.

**Keywords:** Wetlands, NDVI, NDWI, Mann-Kendall test, characteristics

### **1. Introduction:**

A wetland is a land where a large part of the ecosystem is permanently or temporarily saturated with water. It is very sensitive for the view of biodiversity because only special types of vegetation and other organisms are adapted to grow and flourish in wetlands (Shaw and Fredine 1971, Cavallo et al. 2021). Wetlands are very important to humans and nature because they purify water, reduce flooding, store water, prevent soil erosion, and support a variety of biodiversity (Moore et al. 2000, Pradeeppraju N, Nagaraja D, and Sudeep SR 2022). Although wetlands have many benefits, they are commonly understood as breeding grounds for mosquitoes that transmit diseases to humans (Kathoresan and Rajendran 2005).

The Ramsar site is of great importance for the conservation and management of wetlands. The Ramsar Convention is held every year on 2 February in some part of the world. According to the Ramsar Convention, there are a total of 2493 wetlands of international importance in the world. The number of wetlands included in the list of Ramsar Convention in India is 75 in 2022. Of these, only one Kabartal located in Begusarai has been included in the Ramsar list. According to the National Wetland Conservation Program (NWCP), three wetlands in Bihar are Kabartal (Begusarai); Barailatal (Vaishali) and Kusheshwarthan (Darbhanga) have been identified. From environmental point of view hundreds of small and big wetlands are located in Madhubani district, out of which Rajwa, Karamoli Chaur, Rajokhar,

Madhepur Chaur are the main ones. The total area of wetlands in Madhubani district is 5367 hectares, which is spread over 25% of the total area. (National Wetland Atlas of Bihar, 2010).

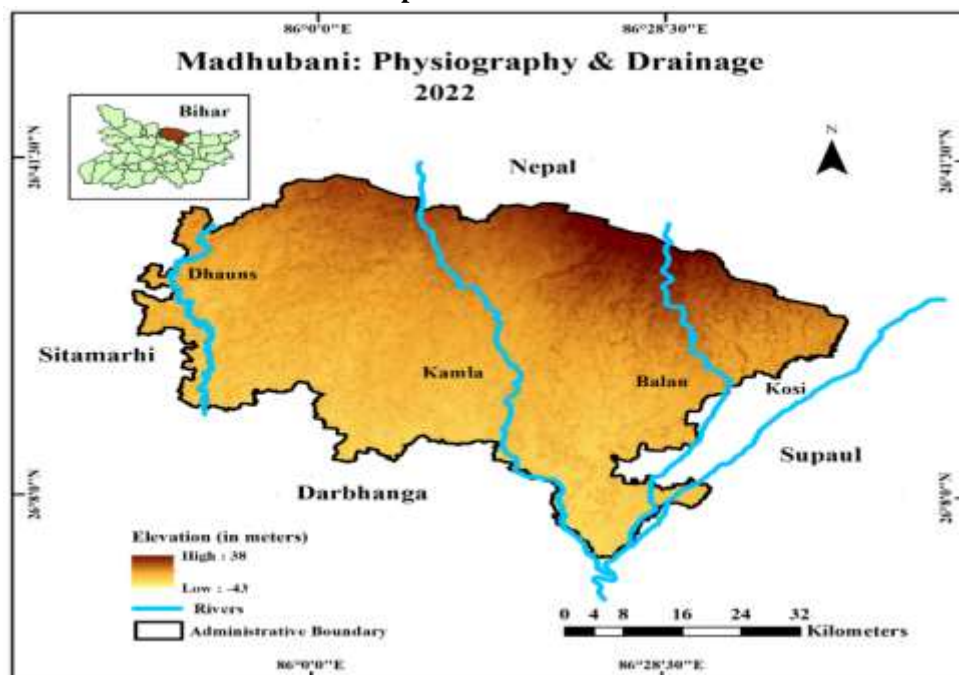
NDWI and NDVI two important indicators have been used to assess the change in the size and area of wetlands in Madhubani district (McFeeters 1996; Rouse et al. 1973; Szabó, Gács, and Balázs 2016; Cavallo et al., 2021; Pradeeppraju N et al., 2022). MK test has been done for the average annual rainfall of the last 30 years to assess climate change. Climate change has an indirect effect on the wetland ecosystem as compared to human activities, but the special types of vegetation found in it such as Makhana, Water Hyacinth, Singhara, Kamal, Lily etc. (Anamika K 2019) are directly affected by extreme temperature and reduction in rainfall is profoundly affected (Jana et al. 2018). The present paper attempts to map and monitor wetlands in Madhubani district of North Bihar through geospatial techniques.

