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LULC Change Detection Studies and Its Possible Linkages with Increased Visitations in the Sagar Island, W.B.

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***Abstract* —** *Sagar Island, located at the confluence of river Hooghly and the Bay of Bengal, is the largest inhabited island in the Indian Sundarbans. This paper presents the time-series analyses of the land use and land cover (LULC) of the island for the four decades of 1986, 1996, 2006 & 2014 by using multi-temporal Landsat satellite data under ten classes - mangrove, settlement with vegetation, agriculture land, creek, waterbody, other vegetation, mudflat, aquaculture farm, marshy land, and open space. It also studies the tourism growth in the island and uses the Pearson correlation coefficient (CC) method to associate this with the LULC changes. Information on visitation was obtained from the state tourism department. Field visits were undertaken for ground verifications and primary surveys of visitor facilities. Agriculture land and settlement with vegetation emerged as the dominant land uses, with the former shrinking by 25% and the latter growing by 38% at the end of the study period. About 20% growth was also observed in the number of tourist beds during the same period. The results of the Pearson CC favor a strong correlation between the two and indicate that the dynamics may be largely attributed to the increase of new settlements and visitor infrastructures.*

Keywords — *Geospatial techniques, Land Use, and Landcover, Pilgrims, Tourism, Sundarbans*

I. INTRODUCTION

River systems, coastal structures and processes, waves, currents, climatic effects, etc., are influential geological variables that create a variety of delta sizes in simple and complex combinations [1]. Ganges delta is the world's largest delta formed at the Bay of Bengal by the confluence of the rivers Ganga, Brahmaputra, and Meghna, hosting the world's largest mangrove forest Sundarbans and spanning the two countries of India and Bangladesh [2]. With some 130 million inhabitants, the Ganges delta belongs to the most densely populated areas in the world [3]. Sagar Island is the largest inhabited island located in the western extreme of the Indian Sundarbans, bounded on the north, east, and west by tributaries of the Hooghly River and on the south by the Bay of Bengal [4]. This paper presents a time-series change detection analysis of the land use and land cover (LULC) of the entire Sagar Island from 1986 till 2014, i.e., over a period of about thirty years. It also attempts to correlate the changes with the increased visitation in the island, as Gangasagar village in the island is a prominent Hindu pilgrimage site. Recognizing the popularity of the island and its tourism potential, the state government constituted the Gangasagar Bakkhali Development Authority (GBDA) in June 2013 with a planning area comprising of sixteen Mouzas of Sagar Development Block and seven Mouzas of Namkhana Development Block [5]. This provided further impetus to the landscape transformations on the island. The current study uses multi-temporal Landsat satellite data for spatial analysis. Non-spatial data involving primary data on tourist facilities were collected through field survey, and secondary data were sourced from Census 2011 and the state tourism department.

II. PRECEDENT STUDIES

Precedent literature was referred to comprehend the common application areas of geospatial techniques as well as past LULC analyses specific to Sagar Island, the study area. The terms ‘land use’ and ‘land cover’ are interrelated as the land cover is the feature that exists on the earth while land use concerns its economic utilization [6]. The remotely sensed data is very effective for LULC studies and is being increasingly applied since the last few decades, especially in the field of change detection analysis. This helps in monitoring the condition of a particular resource over a period of time, leading to its appropriate management. LULC changes can be easily identified using GIS technology, topographic maps, and satellite imagery, and such changes are important to observe for understanding the human-environment dynamics [7, 8, 9]. A LULC study in the Namkhana-Patharpratima CD block areas of the Indian Sundarbans using Landsat data from 1975-2006 indicated a reduction in mangroves vis-a-vis an increase in non-agricultural land uses, particularly settlement with vegetation related to tourism growth [10]. Another study carried out in Sagar Island for the period 1996-1999 using remotely sensed data reported shoreline changes alongside changes in certain land use and land cover classes. It found the erosion rate to be much higher than the accretion rate and identified coastal erosion and loss of forest cover as some of the critical environmental issues [11]. One of the most recent reports on the LULC of the Sagar Island is based on the classification and

comparison of two images (1975 and 2015) to analyze the LULC change trends under select classes. Conversion of mangrove to cropland, cropland to settlement, and similar alteration for other classes were reported [12]. Yet another study on the shoreline detection of Sagar Island from 1975-2017 substantiated the fact that erosion is indeed higher than accretion [13].

Based on these studies, the current paper covers three major aspects – (i) it follows the time series analysis method to systematically detect and document the decadal changes from 1986 to 2014 in ten different LULC classes, (ii) assesses the growth of tourism infrastructure during this period and the annual tourism traffic volume available for 2016, 2017 and 2018, and (iii) correlates the observed changes in the dominant LULC classes with increased visitation and tourism growth by using the Pearson correlation coefficient method.

III. STUDY AREA

Sagar Island, which is situated at 21˚37'21" to 21˚52'28" N and 88˚2'17" to 88˚10'25" E [14] is a community development block in the Kakdwip subdivision of the South 24 Parganas district in West Bengal. The island currently covers an area of 237.19 km^2, with a north-south extension of about 30 km and the maximum spread from east to west of 12 km [14]. According to the 2011 census, the total population of Sagar Island is 212,037, with 52% males and 48% females [15]. The main livelihood of the local people of this region is agriculture and fishing. Alongside, the tourism industry has also opened up new opportunities. Gangasagar, the southernmost village on the island, is a rural center based on the Kapil Muni temple - the main attraction of the island. An age-old pilgrimage site, it is referred to by the honorific title of '*Ganga Sagar Punya Bhoomi*', meaning 'The holy site of Gangasagar'. Being adjacent to the Bay of Bengal, it is also a popular tourist destination of the region. The location map of the island is given in Plate 1.

