Summer Fellowship Report

On

QGIS

Submitted by

Ambadas B. Maske

Under the guidance of

Prof. Pennan Chinnasamy

CTARA Department

IIT Bombay

July 6, 2019

Acknowledgement:

Getting an Internship opportunity in IIT Bombay was great experience for me. First, I would like to give very much thanks to IIT Bombay for starting such an innovative initiative for the promotion of Free and Open Source Software (FOSS). I would like to thank Prof. Kannan Moudgalya who is the PI of FOSSEE Project for his Support and encouragement during the internship.

I am very much thankful to the FOSSEE team for creating such a great platform for the college students, where they can learn, examine and make use of the knowledge they have for the betterment of society.

Prof. Pennan Chinnasamy is my Guide / Mentor during the internship duration. Sir has helped a lot about the technical thing related to QGIS. Also, at various stages of internship Sir, taught me the importance being professional and doing things with the self - confidence. So, I am really grateful for understanding my problems and their timely guidance.

Dr. Snehaltha Kaliappan is my mentor for spoken tutorial project. Ma'am, not only taught me about the Spoken tutorial project, but also helped me for getting positiveness from all situations. I would really like to say thank you for being with us at every problematic stage in internship.

I must say, thanks a million to all my colleagues/ of the FOSSEE Summer Fellowship 2019 for their support and help. I would like to thank all the people who directly/indirectly helped me during the internship.

At last, the internship experience in IIT Bombay, was a great experience for me. I got to learn so much about the free and open software. Also spoken tutorial project realized me to give something for the welfare of society.

With Regards,

Ambadas B. Maske

College of Engineering Pune

Table of Contents:

List of Figures:

List of Tables:

1 About QGIS.

1.1 Introduction:

QGIS (previously known as **Quantum GIS**) is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data.

QGIS supports both raster and vector layers; vector data is stored as either point, line, or polygon features. Multiple formats of raster images are supported, and the software can geo-reference images..

Figure 1 QGIS Logo

1.2 Applications of QGIS:

Since QGIS is free and open source software, it is very much useful in various applications. Some of the applications are as follows:

1. Forestry
2. Mining
3. Oil & Natural gas exploration.
4. Remote Sensing
5. Administration

1.3 Comparison between QGIS and other Commercial Software:

For geo-processing and features ArcGIS needs separate license while QGIS is free software for all. QGIS uses the GDAL/OGR library to read and write GIS data formats. Over 70 vector formats re supported. While in ArcGIS it supports only limited number of formats. Various features are easily accessible in QGIS (i.e. more user friendly) than the ArcGIS

1.4 Future Scope for QGIS:

QGIS allows user to write, modify source code. This make the applications of QGIS in wide spread. QGIS integrates with other open-source GIS packages, including Post GIS, GRASS GIS, and Map Server. Plugins written in Python or C++ extend QGIS's capabilities..

1.5 QGIS features used for current Study:

The current study has multiple analysis using QGIS features, some of the QGIS features used for study are listed as below:

i. Vector Analysis
ii. Raster Analysis
iii. Map composer
iv. SAGA GIS

2 Analyzing Change in Vegetation Cover and Soil moisture in Dahod, Gujarat

2.1 Problem Statement:

The Dahod district in Gujarat State is becoming popular in the agriculture crop quality. The district has 157 check dams constructed on various water bodies. The district is draught prone and tribal. The study helps to understand the check dam's contribution for boost in agriculture productivity in the Dahod district by using various remote sensing and GIS Applications i.e. Spatial Indices.

2.2 Introduction: Study Area

Dahod, District situated in the eastern part of main peninsular shield of Indian subcontinent in the Gujarat state. It is bounded by Madhya Pradesh state, Rajasthan state and other districts of Gujarat viz. Vadodara & Godhra. Dahod district has a geographical area of about 3655 sq.km.

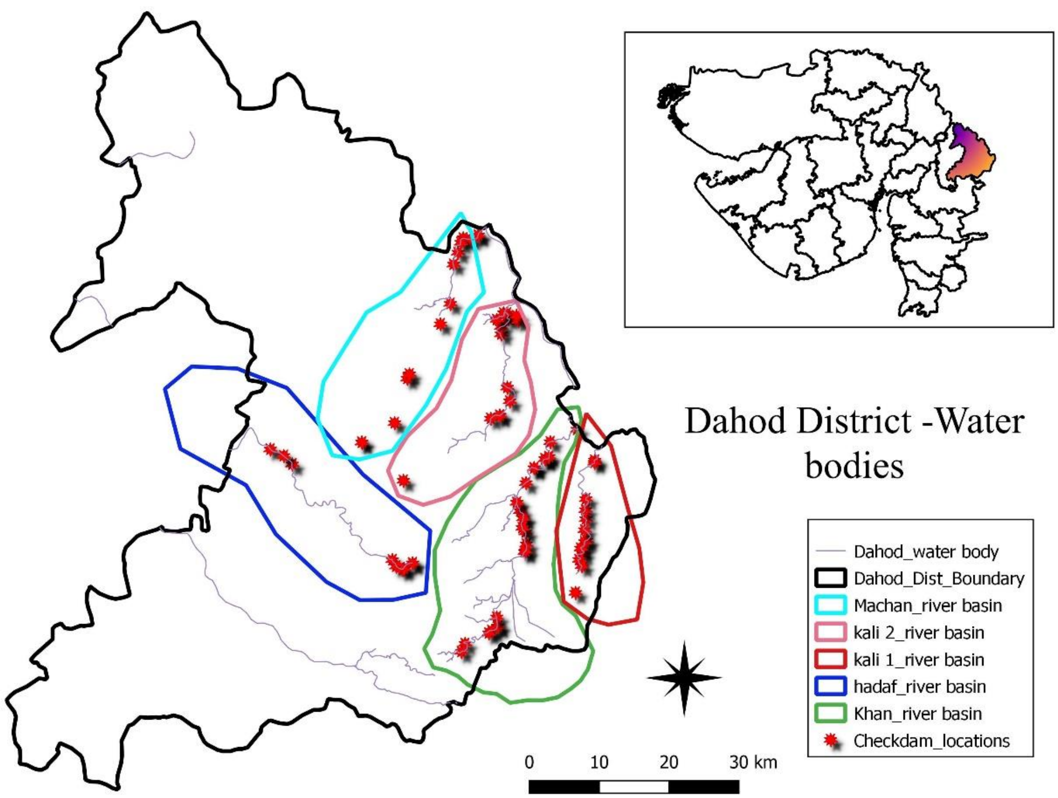


Figure 2 Dahod District A Map

The area forms part of Mahi basin. Dahod district is tribal and drought prone. The district is drained by main tributaries of Mahi River on left bank. They are Panam, Hadap, Goma, Kharod, Anas, Kali, Khan, Machchhan and Chibota (CGWB, 2014)

The people of this district are mainly dependent on rain water for cultivation as the irrigation potential developed so far is very limited. The district has subtropical climates. Since the agriculture which depends on rains water gets drought in alternate year. Thus, the crop suffers to great extent and people move for livelihood from one place to another in search of work. (MSME, 2011)

2.3 Introduction: check dam

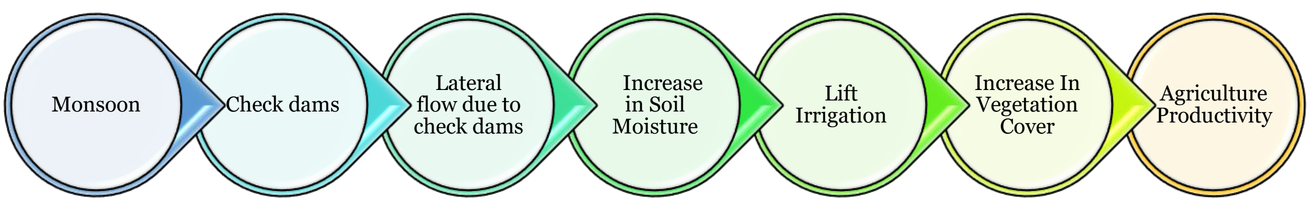
A **check dam** is a small, sometimes temporary, dam constructed across a swale, drainage ditch, or waterway to counteract erosion by reducing water flow velocity.

Dahod District has total 157 Check dams constructed from 1990 to 2019 by the N.M. Sadguru foundation NGO. The NGO works on maintaining the check dams and creating a positive hope for farmers in the draught affected areas.

Figure 3 Check dam in Dahod District

2.4 Present Scenario Due to check dams

As seen in fig.3 the land which needs to be cultivated is at certain height from the water body, so along with construction of check dam there is also the lift irrigation pump installed for farmers. At Present after the construction of check dams the farmers use the Lift Irrigation System for pumping the water from water body.



2.5 Aim:

To analyze the change in vegetation cover and soil moisture from 1989 to 2018 using remote sensing techniques and QGIS

2.6 Objectives:

1. To find the change in vegetation cover i.e. from Normalized difference vegetation Index (NDVI) from 1990-2018.
2. To Find Change in Water content (Moisture) in Soil from Normalized difference water index (NDWI) from 1990-2018.

2.7 Data Used:

Data	Source
Landsat satellite Images from 1990 -2018.	USGS – Earth Explorer website
Rainfall data from 1990-2018.	Secondary data from Sadguru Foundation.
Check dams Locations and related data	Secondary data from Sadguru Foundation.
Basin boundaries	Secondary data from Sadguru Foundation.

Table 1: Data Used

2.8 Spatial Indices:

2.8.1 Normalized difference vegetation Index (NDVI):

Normalized Difference Vegetation Index (NDVI) is developed by Rousse et al. (1973) to estimate the amount of biomass. It takes into consideration the red (RED) and the near infrared bands (NIR). (BALÁZS, 2016) NDVI can be calculated as,

$$\frac{\textbf{NIR - Red}}{\textbf{NIR + Red}}$$

Its Value ranges from -1 to +1, where

1) 0.5- 1 = dense vegetation
2) 0.3 to 0.5 = Sparse Vegetation,
3) 0.1 to 0.3 = Soil or rock structure.
4) 0 or negative = no vegetation or water bodies.