### **2. Study Area:**

Madhubani is one of the 38 districts of northern Bihar. It forms the international boundary with Nepal in the north while Supaul in the east, Darbhanga in the south and Sitamarhi district in the west. Its latitudinal extent is 25°59' north to 26°39' north and longitudinal extent is 85°43' east to 86°42' east (Map-1). The total geographical area of the study area is 3501 square kilometres. According to the census 2011, its total population is 4487379 and the population density is 1282 persons per square kilometres, more than Bihar. While its

literacy rate is 58.62%, even lower than Bihar (61.8%) (District Census Handbook 2011).

**Map 1.**



*Source: Prepared by the author*

Madhubani district is a Terai region formed by rivers originating from the Himalayas. New Khadar soil is found here. The main rivers flowing through the study area are Kosi, Balan, Kamla and Dhauns from east to west. The slope of this region is roughly from north to south. It receives rainfall mainly from the Bay of Bengal branch of the south-west monsoon. Madhubani district is the rainiest district of Bihar. It receives an average annual rainfall of 1100–1200 mm.

### 3. Objective:

Two main objectives have been selected in the present study-

1. To identify and mapping of wetlands in Madhubani district during 2013 to 2022.
2. To assess the impact of climate change on the size and area of wetlands.

### 4. Data Sources and Methodology:

In the present paper, Landsat-7 and Landsat-9 data for 2013 and 2022 respectively have been used for mapping wetlands from USGS Earth Explorer website in ArcMap 10.8.2. NDWI (McFeetes 1996; Kaplan and Avdan 2017) and NDVI (Rousse et al. 1973, Shyamani et al. 2021) are two important indices used to analyse these data. The annual rainfall of the last 30 years has been downloaded from the website of the Indian Meteorological Department (IMD). Mann-Kendall test (MK-test) and Sen's slope test were used to analyse these annual rainfall data of Madhubani district.

#### 4.1. Mann-Kendall Test & Sen Slope:

MK test is best suited to study the trend of annual rainfall. It is easy to understand the change in rainfall through this test. Sen's slope test is suitable

to explain the change in time series data of rainfall. It is easy to understand whether the rainfall is decreasing or increasing significantly or not (Theil 1950; Sen 1968; Kendall 1975; Sharma et al. 2022). MK test is a non-parametric test based on the null hypothesis that it shows the trend. (Kaudahe et al. 2018). Sen's Slope Estimator is suitable for accurate prediction of slope per unit time (Sen 1968).

#### 4.2. Normalized Difference Wetness Index (NDWI):

NDWI is the most suitable index to identify wetlands from satellite images. This index is used from the following equation-

$$NDWI = \frac{Green-NIR}{Green+NIR}$$

(NIR=Near Infrared band; Green= Green band)

The value of NDWI ranges from -1 to +1. Positive value of NDWI indicates wet area whereas, negative value indicates dry area of the study area.

#### 4.3. Normalized Difference Vegetation Index (NDVI):

NDVI is the most suitable index to characterize vegetation from satellite images. This index is used from the following equation-

$$NDVI = \frac{NIR-Red}{NIR+Red}$$

(NIR= Near Infrared band; Red= Red band)

The value of NDVI ranges from -1 to +1. Positive value of NDVI indicates vegetation area whereas, negative value indicates non-vegetative area of the study area.