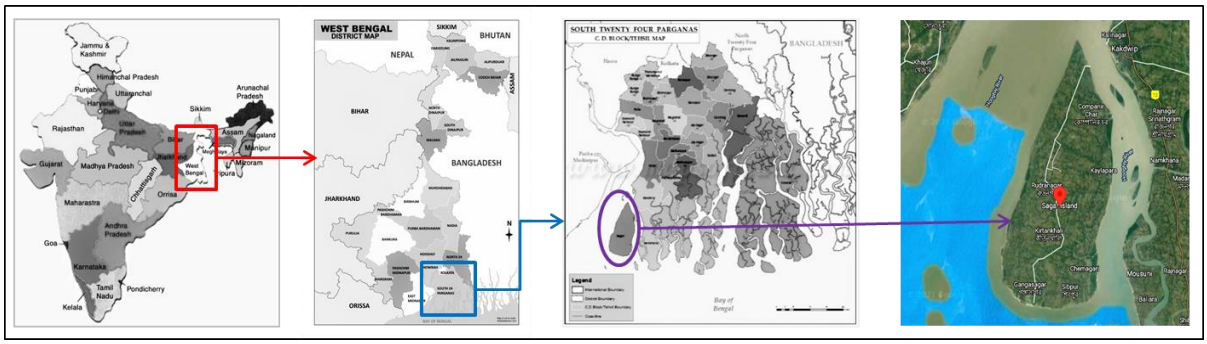

Plate 1 Sagar Island location Map (Source: Google Earth Image)

IV. MATERIAL AND METHODS

The present study focuses on the LULC change detection analyses along with the study of the rate of tourism growth in Sagar Island. Spatial data were collected using Landsat TM satellite imagery downloaded from the United States Geological Survey portal (table 1), and the topographical map was collected from the Survey of India (SOI) in order to create an integrated data structure for the Sagar Island. Non-spatial data materials include the 2011 census data and tourist visitation data, the latter collected from the West Bengal Tourism Department. All other information was collected through the field-based primary survey.

Table 1 Land sat Image properties [16]

Spacecraft Image	Date of Acquisition	Spatial Resolution	Band	Path/Row
Landsat TM	January 1986	30 m	1 -7	148/45
Landsat TM	February 1996	30 m	1 -7	148/45
Landsat TM	January 2006	30 m	1 -7	148/45
Landsat TM	January 2014	30 m	1 -7	148/45

The LULC maps of Sagar Island have been prepared from the satellite data followed by field checks. The change detection analysis and transformation matrix analysis of this area has been prepared for the periods of 1986, 1996, 2006, and 2014. Table 1 shows the detailed specification of the satellite images. The methodology of the study has been presented in the flow diagram (Fig. 1).

Satellite data were analyzed and interpreted using digital image processing software ARCMAP 10.4 and ERDAS IMAGINE 9.1. An accuracy test was also conducted by ERDAS imaging software to confirm the method/classification [17]. LULC features are shown divided into ten main categories, namely Mangrove, Settlement with Vegetation, Agriculture land, Creek, Waterbody, Other Vegetation, Mudflat, Aquaculture Farm, Marshy Land, and Open Space. These were cross-checked through field verification. The main types of land use, geographical concentration of hotels, and tourism data were also verified between field observation and GPS point data. The ARC-GIS software was used to estimate changes in the land use and land cover characteristics,

including the transformation matrix, to note changes in post-classification comparison techniques. On a parallel track, a tourism assessment of the region was conducted to find out the growth in tourist accommodation and visitations. The former was done by primary field survey while the data on tourist traffic was availed from the state tourism department. Tourism growth was then compared with the most dominant LULC classes of Agriculture land and Settlement with vegetation, as these two were also found to be the most rapidly changing classes with an average annual rate of conversion of ≥ 1.0 km^2/year. The Pearson Correlation Coefficient method was used to assess the level of association.

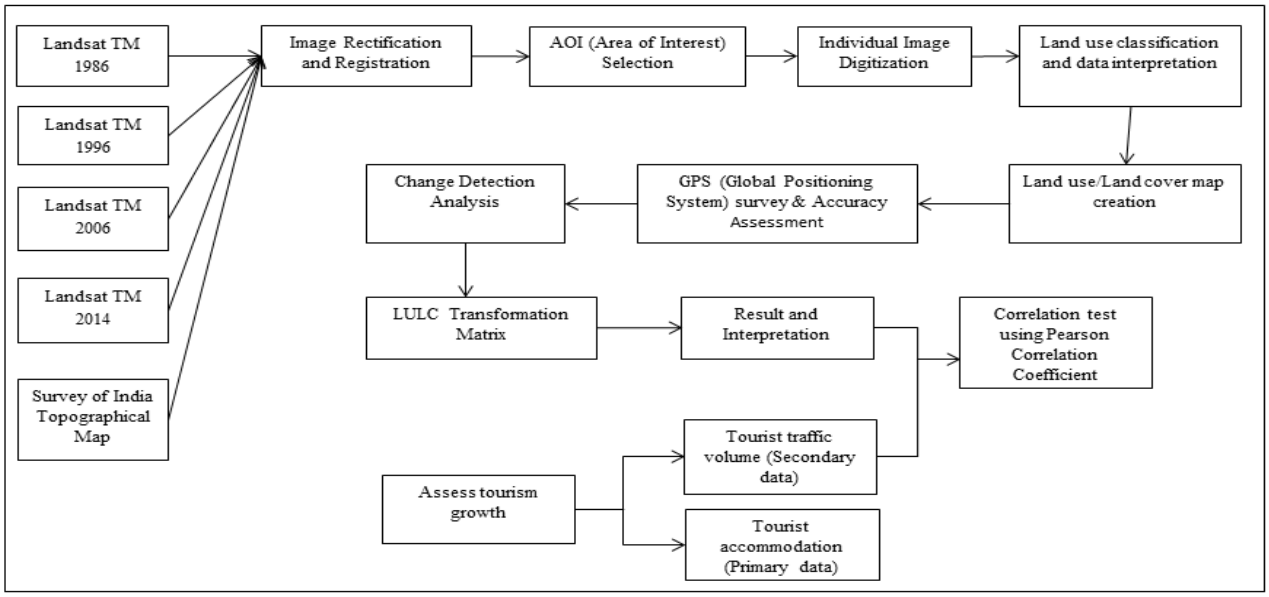

Fig. 1 Methodology Flow diagram

V. RESULTS & DISCUSSIONS

A. *Sagar Island Land Use and Land Cover Change: Time Series Analysis*

This study shows the classification of land use land cover and also imagines the most probable algorithm in software ERDAS using the supervised classification method for the ten LULC classes. It was observed that the region underwent numerous development-related activities during the period 1986-2014, like settlement growth, redistribution of forest land for settlements, settlements, and agriculture, construction of roads, change of landforms for tourism development, and the like. The LULC four-decade map is presented in figures 2a, 3a, 4a, and 5a. Figures 2b, 3b, 4b, and 5b show the corresponding percentages of each class of land use over four decades on Sagar Island.