2.8.2 Normalized Difference Water Index (NDWI):

NDWI is developed by Mc Feeters (1996) to enhance the water related features of the landscapes. It uses the green (GREEN) and the short-wave infrared (SWIR) bands. (BALÁZS, 2016) . NDWI can be calculated as,

$$\frac{\textbf{NIR – SWIR}}{\textbf{NIR + SWIR}}$$

Its Value ranges from -1 to +1 where,

1) -1 to 0 = Bright surface with no vegetation or water content
2) 0 to +1 = represent water content

2.9 Detailed Methodology

Figure 4 Detailed Methodology

2.10 Graphs and Charts Showing Various Trends:

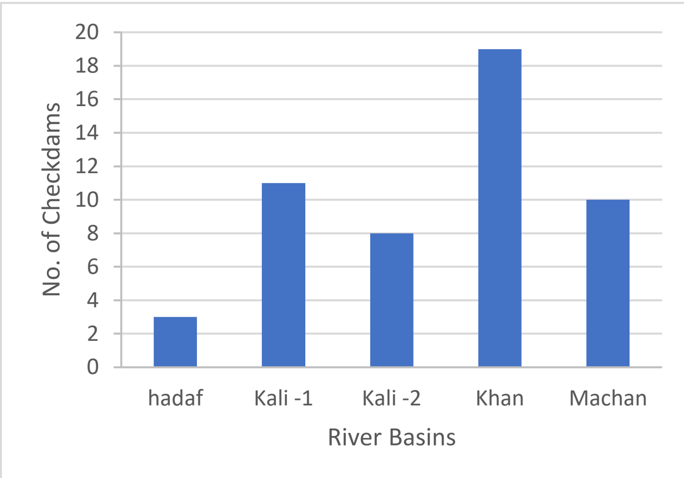


Figure 5 Check dam Constructed - Basin Wise

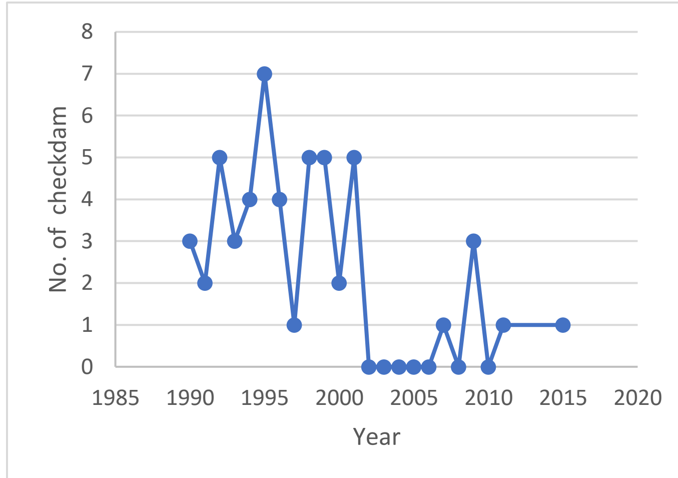


Figure 6 Check dam Constructed - Year wise

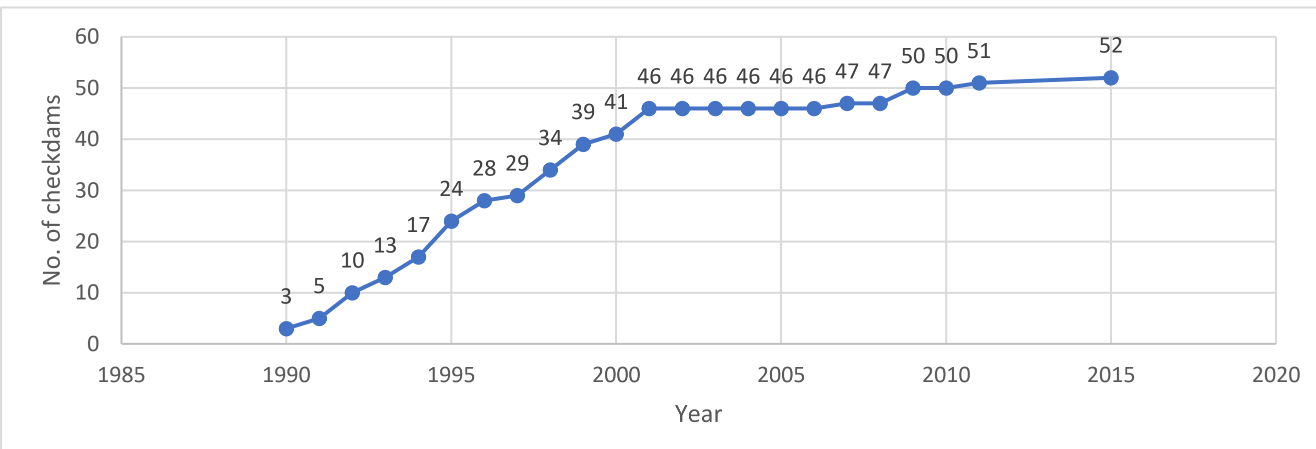


Figure 7 Check dam Constructed - Cumulative

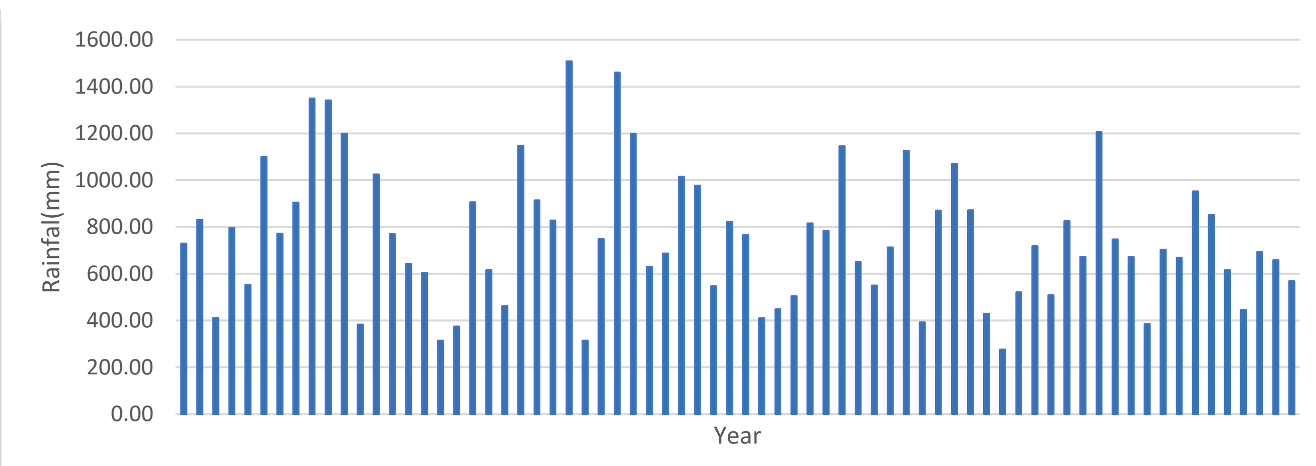


Figure 8 Dahod District Annual Rainfall

2.11 Spatial Indices trends from 1990-2018

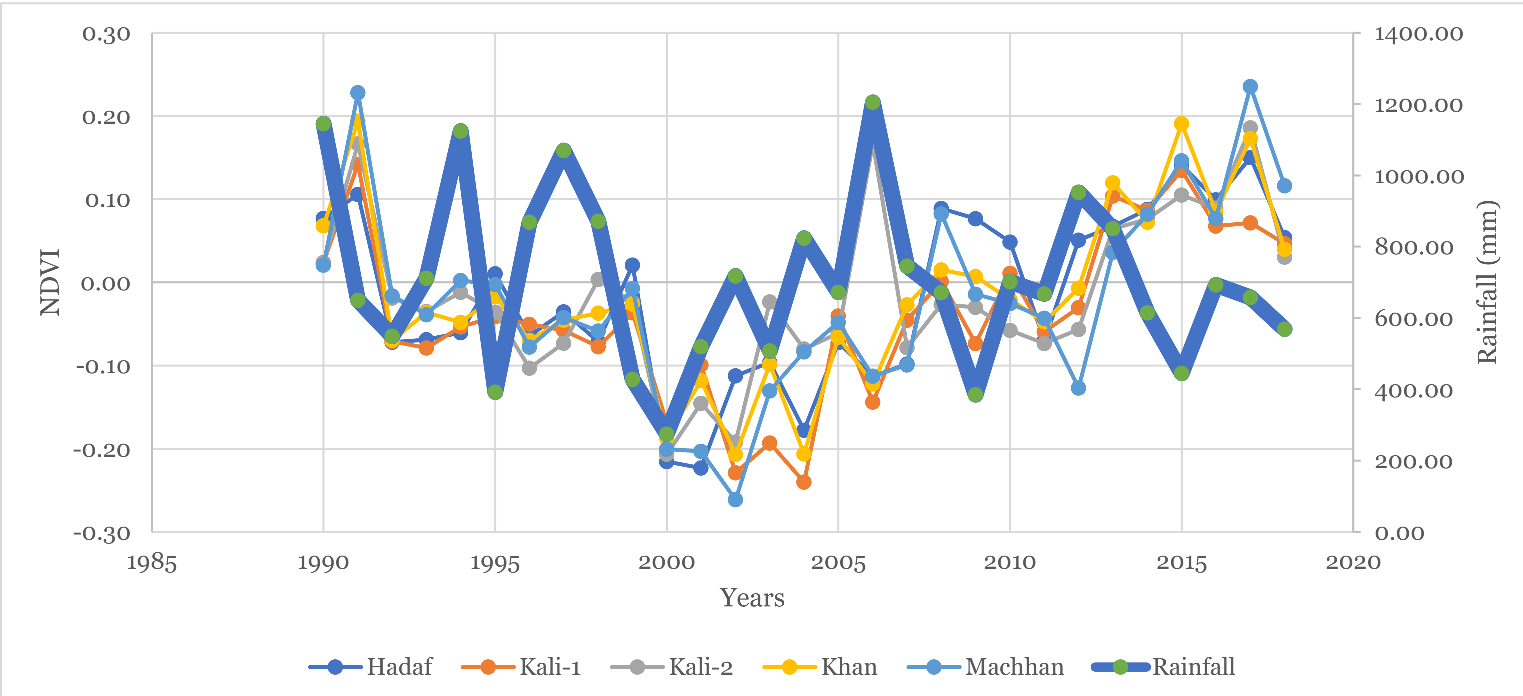


Figure 9 NDVI trends from 1990-2018.