### 5. Results and Discussion:

In the present paper, the use of Topographical

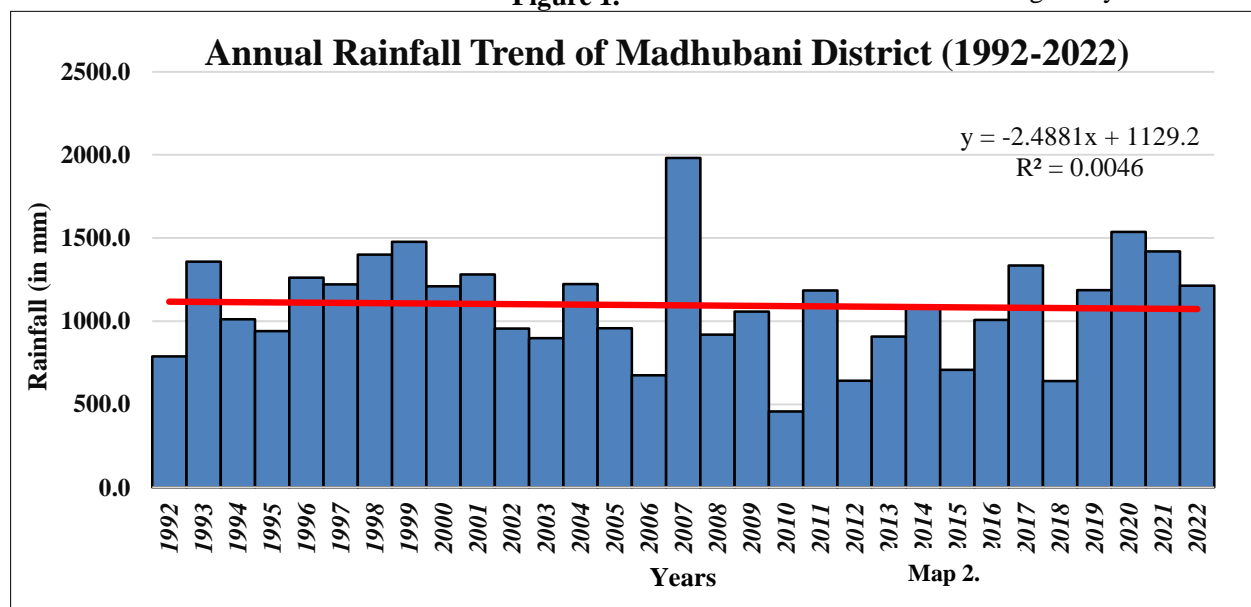
Wetness Index (TWI) is appropriate in studying the water characteristics of Madhubani. The run off pattern can also be understood from this index. NDWI (McFeeters 1996) and NDVI (Rousse et al. 1973) are the most suitable indices for wetness and vegetation clarity respectively in Madhubani district. Sen's slope and MK test (Sen 1968; Kendall 1975; Sharma et al. 2022) are suitable for clarifying the trend of annual rainfall and the reality of slope per unit time.

### 5.1. Annual rainfall trends (1992-2022):

Climate change refers to spatial and temporal changes in rainfall temperature and humidity. In this study the effect of climate change has been evaluated considering only rainfall as the basis. MK test and Sen's slope estimators are used in to analyse the time series data of annual rainfall trend increasing or decreasing (figure-1).

It is clear from Figure-1 that the average annual rainfall of Madhubani in the year 1992 was 788.4 mm while in 2002 it was 954.8 mm. The trend of average annual rainfall in these ten years has been almost same but during 2002 to 2012 there has been negative change in the year as it decreased to 641.8 mm in 2012. During 2012 to 2022 also a change in the trend of rainfall has been found. Till the year 2018, the trend of rainfall has been negative whereas from 2019 to 2022, the change in the trend of annual rainfall is being seen due to the change in monsoon. The trend of annual rainfall during 1992 to 2022 is clear from Figure-2 that there is a negative trend. The decrease in the rate of this rainfall and the seasonal change of rainfall is the result of climate change. It has a direct effect on the wetlands. Changes have been observed in both the size and area of wetlands due to this irregularity of rainfall.