Tables 2, 3, 4, and 5 tabulate the areas and percentages of the different LULC classes at the end of 1986, 1996, 2006, and 2014, respectively.

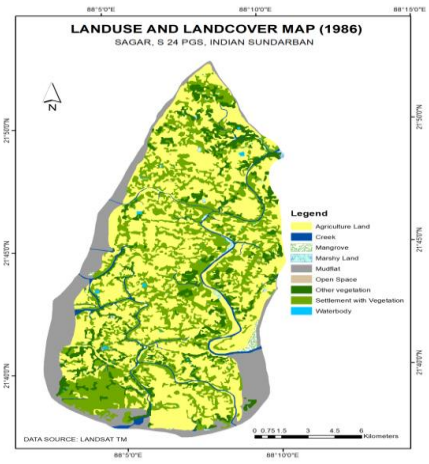

Fig. 2a Land use and land cover Map, 1986

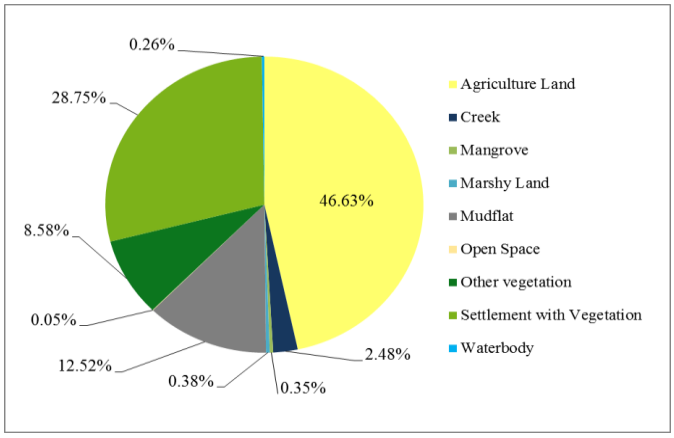

Fig. 2b Percentage occurrence of difference LULC.s, 1986

Table 2 Land use Land cover Classes and Area in km^2 of Sagar Island (1986)

Sl No.	LULC Type	Area in km^2	Percentage of Area in km^2
1	Agriculture Land	118.64	46.63
2	Aquaculture Farm	0	0
3	Creek	6.32	2.48
4	Mangrove	0.89	0.35
5	Marshy Land	0.96	0.38
6	Mudflat	31.85	12.52
7	Open Space	0.14	0.05
8	Other vegetation	21.83	8.58
9	Settlement with Vegetation	73.16	28.75
10	Waterbody	0.65	0.26
	Total	**254.42**	**100**

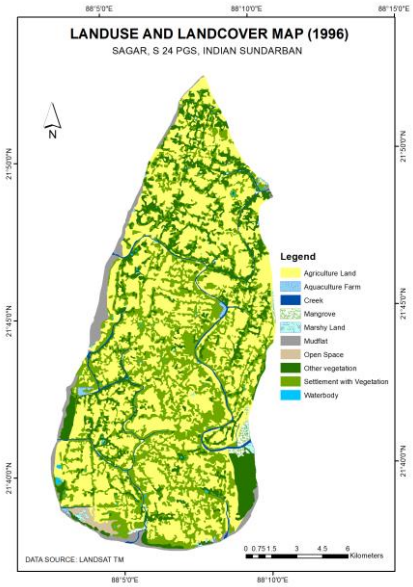

Fig. 3a Land use and land cover Map, 1996

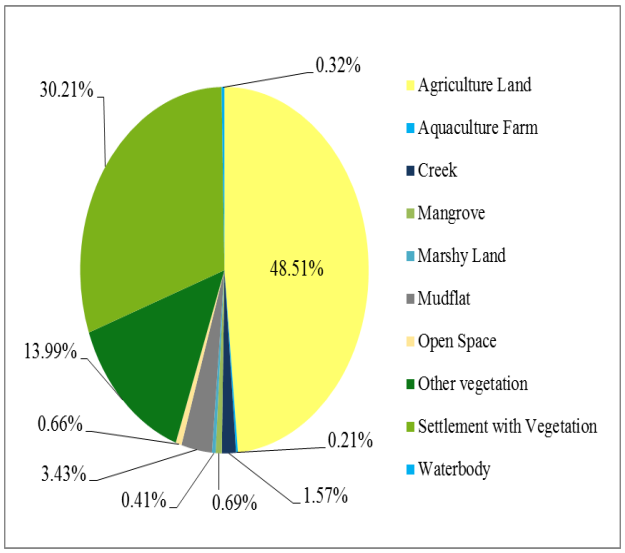

Fig. 3b Percentage occurrence of difference LULC.s, 1996

Table 3 Land use and Land cover Classes and Area in km^2 of Sagar Island (1996)

Sl No.	LULC Type	Area in km^2	Percentage of Area in km^2
1	Agriculture Land	116.16	48.51
2	Aquaculture Farm	0.51	0.21
3	Creek	3.76	1.57
4	Mangrove	1.65	0.69
5	Marshy Land	0.98	0.41
6	Mudflat	8.21	3.43
7	Open Space	1.59	0.66
8	Other vegetation	33.50	13.99
9	Settlement with Vegetation	72.34	30.21
10	Waterbody	0.77	0.32
	Total	**239.47**	**100**