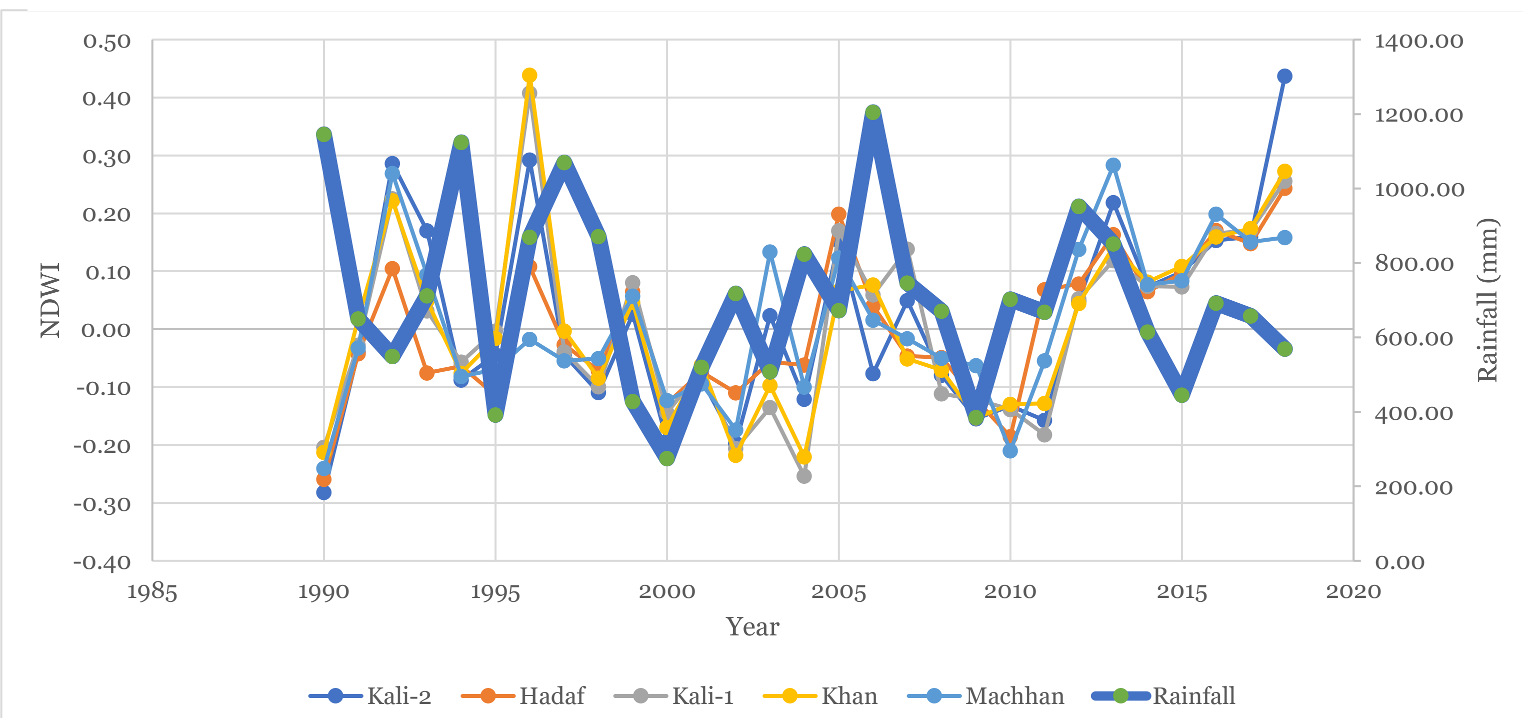


Figure 10 NDWI trends from 1990-2018.