**Figure 1.**



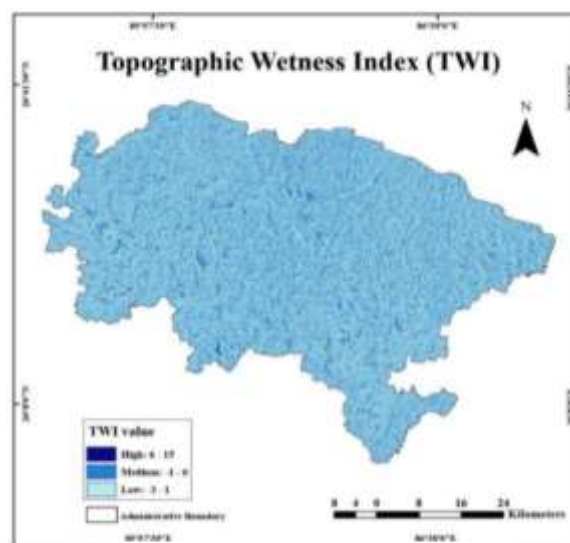
Source: Prepared by the author

### Hydrological Profile of Wetlands:

The topographical wetness index is shown in Map-2. The value of TWI ranges from -3 to +15. High value of TWI indicates high wetness whereas low value of TWI indicates dryness. It is clear from Map-2 that high wetness is in the north-central part of Madhubani. In its western part, the slope of the drainage is from north-east to south-west direction while in the central part it is from north to south-east. There is low wetness but in all parts of Madhubani as it is a Terai region.

The use of TWI is clear in the following steps.

DEM → Fill DEM → Flow direction → Flow accumulation Slope in degree → Radians of slope → Tan slope → Flow accumulation Scaled → TWI