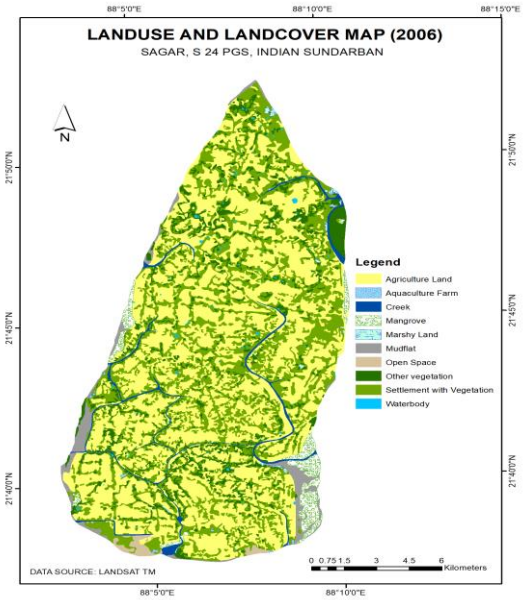

Fig. 4a Land use and land cover Map, 2006

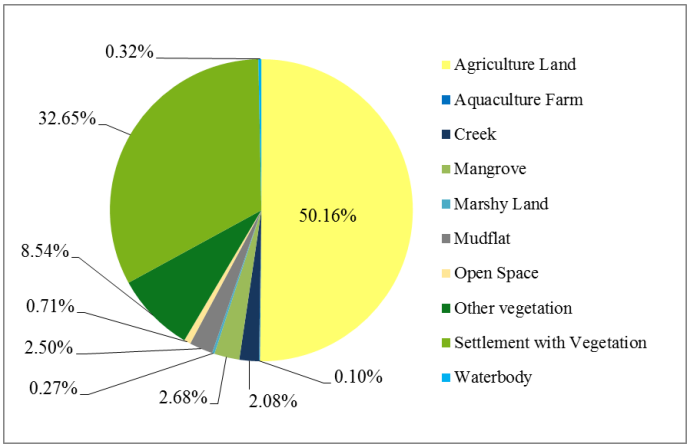

Fig. 4b Percentage occurrence of difference LULC.s, 2006

Table 4 Land use and Land cover Classes and Area in km^2 of Sagar Island (2006)

Sl No.	LULC Type	Area in km^2	Percentage of Area in km^2
1	Agriculture Land	118.46	50.16
2	Aquaculture Farm	0.22	0.10
3	Creek	4.92	2.08
4	Mangrove	6.33	2.68
5	Marshy Land	0.63	0.27
6	Mudflat	5.91	2.50
7	Open Space	1.67	0.71
8	Other vegetation	20.17	8.54
9	Settlement with Vegetation	77.11	32.65
10	Waterbody	0.75	0.32
	Total	**236.17**	**100**

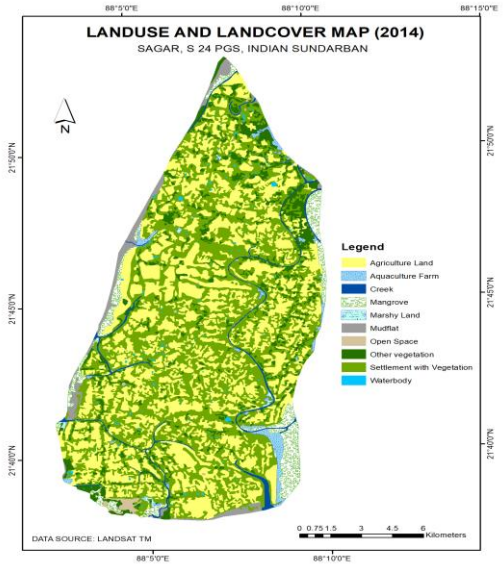

Fig. 5a Land use and land cover Map, 2014

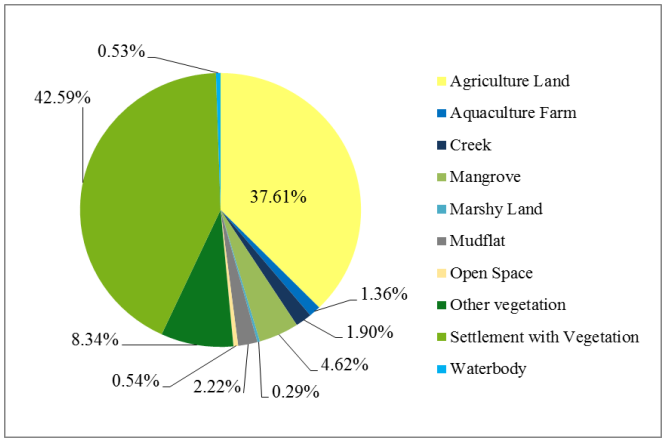

Fig. 5b Percentage occurrence of difference LULC.s, 2014

Table 5 Land use and Land cover Classes and Area in km^2 of Sagar Island (2014)

Sl No.	LULC Type	Area in km^2	Percentage of Area in km^2
1	Agriculture Land	89.21	37.61
2	Aquaculture Farm	3.23	1.36
3	Creek	4.49	1.90
4	Mangrove	10.96	4.62
5	Marshy Land	0.68	0.29
6	Mudflat	5.27	2.22
7	Open Space	1.28	0.54
8	Other vegetation	19.79	8.34
9	Settlement with Vegetation	101.02	42.59
10	Waterbody	1.25	0.53
	Total	**237.19**	**100**

Table 6 presents a comprehensive decadal evolution of the different classes, showing the area of agricultural land to be 118.64 km^2 and the settlement with vegetation area as 73.16 km^2 in 1986, the baseline year. Land use analysis of the last four decades indicates a near 20% decline in the agricultural land area (89.21 km^2) against a 38% increase in the habitation area (101.02 km^2) in 2014. It also identifies these to be the two dominant LULC classes, together covering 75.38% of the total island area in 1986 only to increase to 80.2% in 2014. This indicates a steady increase in the built-up area during the four decades, which corroborates well with the precedent research findings. Also, as reported in the past studies, shoreline changes contributed to a reduced landmass from 1986 to 2006 - 254.42 km^2 in 1986 to 239.47 km^2 in 1996 and further dropping to 236.17 km^2 in 2006, while very little land area increase was observed in 2014.