2.12 Basin wise Spatial Trend Analysis

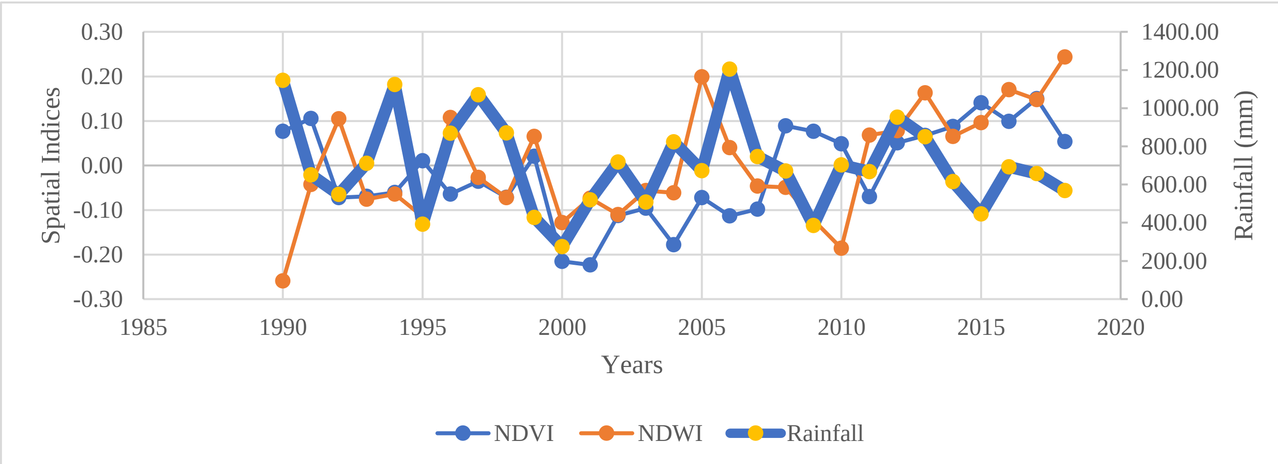


Figure 11 Hadaf Basin Trends

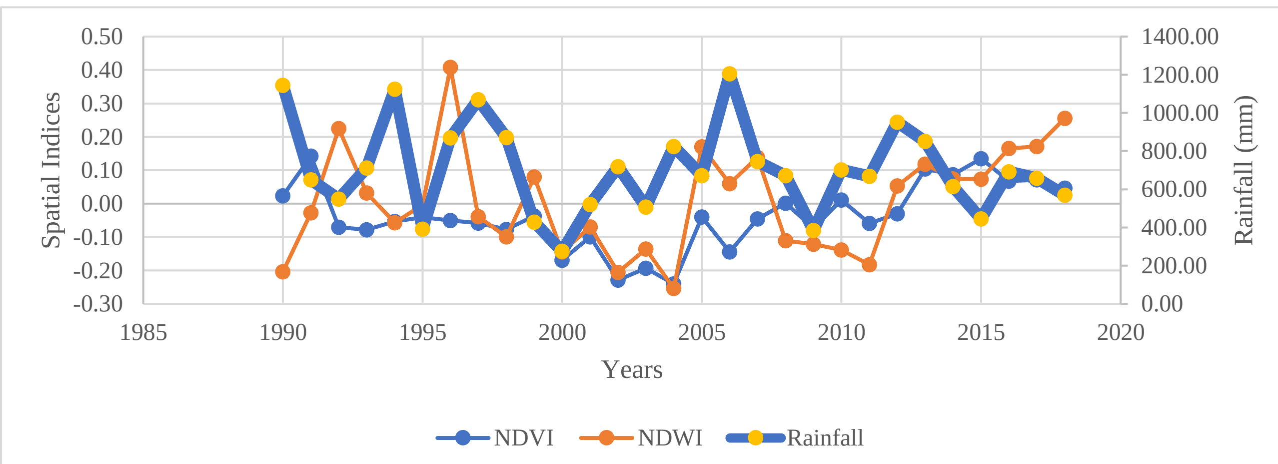


Figure 13 Kali-1 Basin Trends

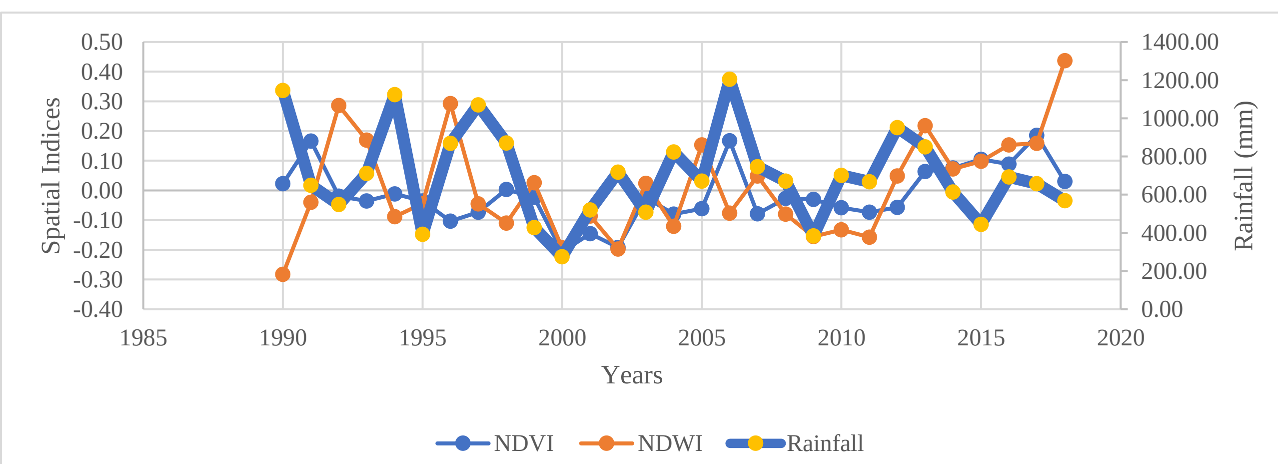


Figure 12 Kali-2 Basin Trends

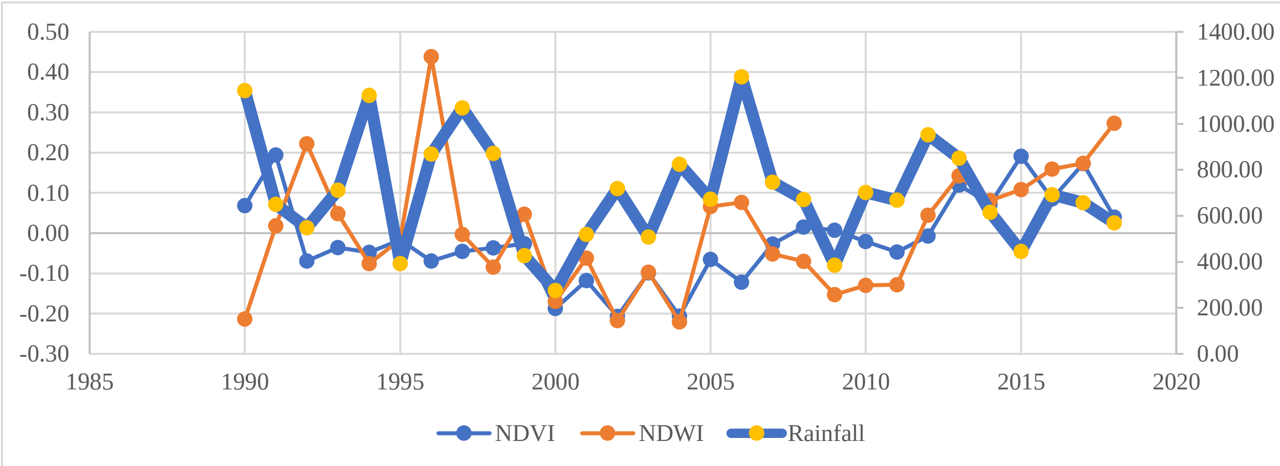


Figure 15 Khan Basin Trends

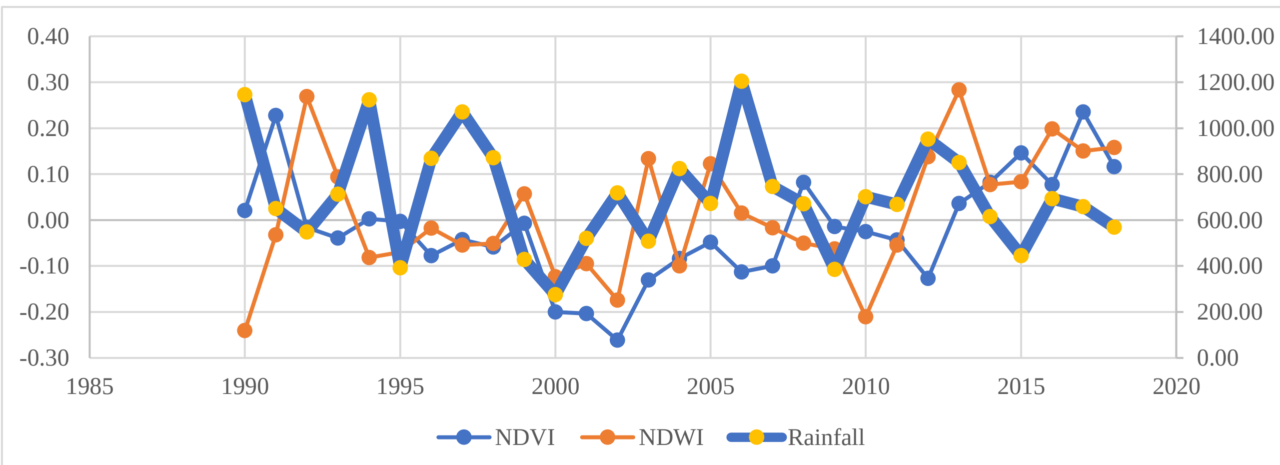


Figure 14 Khan Basin Trends

2.13 Khan River Basin Spatial Analysis:

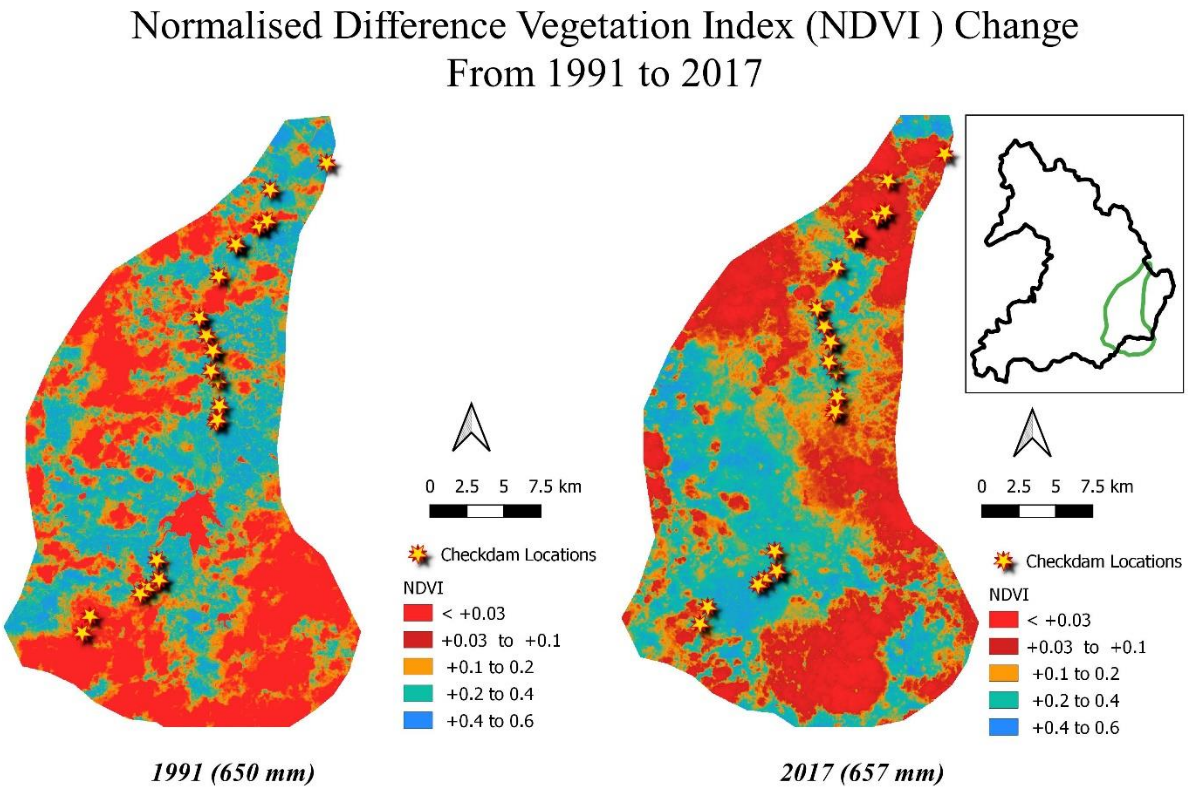


Figure 16 NDVI Change From 1990 -2018

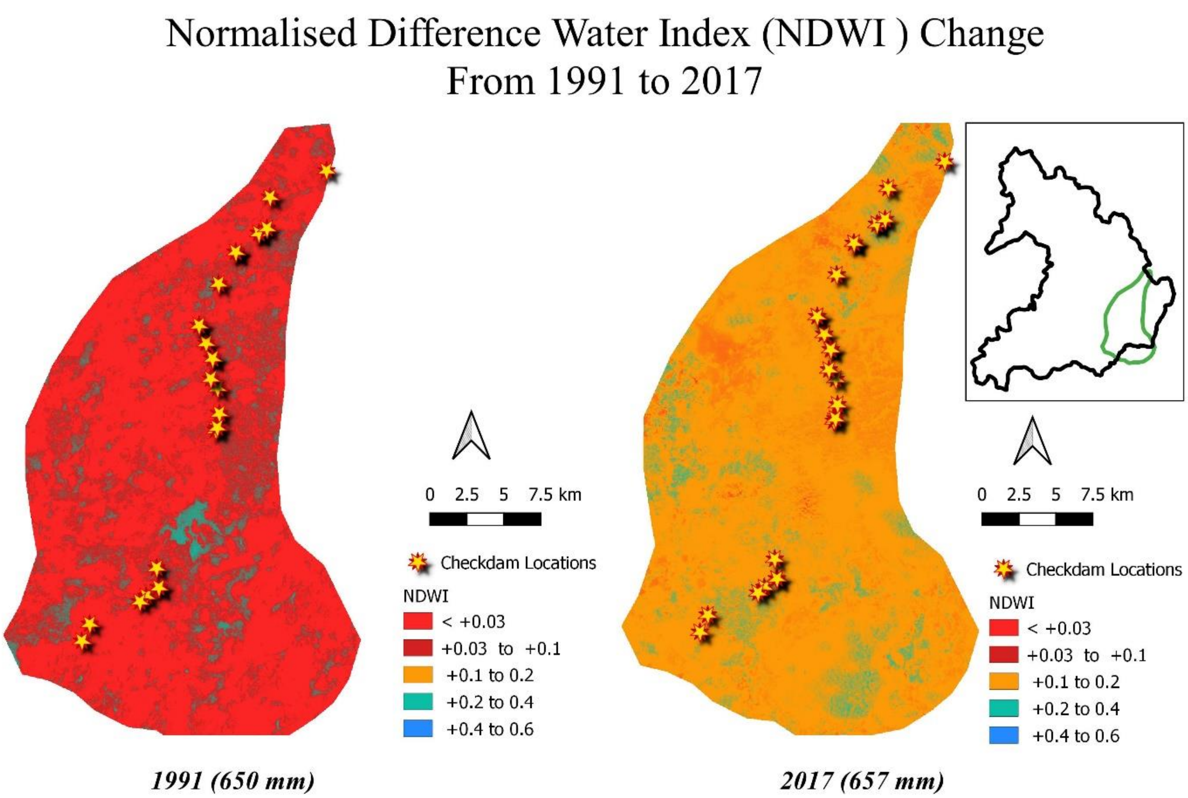


Figure 17 NDWI Change From 1990-2017

2.14 Average Values for Spatial Indices for Dahod district

Years	Rainfall (mm)	Average NDVI	Average NDWI
1989	783	0.11	-0.07
1990	1145	0.04	-0.24
1991	650	0.17	-0.02
1992	549	-0.05	0.22
1993	712	-0.05	0.05
1994	1124	-0.03	-0.07
1995	392	-0.02	-0.05
1996	869	-0.07	0.25
1997	1070	-0.05	-0.03
1998	871	-0.05	-0.08
1999	428	-0.01	0.06
2000	275	-0.20	-0.15
2001	520	-0.16	-0.08
2002	718	-0.20	-0.18
2003	508	-0.11	-0.03
2004	824	-0.16	-0.15
2005	672	-0.06	0.14
2006	1205	-0.06	0.02
2007	746	-0.07	0.01
2008	671	0.03	-0.07
2009	385	-0.01	-0.12
2010	702	-0.01	-0.16
2011	668	-0.06	-0.09
2012	952	-0.03	0.07
2013	851	0.08	0.19
2014	615	0.08	0.07
2015	446	0.14	0.09
2016	693	0.08	0.17
2017	658	0.16	0.16
2018	569	0.06	0.27

Table 2 Average Values of Spatial Indices for Dahod District.

2.15 Conclusion and Discussions:

i. The India has so much other drought prone areas, we can go for check dam techniques. Since check dams serve as a very ecofriendly, beneficial water harvesting medium. (GOVINDASAMY AGORAMOORTHY, 2008)
ii. As seen in fig 15. due to construction of check dams there is increased in NDVI values from negative to positive (from red to blue color) which shows increase in vegetation cover even though the annual rainfall is almost same for 1991 and 2017.
iii. Also, from fig 16. it is observed that NDWI values shifted drastically from small negatives to positive values (from red to yellow color) which show increase in soil moisture.
iv. The trend graphs show how the vegetation cover and soil moisture has increased even though the district received less rainfall.
v. This increase in soil moisture and vegetation cover due to construction of check dams has improved the agriculture activity in the area.
vi. Since due to non-availability of water the land has been not cultivated for several years and now due to water condition improvement the productivity of land is strong.
vii. The overall food quality and crop quality on this land is become more nutritious and has very much market demand.

3 Calculating rate of deforestation in North Eastern States

3.1 Problem Statement:

North Eastern State are considered as one of the global biodiversity hotspots in the India. The deforestation or reforestation can be observed prominently by using various remote sensing techniques Land use Land Cover Change (LULC) is very much useful to detect the various changes in the forest areas. (Nikhil Lele, P.K. Joshi, 2000)

The Study helps to understand the rate at which the deforestation or reforestation happens in the North Eastern States. The purpose of the study is to use GIS and remote sensing for the forest cover trend analysis.

3.2 Introduction:

India is blessed with various diverse forest types ranging from tropical west evergreen forests in the northeast and the southwest, to tropical dry thorn forests in central and western India. (Shodhganga, 2013) .

North East India (Officially North Eastern Region, NER) is the easternmost region of India is one of the most biodiversity hotspot. It comprises of eight states – Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura. North Eastern Region (NER) Contribute to about 8.3% of land area. Out of total geographical area NER itself has almost 80% of total forest cover area.

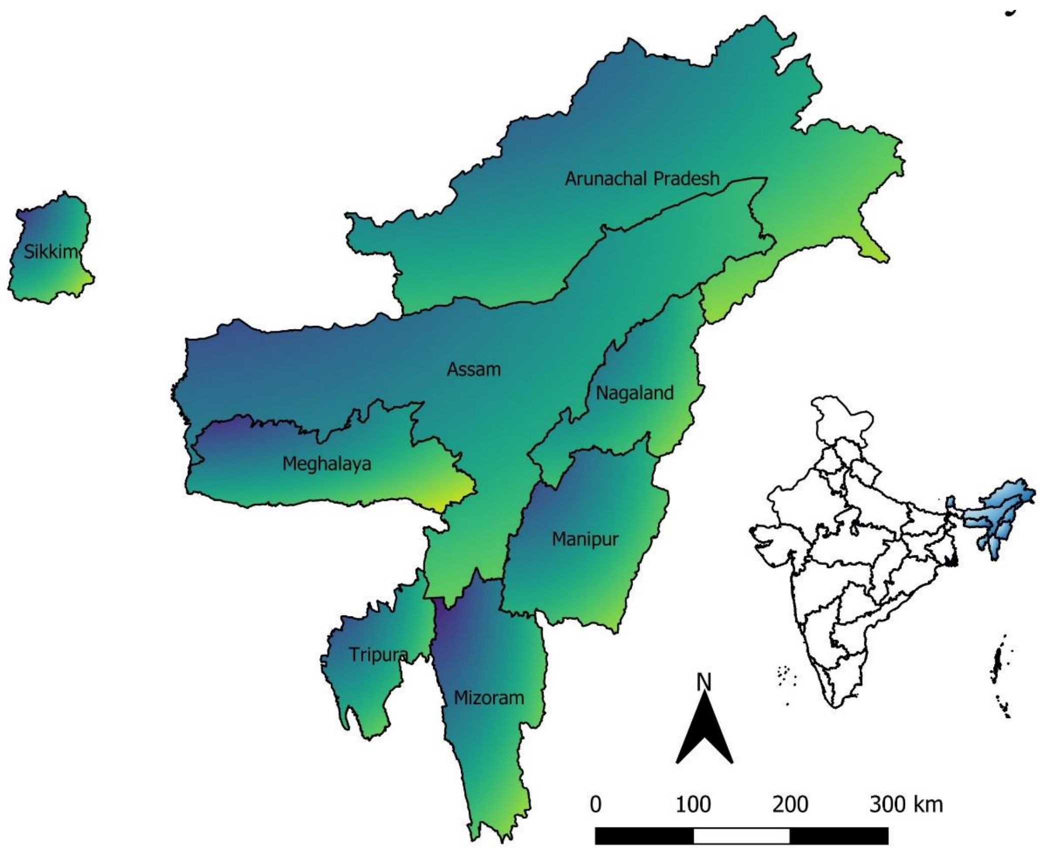


Figure 19 North Eastern Region (NER) Administrative Boundary

3.3 Deforestation:

Deforestation is the conversion of forested areas to non-forest land use such as arable land, urban use, logged area or wasteland. According to Food and Agriculture Organization (FAO), deforestation is the conversion of forest to another land use or the long-term reduction of tree canopy cover below the 10%. (FAO, 2007)

Figure 20 Deforestation scenario- general

Forest degradation is a process leading to a 'temporary or permanent deterioration in the density or structure of vegetation cover or its species composition'. (FAO, 2007)

3.4 Aim:

To find rate of Deforestation in the North Eastern States from 1990-2019 using remote sensing techniques and QGIS.

3.5 Objectives:

1. To Find the Forest cover Classification for North Eastern states for the year 1990,2000,2010,2019.
2. To Find the Normalized Difference Vegetation Index (NDVI)Change for North Eastern States.
3. To Find the Normalized Difference water Index (NDWI) Change for North Eastern States.
4. To find overall rate of Deforestation in the North Eastern States.

3.6 Data used:

Data	Source
Various Shapefiles	Diva - GIS (DIVA GIS, 2019)
Landsat satellite Images from 1990 -2019.	USGS – Earth Explorer website. (USGS, 2019)
Forest classification Maps (For Supervised classification)	Forest Survey of India (FSI) Reports.

Table 3 Data Used for NER

3.7 Brief Methodology:

1. The dataset for all year is chosen such that it will have minimum atmospheric corrections.
2. For calculating the spatial indices all the Red bands, NIR bands, and SWIR bands are mosaiced for all the respected years.
3. For Supervised classification, signatures were created from forest classification report by Forest Survey of India (FSI) using Semi-Automatic Classification Plugin (SCP) in QGIS.