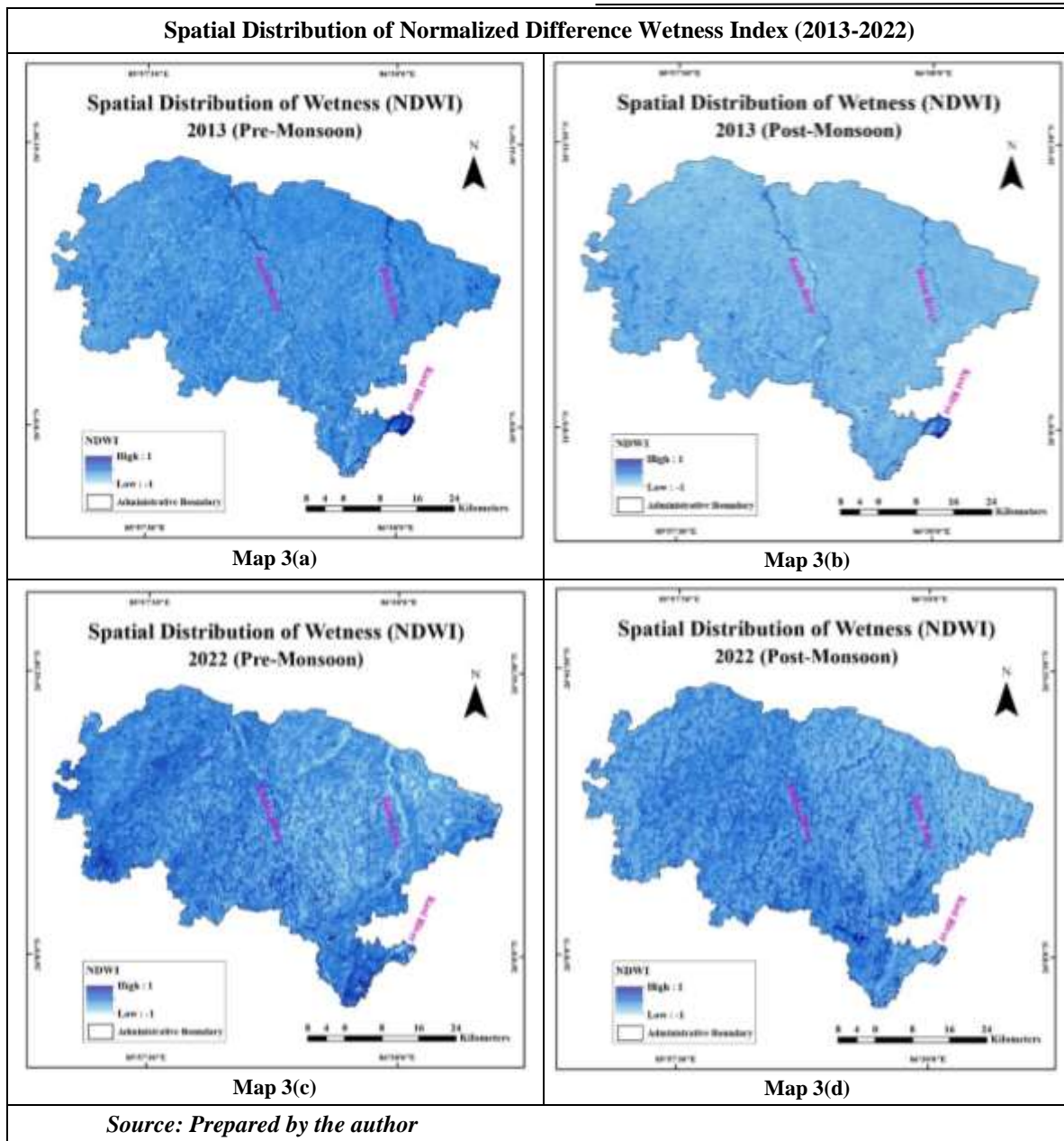
Source: Prepared by the author

## 5.2. Hydrological Changes in Wetlands:

In this section, mapping has been prepared using pre- monsoon and post-monsoon NDWI index to analyse the hydrological changes in wetlands during 2013 to 2022 (Map-3a to 3d). Two maps of 2013 3a. and 3b. and two maps of 2022 3c. and 3d. Changes in the wetland of Madhubani have been understood since. Most of the wetness in pre-monsoon of 2013 is evident in upper Kamala-Balan Doab and Balan-Kosi Doab whereas low wetness is observed in western and southern parts of Madhubani (Map- 3a.). In the post-monsoon of 2013, the Kamla, Balan and Kosi rivers have observed excess wetness whereas, southern parts of Madhubani have observed low wetness (Map-3b). In the pre- monsoon season of 2022, there is most of the wetness in the south-west

parts of the Kamla, whereas there is a deficiency in wetness in its eastern part (Map-3c.). In the post-monsoon of 2022, there is the most wetness in the central southern parts and western parts of Madhubani, whereas there is an extreme lack of wetness in the east and western parts of the Kamla (Map- 3d).

From the NDWI calculation, it is known that the change in wetness during pre-monsoon from 2013 to 2022 is observed. The wetness in 2013 was east of the Kamla whereas, the wetness in 2022 is seen west of the Kamla. The post-monsoon wetness in 2013 was normal all parts of Madhubani district whereas, in 2022 it was found to be very low wetness in the eastern parts of Kamla.