Table 6 Comparison between classified Land use and Land cover during the years 1986, 1996, 2006 and 2014

Sl No.	LULC Type	1986		1996		2006		2014	
		Area in km^2	Percentage (%)	Area in km^2	Percentage (%)	Area in km^2	Percentage (%)	Area in km^2	Percentage (%)
1	Agriculture Land	118.64	46.63	116.16	48.51	118.46	50.16	89.21	37.61
2	Aquaculture Farm	0	0	0.51	0.21	0.22	0.10	3.23	1.36
3	Creek	6.32	2.48	3.76	1.57	4.92	2.08	4.49	1.90
4	Mangrove	0.89	0.35	1.65	0.69	6.33	2.68	10.96	4.62
5	Marshy Land	0.96	0.38	0.98	0.41	0.63	0.27	0.68	0.29
6	Mudflat	31.85	12.52	8.21	3.43	5.91	2.50	5.27	2.22
7	Open Space	0.14	0.05	1.59	0.66	1.67	0.71	1.28	0.54
8	Other vegetation	21.83	8.58	33.50	13.99	20.17	8.54	19.79	8.34
9	Settlement with vegetation	73.16	28.75	72.34	30.21	77.11	32.65	101.02	42.59
10	Waterbody	0.65	0.26	0.77	0.32	0.75	0.32	1.25	0.53
	TOTAL	**254.42**		**239.47**		**236.18**		**237.19**	

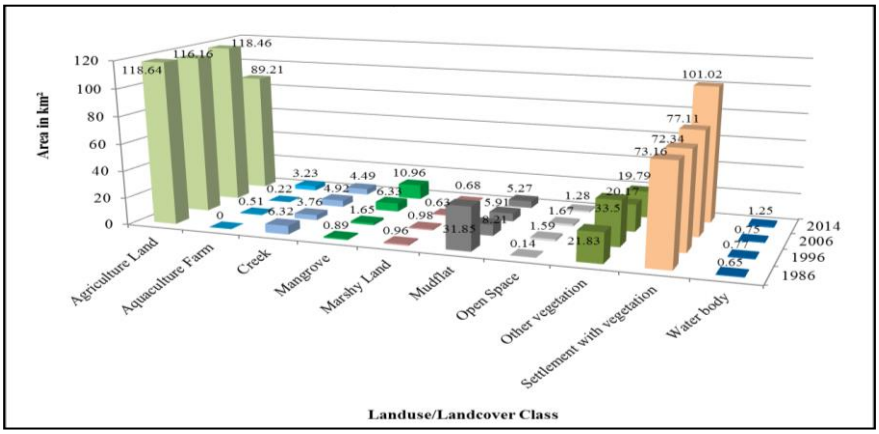

Fig. 6 Decadal change dynamics of the LULC classes from 1986 – 2014

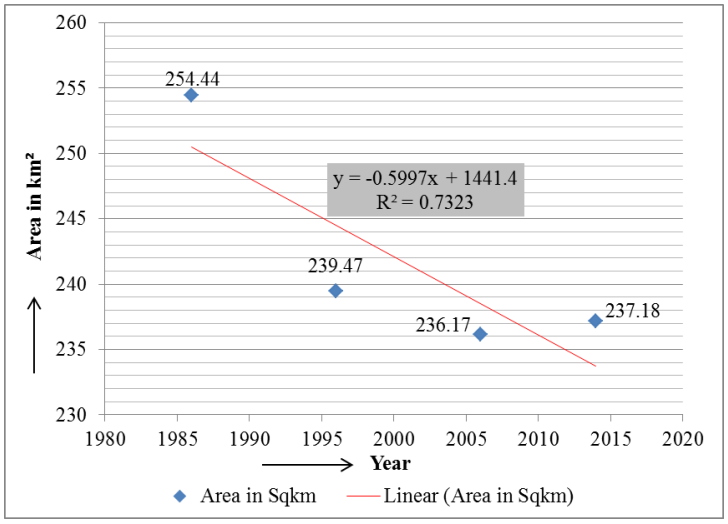

Fig. 7 Trend (decreasing) analysis of Island area dynamics due to erosion & accretion

Fig. 6 presents the decadal changes of the land use and land covers from 1986 – 2014 for all the ten classes, and Fig. 7 demonstrates the consequent decreasing trend of the island area. Continuous erosional activities have reduced the landmass, although marginal accretion in the last decade of the study period is encouraging. Tables 7, 8, and 9 explain in detail the land transformation dynamics during the three decades (1986 to 1996, 1996 to 2006, and 2006 to 2014).

Table 7 Land use and Land cover transformations matrix of Sagar Island from 1986 to 1996 (in hectare)

Land Class		Land Class 1996										
		Agriculture Land	**Aquaculture Farm**	**Creek**	**Mangrove**	**Marshy Land**	**Mudflat**	**Open Space**	**Other Vegetation**	**Settlement with Vegetation**	**Waterbody**	**Grand Total**
Land Class 1986	Agriculture Land	8382.63	17.64	72.06	13.43	19.51	82.45	11.84	10.12	3339.94	17.06	11966.68
	Creek	96.35	12.79	197.98	5.30	5.40	33.64	2.94	-	251.86	3.15	609.40
	Mangrove	6.90	-	3.83	65.59	-	1.30	-	-	7.36	2.72	87.70
	Marshy Land	37.69	13.68	3.46	-	0.64	5.66	-	-	27.39	0.14	88.67
	Mudflat	251.15	0.62	19.93	47.95	22.62	676.70	29.78	-	721.64	16.90	1787.29
	Open Space	7.96	-	-	-	-	-	0.02	-	5.89	-	13.87
	Other Vegetation	269.04	-	2.06	19.28	0.95	3.08	-	7.87	356.29	0.66	659.23
	Settlement with Vegetation	2689.15	6.38	81.77	0.53	48.61	28.49	114.96	1.74	5945.05	26.51	8943.20
	Waterbody	9.92	0.52	0.05	-	0.95	0.07	1.69	-	41.82	10.97	65.99
	Grand Total	**11750.79**	**51.63**	**381.14**	**152.07**	**98.68**	**831.40**	**161.23**	**19.74**	**10697.24**	**78.11**	**24222.03**