3.8 Detailed Methodology:

Figure 21 Detailed Methodology

3.9 Spatial Indices:

3.9.1 Normalized Difference Vegetation Index (NDVI):

NDVI Uses the Red and Near Infra- Red Bands and highlights the vegetation of the area. (For detailed information about NDVI see section 2.7.1)

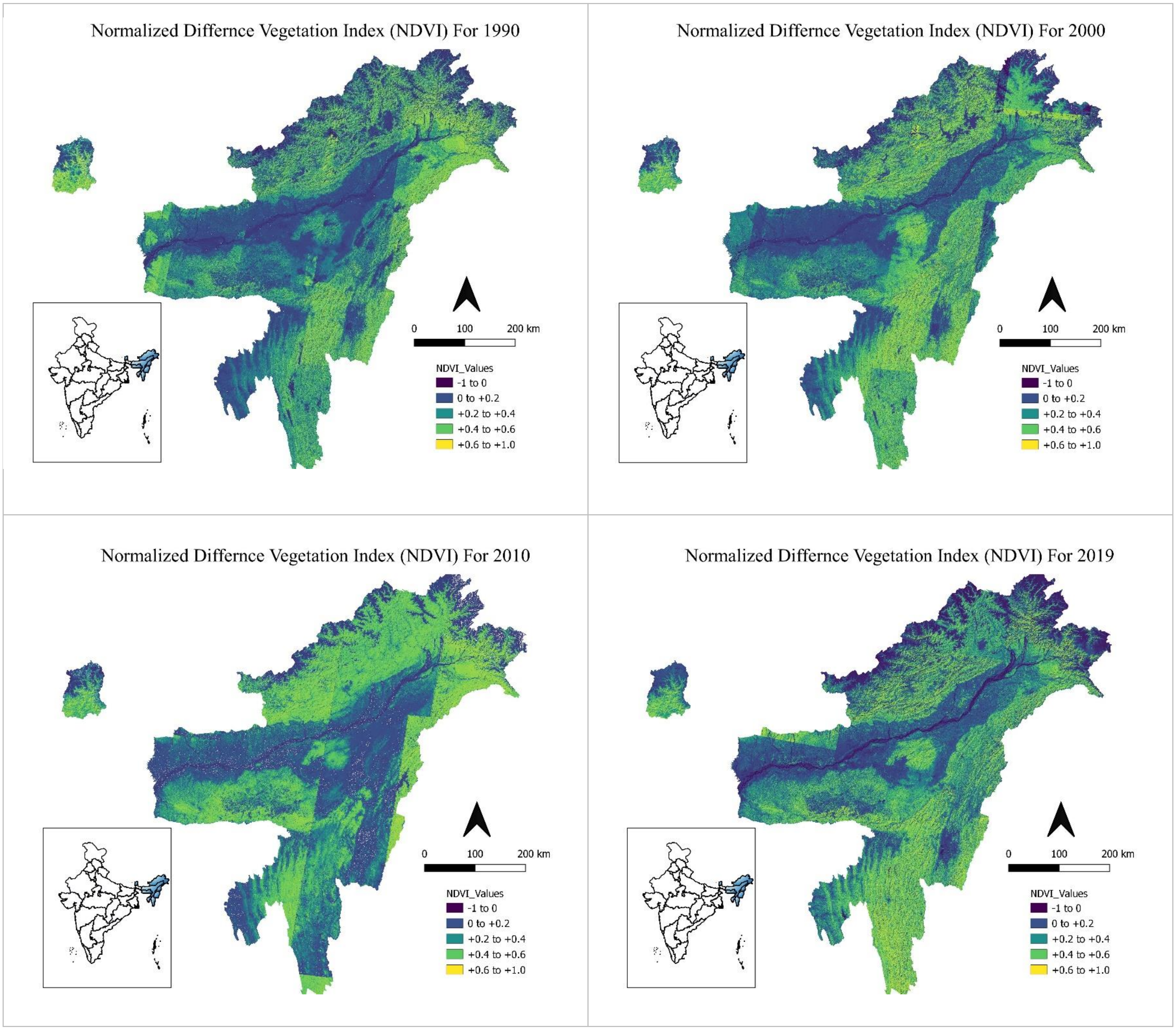


Figure 22 NDVI Trends for North Eastern states

3.9.2Normalized Difference Water Index (NDWI):

NDWI Uses the Near Infra - Red (NIR) Band and Short wave Infra - Red (SWIR) Band to highlight moisture content. (For detailed information about NDWI see section 2.7.2)

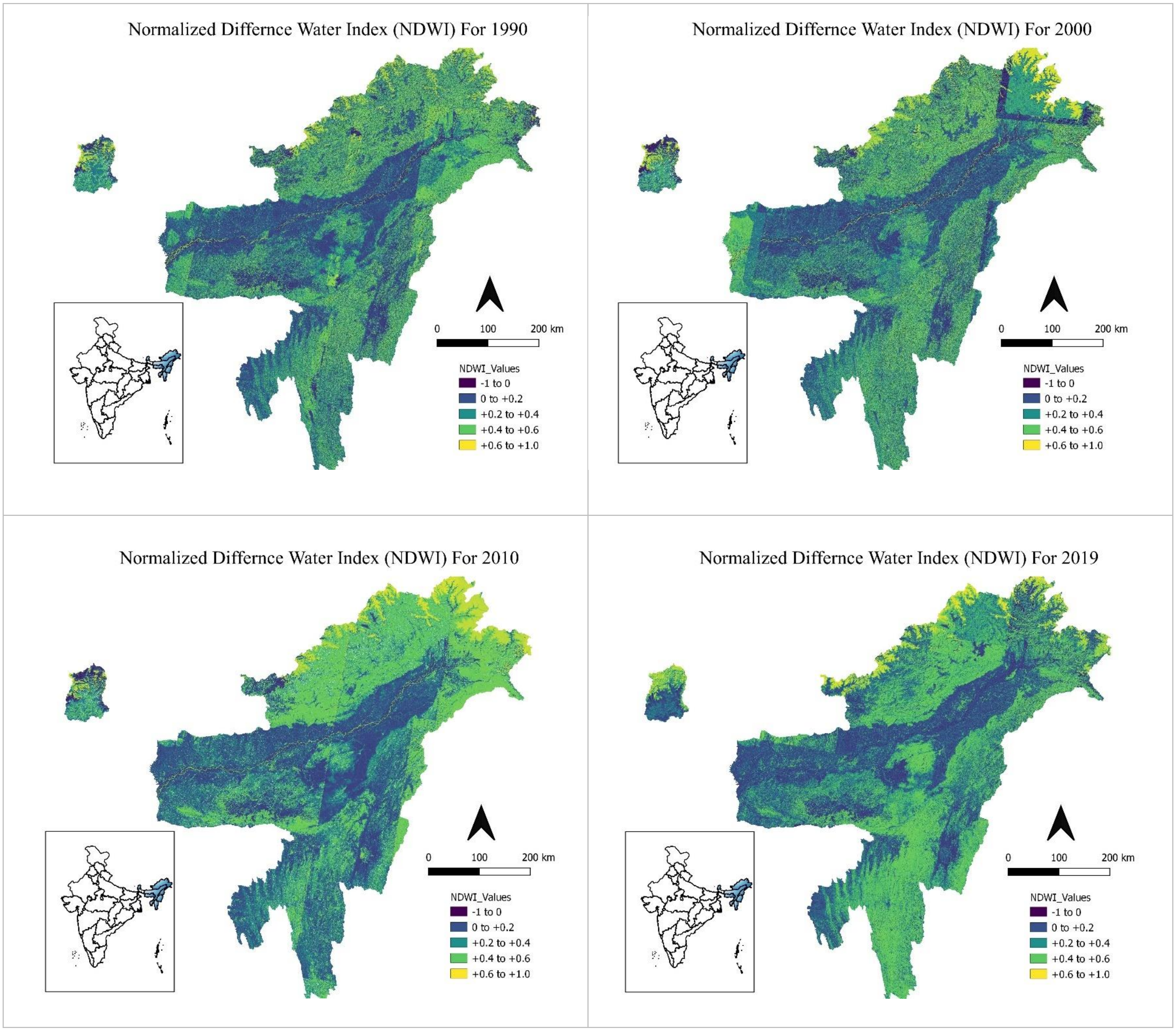


Figure 23 NDWI Trends for North Eastern states

3.10 Forest Cover Classification:

Using Iso-cluster unsupervised classification method, the mosaiced bands were classified into four main classes i.e. Dense forest, Open Forest, Non- Forest, and Waterbody/others.