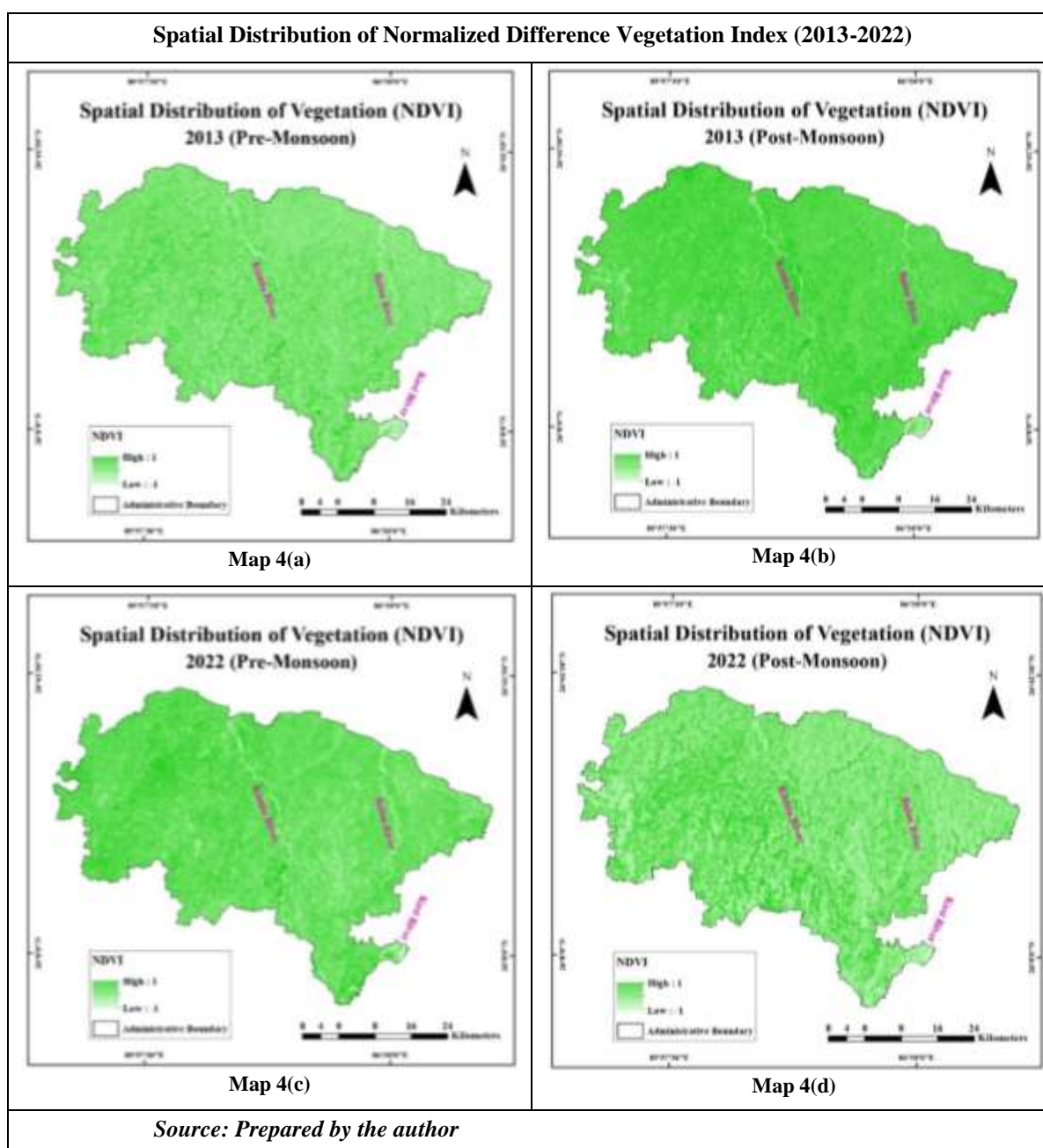




### 5.3. Vegetative changes in wetlands:

In this section, pre-monsoon and post-monsoon mapping using NDVI index has been prepared to analyse the vegetation change in wetlands during 2013 to 2022 (Map-4a to 4d). Two maps each to understand the vegetation change in 2013 and 2022 respectively (Map 4a & 4b) and (Map 4c & 4d) have been prepared. In the pre-monsoon of 2013, there is an excess of vegetation in the west of the Kamla whereas, in all other parts there is a lack of vegetation (Map-4a). In the post-monsoon of 2013, vegetation cover has been observed in all other parts of Madhubani district except the southern parts (Map -4b). The distribution of vegetation in the pre-monsoon of 2022 is more in the west- northern parts of the Kamla whereas, it

is much less in the middle doab of Kamla-Balan (Map - 4c). The distribution of vegetation in the post-monsoon of 2022 is less than normal in Madhubani district. Vegetation is sparse in the lower doab of Kamla-Kosi and western parts of Madhubani. It has a normal distribution in the west central parts of the Kamla (Map 4d). It is clear from the NDVI calculation that there was a change in the distribution of vegetation during both pre-monsoon and post-monsoon periods from 2013 to 2022. The maximum change of vegetation in the study area was observed during post-monsoon whereas, the distribution of vegetation in 2013 was more than normal, in 2022 the distribution of vegetation was found to be less than normal.



## 6. Conclusion:

In the present study, two important indices NDWI and NDVI were used to achieve the objectives. Also, annual rainfall trend was analysed using Mann-Kendal test and Sen's slope estimator. From the analysis of the trend of annual rainfall for the last 30 years during 1992 to 2022, it is clear that the annual trend of rainfall is decreasing. Apart from this, the distribution of rainfall is also unusual and the monsoon comes late and leaves early. The effect of this climate change on the size and area of wetlands have been clearly seen using NDWI and NDVI indexes. This can be understood from the following table- Wetlands include various types of features, such as flood control, prevention of soil erosion, ground water supply, etc. Madhubani district is a Terai region and is the district receives maximum rainfall. Despite this, human activities have contributed to the degradation of wetlands.

Year	Wetland area (%)	
	Pre-monsoon	Post-monsoon
2013	2.8%	6.9%
2022	2.1%	6.4%
<b>Total change</b>	0.7%	0.5%

Therefore, humans should be sensitive to it and save it from decay. On the basis of this study, both local people and governments should understand the importance of wetlands and pay attention to its conservation and management. This conclusion will prove helpful to the local administration, government and private organizations in making plans related to wetlands.

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