Table 8 Land use and Land cover transformations matrix of Sagar Island from 1996 to 2006 (in hectare)

Land Class		Land Class 2006										
		Agriculture Land	**Aquaculture Farm**	**Creek**	**Mangrove**	**Marshy Land**	**Mudflat**	**Open Space**	**Other Vegetation**	**Settlement with Vegetation**	**Waterbody**	**Grand Total**
Land Class 1996	Agriculture Land	7144.89	5.38	122.89	34.67	8.66	138.13	31.10	11.55	4116.35	23.86	11637.48
	Aquaculture Farm	19.27	-	4.36	-	-	-	-	-	27.06	0.44	51.12
	Creek	120.13	1.16	45.54	21.00	0.98	5.21	0.95	1.03	172.85	0.90	369.75

	Mangrove	22.16	-	8.67	111.02	-	0.12	-	-	8.98	-	150.94
	Marshy Land	8.76	-	6.43	11.15	1.63	4.91	3.72	-	39.16	0.23	75.99
	Mudflat	48.76	5.42	38.18	153.41	4.57	149.73	27.40	0.25	111.83	0.70	540.25
	Open Space	34.53	-	15.91	-	1.52	0.72	28.62	-	79.92	-	161.23
	Other Vegetation	2.87	-	-	-	-	-	-	-	14.82	2.05	19.74
	Settlement with Vegetation	4560.58	10.39	226.04	271.90	44.55	276.39	36.52	11.37	5043.62	45.96	10527.32
	Waterbody	31.43	0.36	0.87	3.37	1.18	2.77	0.69	0.46	33.80	2.03	76.97
	Grand Total	**11993.37**	**22.71**	**468.91**	**606.50**	**63.10**	**577.98**	**129.00**	**24.66**	**9648.38**	**76.18**	**23610.80**

Table 9 Land use and Land cover transformations matrix of Sagar Island from 2006 to 2014 (in hectare)

Land Class		**Land Class 2014**										
		Agriculture Land	**Aquaculture Farm**	**Creek**	**Mangrove**	**Marshy land**	**Mudflat**	**Open Space**	**Other Vegetation**	**Settlement with Vegetation**	**Waterbody**	**Grand Total**
Land Class 2006	Agriculture Land	4689.40	122.51	183.29	160.34	31.72	64.31	50.80	115.05	6125.79	63.34	11606.55
	Aquaculture Farm	5.50	-	-	2.69	-	0.32	-	--	4.83	-	13.34
	Creek	149.25	10.80	10.71	34.59	1.26	6.38	3.85	1.73	215.20	4.76	438.54
	Mangrove	88.31	6.75	15.22	187.11	-	3.07	1.14	-	61.97	0.39	363.96
	Marshy Land	6.02	5.21	1.41	4.58	0.06	1.98	0.71	0.39	20.58	0.00	40.94
	Mudflat	134.57	40.72	4.76	137.01	-	9.01	1.56	-	145.76	2.64	476.04
	Open Space	4.91	-	0.53	7.12	-	0.04	19.62	4.55	28.87	0.86	66.52
	Other Vegetation	9.31	-	-	2.21	-	0.07	-	0.68	9.04	-	21.30
	Settlement with Vegetation	3518.60	115.27	188.82	279.22	25.88	58.69	52.14	121.66	4837.05	45.57	9242.92
	Waterbody	29.05	0.68	1.17	2.32	-	-	0.16	1.59	38.69	0.33	73.99
	Grand Total	**8634.92**	**301.94**	**405.92**	**817.19**	**58.93**	**143.85**	**129.98**	**245.66**	**11487.79**	**117.90**	**22344.09**

B. Growth of tourism in the Sagar Island

Every year on the occasion of *Makar Sankranti*, considered to be an auspicious cosmic alliance, millions of pilgrims from different parts of India arrive at the Gangasagar to take a holy dip in the sea and offer worship at the Kapil Muni temple. This gathering is known as the *Ganga Sagar Mela*, which is the second-largest religious fair in India after *Kumbh Mela* [18]. This religious event has become the center of tourism growth on the island. The Bengali proverb *"সব তীর্থ বারবার সাগর তীর্থ একবার"*, meaning 'While other pilgrimages may be repeated, Sagar pilgrimage is only once a lifetime' may be attributed to the fact that the accessibility to the island was very treacherous and immensely challenging in the past. However, with the improvement of roads and transportation systems, visitations have been steadily increasing. The authors conducted a primary survey of the hotels in the Gangasagar area, including their chronological growth from 1901. The survey revealed that pilgrim accommodation facilities started developing from the beginning of the 20th century as part of public welfare (table 10). Several religious organizations also contributed to such initiatives for their devotees and pilgrims. There were 1323 beds available at Gangasagar till the end of the British period. In recent times, the spate of hotel construction has seen a rise, and the last information obtained in 2019 shows the total number of beds at 2804, although new lodging facilities are expected to get added to this figure in a year or two. The share of government-owned accommodation was, however, a meagre 4% of the total number of available beds in 2019. The growth in the number of beds from 1986 to 2014 is found to be about 20%. Figure 8 shows the decadal rise in visitor accommodation in terms of bed capacity in the Gangasagar village of the island.