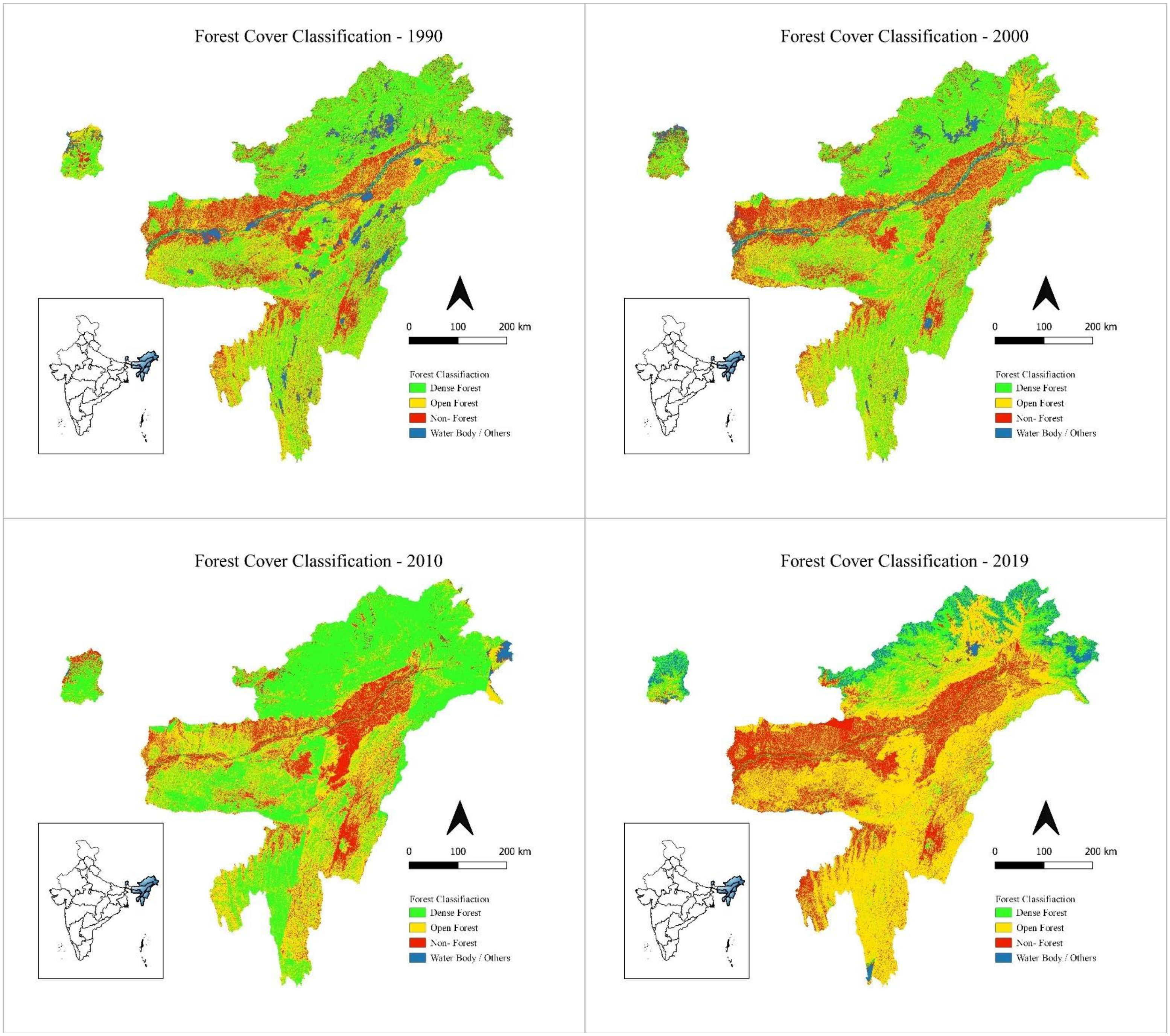


Figure 24 Forest Cover Change Trends in North Eastern States

3.11 Comparison between Classifications:

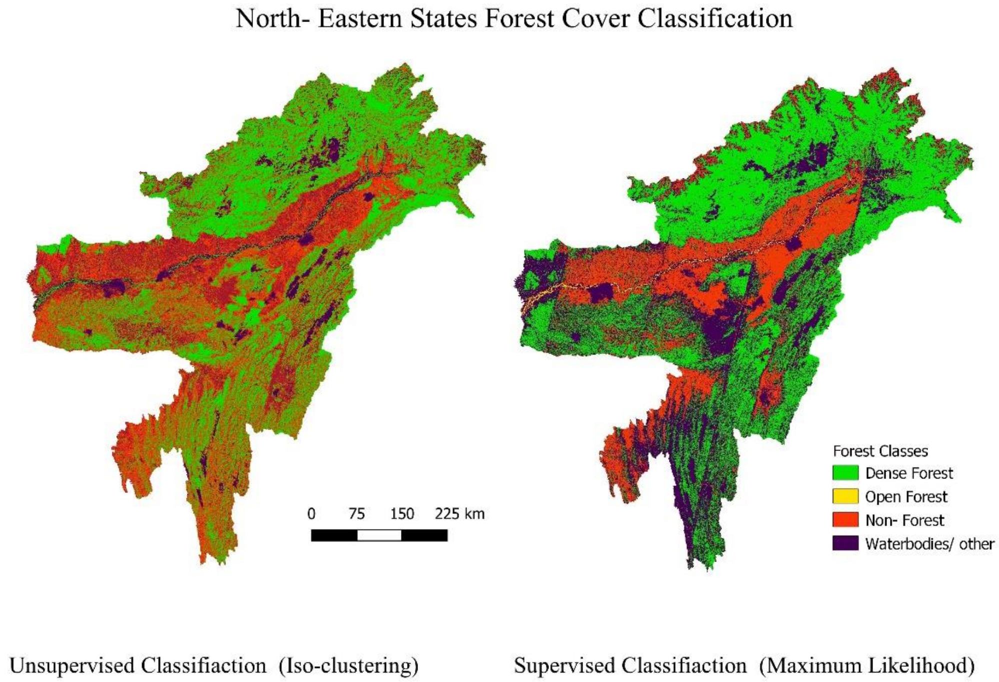


Figure 25 Accuracy Comparison between Two Classification

3.12 Forest Cover Analysis Tables:

Note: ***GA= Geographical Area*** (All Areas are **in Sq.Km**)

Year	1990		2000		2010		2019	
State\ Area	**Forest Area**	**% Of GA**	**Forest Area**	**% Of GA**	**Forest Area**	**% Of GA**	**Forest Area**	**% Of GA**
Arunachal Pradesh	52623	64	50715	62	67417	82	30712	37
Assam	16703	21	17513	22	21520	27	2256	3
Manipur	9586	43	10886	49	5609	25	765	3
Meghalaya	8359	37	7405	33	12656	56	340	2
Mizoram	8076	38	9536	45	9757	46	785	4
Nagaland	7390	45	8063	49	4629	28	963	6
Sikkim	3202	45	3152	44	3311	47	3837	54
Tripura	2216	21	2956	28	4536	43	84	1
North East Region	**108155**	**30**	**110225**	**35**	**129436**	**35**	**39740**	**14**

Table 4 Dense Forest Cover Change Analysis in NER region

3.12.1 Forest Cover Analysis Tables (Continued):

Note: ***GA= Geographical Area*** (All Areas are **in Sq. Km**)

Year	1990		2000		2010		2019	
State\ Area	**Forest Area**	**% Of GA**	**Forest Area**	**% Of GA**	**Forest Area**	**% Of GA**	**Forest Area**	**% Of GA**
Arunachal Pradesh	18467	23	22177	27	10588	13	36530	45
Assam	31295	40	29356	37	31375	40	38037	49
Manipur	8362	37	8175	37	11527	52	17744	80
Meghalaya	10213	46	10545	47	8139	36	16164	72
Mizoram	10272	49	10132	48	9720	46	18799	89
Nagaland	5496	33	6247	38	9068	55	13635	82
Sikkim	2396	34	1737	24	2385	34	1147	16
Tripura	6518	62	6214	60	5405	52	7485	72
North East Region	**93021**	**53**	**94584**	**49**	**88207**	**55**	**149542**	**66**

Table 5 Open Forest Cover Change Analysis in NER region

Year	1990		2000		2010		2019	
State\ Area	**Forest Area**	**% Of GA**	**Forest Area**	**% Of GA**	**Forest Area**	**% Of GA**	**Forest Area**	**% Of GA**
Arunachal Pradesh	71090	87	72892	89	78005	95	67242	82
Assam	47999	61	46869	60	52895	67	40293	51
Manipur	17948	80	19061	85	17136	77	18510	83
Meghalaya	18572	83	17950	80	20795	93	16504	74
Mizoram	18348	87	19668	93	19477	92	19584	93
Nagaland	12886	78	14311	86	13697	83	14597	88
Sikkim	5599	79	4889	69	5696	80	4984	70
Tripura	8734	84	9170	88	9941	95	7569	73
North East Region	**201177**	**83**	**204809**	**79**	**217643**	**84**	**189282**	**73**

Table 6 Total Forest Cover Change Analysis in NER region

3.13 Deforestation Analysis (Interval- Wise):

3.13.1 Interval 1990-2000:

In 1990, the Dense forest cover is highest in Arunachal Pradesh (62%) and lowest in Assam, and Tripura (21%) while in 2000, The Assam (22%) and Tripura (28%) shown in increase and Arunachal Pradesh slightly decrease (62%) in Dense Forest. Overall Dense Forest Cover is increased from 30% to 35%.

Arunachal Pradesh (23%) has the lowest amount of open forest in 1900 which is got increased in 2000 (27%). While Tripura (62%) has the highest amount of open forest which got decreased (60%). Over all Open Forest Cover Decreased from 53% to 49%.

Except Assam, Meghalaya, and Sikkim all other state shows the great increase in forest cover of area. Nagaland shows the highest increase while Sikkim shows the highest decrease in forest cover. Overall scenario is decrease in forest cover of area i.e. from 83% to 79%.

3.13.2 Interval 2000-2010:

In 2000, the dense forest cover is highest in Arunachal Pradesh (62%) and lowest in Assam (22%), while in 2010, The Assam (27%) and Arunachal Pradesh (82%) both show increase in Dense Forest. Overall Dense Forest Cover is remained same. (35%).

Sikkim (24%) has the lowest amount of open forest in 2000 which is got increased in 2010 (34%). While Tripura (60%) has the highest amount of open forest which got decreased (52%). Over all Open Forest Cover Increased from 49% to 55%.

Except Manipur, Mizoram and Nagaland all other state shows the increase in forest cover of area. Meghalaya shows the highest increase while Manipur shows the highest decrease in forest cover. Overall scenario is increase in forest cover of area i.e. from 79% to 84%.

3.13.3 Interval 2010-2019:

In 2010, the dense forest cover is highest in Arunachal Pradesh (82%) and lowest in Manipur (25%), while in 2019, The Arunachal Pradesh (82%) and Manipur (3%) both show decrease in Dense Forest. Overall Dense Forest Cover is decreased from.35% to 14%.

Arunachal Pradesh (13%) has the lowest amount of open forest in 2010 which is got increased in 2010 (45%). While Nagaland (55%) has the highest amount of open forest which got increased (82%). Over all Open Forest Cover Increased from 55% to 66%.

Except Manipur, Mizoram and Nagaland all other state shows the decrease in forest cover of area. Manipur shows the highest increase while Tripura shows the highest decrease in forest cover. Overall scenario is Decrease in forest cover of area i.e. from 84% to 73%.

3.13.4 Interval 1990-2019:

In 1990, the dense forest cover is highest in Arunachal Pradesh (62%) and lowest in Assam, (22%) while in 2019, Assam (3%), Tripura (1%) and Arunachal Pradesh (37%) shows great decreased in Dense Forest. Overall Dense Forest Cover is decreased from 30% to 14%.