Table 10 Chronological development of hotels in Sagar Island, 2019
(Source: Primary survey by authors in 2018-'19)

Sl No	Name of the Hotel	Year Established	No. of Beds	Cumulative beds	Ownership
			D	∑ D	
1	Calcutta Vastra Vyavsayi Seva Samiti Dharma Sala	1901	660	660	Private
2	Shri Shankaracharya Ashram	1903	6	666	Private
3	Kapil Kuthi Sangkhyayoga Ashram	1905	256	922	Private
4	Ganga Sagar Bhavan (Shri Shri Kapil Muni Charitable Trust)	1905	120	1042	Private
5	Manav Seva Samiti	1920	180	1222	Private
6	Shri Guru Sangha	1933	25	1247	Private
7	Kapil Kalpataru Ashram	1945	76	1323	Private
8	Arya Wrishi Ashram	1953	36	1359	Private
9	Gaudiya Ashram	1953	15	1374	Private
10	Hindu Sanatan Dharma Prachar Ashram Sangha	1957	90	1464	Private
11	Ganga Sagar Shri Shri Nigamananda Sevashram	1965	12	1476	Private
12	Ganga Sagar Shankar Dham Ashram	1969	30	1506	Private
13	Kapil Muni Dharma Sala	1972	45	1551	Private
14	Bharat Sevashram	1979	330	1881	Private
15	Basudebananda Tatsangha Ashram	1980	100	1981	Private
16	Purnashram	1980	32	2013	Private
17	Sankhya Yogashram	1981	56	2069	Private
18	Ganga Sagar Youth Hostel	1984	76	2145	W.B Govt.
19	Vishwa Hindu Parisad (Madhav Ashram)	1985	70	2215	Private
20	Swami Debananda Ashram	1987	12	2227	Private
21	Sanatan Bramhacharya Seva Ashram Sangha	1988	20	2247	Private
22	Ganga Sagar Tourist Lodge	1993	36	2283	W.B Govt.
23	Loknath Mission	1993	24	2307	Private
24	Jogendra Math	1994	24	2331	Private
25	Vishalaxmi Hanuman Mandir Dharma Sala	1996	12	2343	Private
26	Ganga Sagar Ananda Ashram	1997	15	2358	Private
27	Haryana Charitable Society	2003	60	2418	Private
28	Kapil Muni Dharma Sala, Nat Mandir	2006	320	2738	Private
29	Howrah Bhartiya Sahu Samaj	2006	30	2768	Private
30	Ramakrishna Mission Ashram	2008	36	2804	Private
	TOTAL		**2804**		

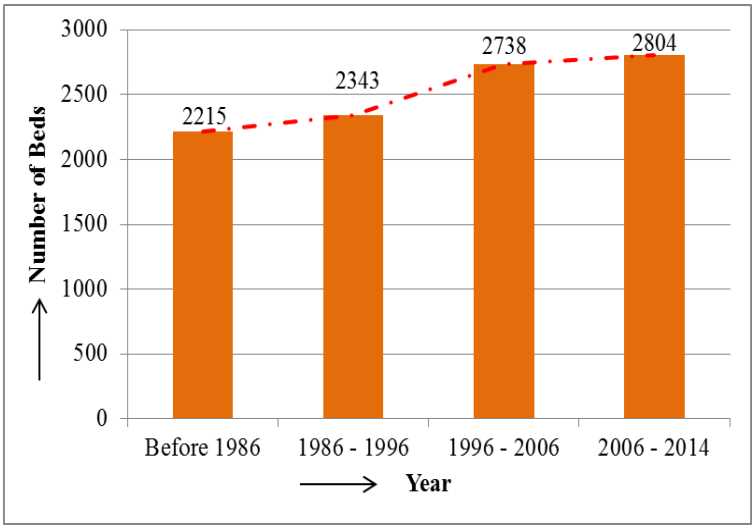

Fig. 8 Decadal rise of visitor accommodation (bed capacity) in Sagar Island

The following information was also obtained from the state tourism department office for the years 2016, 2017, and 2018:

i. Total tourist traffic (TTT) data, as presented in figure 9

ii. Month-wise distribution of visitors (includes both pilgrims and tourists), as presented in figures 10, 11, and 12.

Tourist data prior to 2016 could not be accessed, which is a limitation of this study.