Arunachal Pradesh (23%) has the lowest amount of open forest in 1900 which is got increased in 2019 (45%). While Tripura (62%) has the highest amount of open forest which got increased (72%). Over all Open Forest Cover increased from 53% to 66%.

Except Manipur, Mizoram and Nagaland all other state shows the decrease in forest cover of area. Nagaland shows the highest increase while Assam shows the highest decrease in forest cover. Overall scenario is Decrease in forest cover of area i.e. from 83% to 73%.

3.14 Rate of Deforestation:

Rate of Deforestation is calculated in North Eastern region Using following, (Nikhil Lele, P.K. Joshi, 2000) .

$$\textbf{Deforestation Rate} = \frac{(\log Ft2 - \log Ft1) \times 100}{t2 - t1}$$

Where,

F indicates the area under forest in square kilometers & **'t1'** and **'t2'** indicates time-1 and time-2 Deforestation rate is in **Sq. Km per year**

The rate has been calculated for each interval and for each state as shown,

States\ Interval	1990-2000	2000-2010	2010-2019	1990-2019
Arunachal Pradesh	0.109	0.294	-0.645	-0.083
Assam	-0.103	0.525	-1.182	-0.262
Manipur	0.261	-0.462	0.335	0.046
Meghalaya	-0.148	0.639	-1.004	-0.177
Mizoram	0.302	-0.042	0.024	0.098
Nagaland	0.455	-0.190	0.277	0.187
Sikkim	-0.589	0.664	-0.580	-0.174
Tripura	0.212	0.351	-1.184	-0.214
North East Region	0.078	0.264	-0.606	-0.091

Table 7 Rate of Deforestation in (Sq.km /year)) in NER region

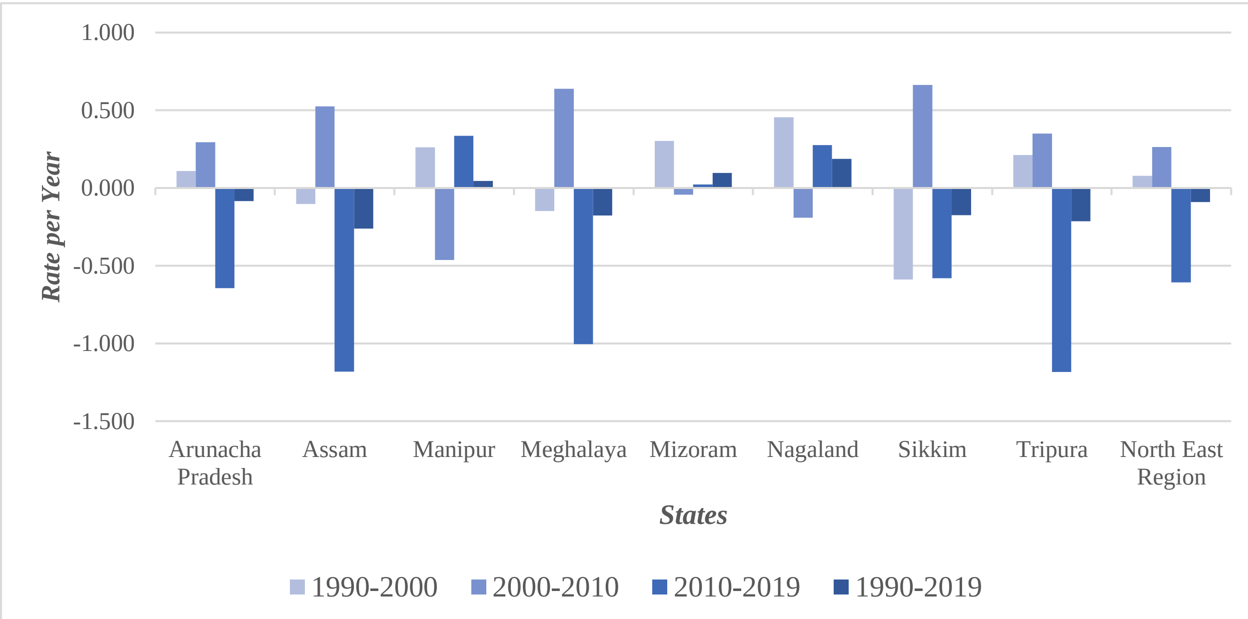


Figure 26 Rate of Deforestation trends from 1990-2019 in NER region

3.15 Conclusion and Discussion:

i. From the Spatial Indices trends i.e. NDVI and NDWI it can observe as the trends of increase / decrease in values of indices is directly corelated with forest cover changes.
ii. Due to Shifting cultivation, population encroachment and other reasons, North Eastern States are facing the deforestation issue. (Dutta Papumoni ,Das Sanjay, 2014)
iii. From the LULC maps it can be observed that there is increase in non- forest area in North Eastern states.
iv. The North eastern states experience very high rate of deforestation (0.264) during 2000-2010 and from 1990-2019 the rate is slightly decreased i.e. (-0.091).
v. Sudden increase in open forest in 2019, is due to conversion of dense forest to open forest.
vi. Except in 2000-2010, Nagaland faced the highest rate of deforestation in all interval i.e. 1990-2000, 2010-2019, & 1990-2019.
vii. Sikkim, shows the least rate of deforestation in 1990-2000 & in 2010-2019.
viii. From 2010-2019, the forestation conditions become very much poor as the forestation is reduced over this period.

4 Spoken Tutorial Project:

4.1 Introduction

This project is part of Free FOSSEE. The Spoken Tutorial project is the project started for making the spoken tutorial on Free and Open Source Software (FOSS) in various Indian languages for all the learners to learn in their vernacular language. (Spoken Tutorial Project, FOSSEE, 2019)

Figure 27 Spoken Tutorial Logo

The Spoken Tutorial team prepares the lecture series videos in all Indian languages. The spoken tutorials are made by various experts/professionals of that field. The tutorials are made from various levels of expertise i.e. beginners' level, Intermediate level, Advanced level. (Spoken Tutorial Project, FOSSEE, 2019)

4.2 Project Description:

The project aims to involve various levels professionals, experts and learners. The project emphasizes on the Side by Side learning method. The project starts with writing the script for the tutorial, this scripts then goes through various quality check and then the final tutorial is recorded using the script. For writing the script, a writer has to give the checklist test which of 5 minutes consisting 10 questions in which various things are examined from the writer. (Spoken Tutorial Project, FOSSEE, 2019)

4.3 Contribution for the Spoken tutorial Project:

The tutorial creation procedure itself is so much innovative and informative. Working for the spoken tutorial project taught us more than anything. I had contributed few scripts for the Quantum GIS (QGIS) FOSS, some of them are as follows:

1. Table Joins and Spatial Joins
2. Interpolation Analysis in QGIS
3. Downloading Data from USGS earth explorer and DIVA GIS
4. Nearest Neighbor Analysis
5. Network Analysis in QGIS.

5 References

BALÁZS, S. S.–Z.–B. (2016). SPECIFIC FEATURES OF NDVI, NDWI AND MNDWI AS REFELECTED IN LAND COVER CATEGORIES. *Landscape & Environment 10 (3-4) 2016. 194-202*, 194-202.

CGWB. (2014). *GROUNDWATER BROCHURE - DAHOD District*. Ahmedabad: Central Ground Water Board West ,Central Region, Ahmedabad Ministry of Water Resources Government of India.

DIVA GIS. (2019). Retrieved from DIVA GIS: https://www.diva-gis.org/gdata

Dutta Papumoni ,Das Sanjay. (2014, October). LOOKING INTO THE TREND OF DEFORESTATION IN NORTH EAST INDIA:A WAY FORWARD. *Internation Jornal Of Social Relevence & Concern*, 20-27. Retrieved from http://ijournals.in/wp-content/uploads/2017/07/5.2902-Sanjay.pdf

FAO. (2007). MANUAL ON DEFORESTATION, DEGRADATION, AND FRAGAMENTATION USING REMOTE SENSING AND GIS. In F. a. Nations, *STRENGTHENING MONITORING, ASSESSMENT AND REPORTING ON SUSTAINABLE FOREST MANAGEMENT IN ASIA*. Rome: FAO. Retrieved from http://www.fao.org/forestry/18222-045c26b711a976bb9d0d17386ee8f0e37.pdf

Foundation, N. W. (2019). *Annual Report 2019*. Dahod: N.M.Sadguru Water and Development Foundation. Retrieved from http://www.nmsadguru.org/pdf/Sadguru-AnnualReport2019.pdf

GOVINDASAMY AGORAMOORTHY, S. C. (2008). The Check-Dam Route to Mitigate India's Water Shortages. *Natural Resources Journal*, J-565. Retrieved from https://digitalrepository.unm.edu/nrj/vol48/iss3/3

MSME. (2011). *Brief Industrial Profile of Dahod District*. Dahod: Ministry of Micro, Small & Medium Enterprises, Government Of India.

Nikhil Lele, P.K. Joshi. (2000). Analyzing deforestation rates, spatial forest cover changes and identifying critical areas of forest cover changes in North-East India during 1972–1999. *Environ Monit Assess*, 159-170. Retrieved from https://link.springer.com/content/pdf/10.1007%2Fs10661-008-0472-6.pdf

Sadguru, F. N. (2018,2019). *Annual Report 2018,2019- N.M. Sadguru Water and Development Foundation*. Dahod: N.M. Sadguru Water and Development Foundation. Retrieved from https://en.wikipedia.org/wiki/Check_dam.

Shodhganga. (2013). Status of Forests in India. In *STATUS OF FORESTS IN INDIA* (pp. 56-84). Retrieved from https://shodhganga.inflibnet.ac.in/bitstream/10603/63583/9/09_chapter%203.pdf

Spoken Tutorial Project, FOSSEE. (2019, June). Retrieved from Spoken Tutorial: https://spoken-tutorial.org/

USGS. (2019). Retrieved from Earth Explorer: https://earthexplorer.usgs.gov/