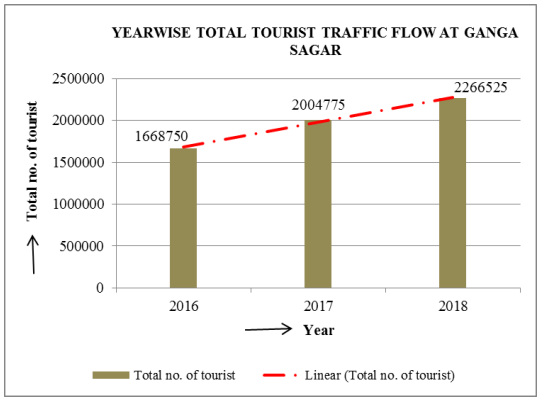

Fig. 9 Total Tourist Traffic trend in 2016-2018

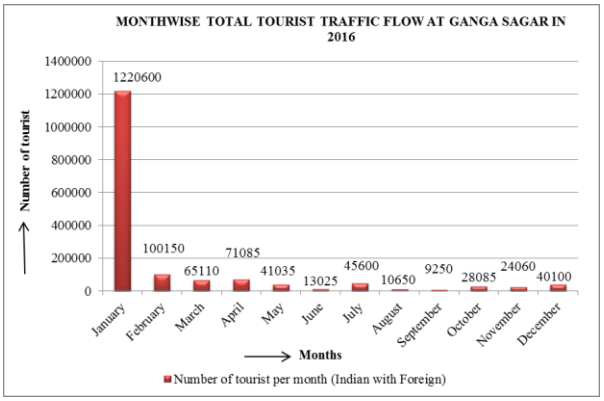

Fig. 10 Total Tourist Traffic flow in Sagar Island from Sagar Island in 2016

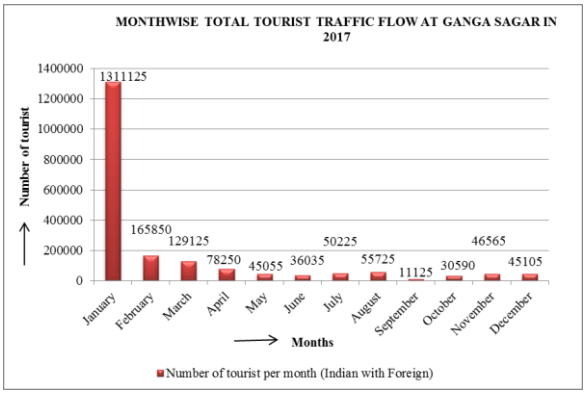

Fig. 11 Total Tourist Traffic flow in

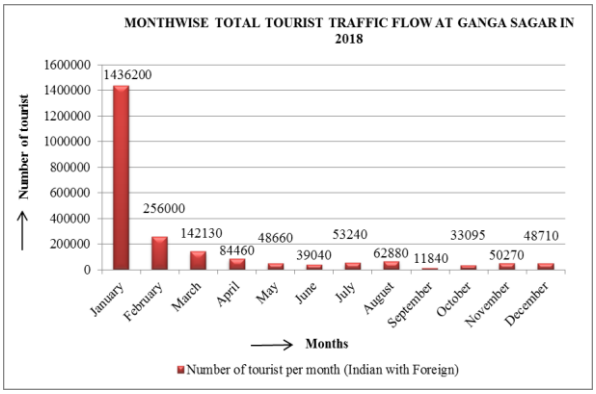

Fig. 12 Total Tourist Traffic flow in Sagar Island in 2017 Sagar Island in 2018

VI. ANALYSIS OF RESULTS

A. Factors influencing LULC changes

Erosion and Accretion of Land:

From table nos. 7, 8, 9, and Fig. 7, it is clear that the erosion is greater than the accretion and is active in certain parts of the island, which are otherwise protected by river embankment, Casuarina trees, and mangroves. The amount of land erosion during the study period is observed to be 16.24 km^2, whereas the maximum erosion between 1986 and 1996 is about 14.95 km^2 as against an accretion of 1.01 km^2 in the last decade.

Change in Agriculture land and Settlement with vegetation:

Population pressures are increasing, which is playing a major role in land-use change. According to the Indian Census, the total population of Sagar Island was 2,06,890 in 2001 and increased to 2,12,037 in 2011 (Census of India 2001 and 2011). In this case, the major change has been seen in the settlement with vegetation and agricultural lands. Table 6 shows that out of the total area of land in 1986, that of agricultural land was 118.64 km^{2,} and it gradually decreased to 89.21 km^2 in 2014. In contrast, the settlement with vegetation has gradually increased from 73.16 km^2 in 1986 to 101.02 km^2 in 2014. However, increased salinity has also been one of the reasons for the conversion of agricultural land into other uses [19].

Waterbody:

In 1986, the water body in the study area occupied about 0.65 km^2 of land on Sagar Island, representing about 0.26% of the total land for that year (Table 6 and Fig. 6). By 1996, the area occupied by the water body had

increased marginally to about 0.77 km^2, but by 2006 there had been no change. Again in 2014, it is seen that the occupied area of the water body has risen to about 1.25 km^2 (table 6 and Fig. 6).

Mudflats:

Table 6 and Fig. 6 show that in the four decades (1986, 1996, 2006, and 2014), the number of mudflats was the highest in 1986, at about 12.52% of the total land, whereas it gradually declined to about 2.22 % in 2014.

Open Space:

Table 6 and Fig. 6 show that the amount of agricultural land has been declining over the four decades (1986, 1996, 2006, and 2014), as against the increasing area under a settlement with vegetation cover and open space. This may be attributed to the natural growth in the local population as well as the increased visitations by pilgrims and tourists alike as evident from the figure series 10, 11, and 12, a high concentration of pilgrim visitation occur during the Ganga Sagar Mela in January, when the Kapil Muni Ashram area remains overcrowded for three to four days at a stretch. As a result, some agricultural lands have been converted into temporary fairgrounds to cope with this large number of pilgrims. However, these places are seasonal in use and are denoted as open spaces at other times.

Changes in other vegetation and Mangrove:

Fig. 6 also shows that while the amount of other vegetation is decreasing, the mangrove is gradually increasing. Based on the total land area is 1986, the amount of mangrove was 0.89 km^2, which increased to 10.96 km^2 in 2014, revealing the positive structural aspects of the environment.

Plate 2 Site visuals showing the LULC dynamics with Agriculture land being changed to open Space (Source: Author, 2019)

B. The pilgrimage tourism phenomenon

As mentioned earlier, the village of Gangasagar, located on the shores of the Bay of Bengal, is the main tourist destination and has been one of the Hindu pilgrimage sites since ancient times. The tourism industry has taken its roots based on Kapil Muni's temple, but now it also capitalizes on the scenic beauty of the seaside. Previous LULC analysis indicated that the village had undergone a major change in land use due to the gradual loss of agricultural land and steady increase in settlement with vegetation. There were 19 hotels in the region with 2343 bed capacity before 1986, but the total number of hotels has increased to 30 with 2804 bed capacity by 2014. Other than Kapil Muni's Ashram, which is the main attraction for tourists, other tourist attractions include the Gangasagar beach, Beguakhali Light House, and Bharat Sevashram temple. Comparison of total tourist traffic (Fig. 9) with the total number of residents shows that the visitor population is almost ten times the resident population of the island. This indicates very high visitor density and, therefore, high tourism penetration. The month-wise distribution of visitors to the island (Fig. 10, 11, and 12) shows that almost 70% (average) of the total tourist traffic visit during the Ganga Sagar Mela in January alone, while the balance of 30% traffic is distributed over the other 11 months. Hence, it may be logical to consider the January visitors as pilgrims, and Fig. 13 indicates the rising trends of these two types of visitors and marks a steeper growth of tourists compared to pilgrims.

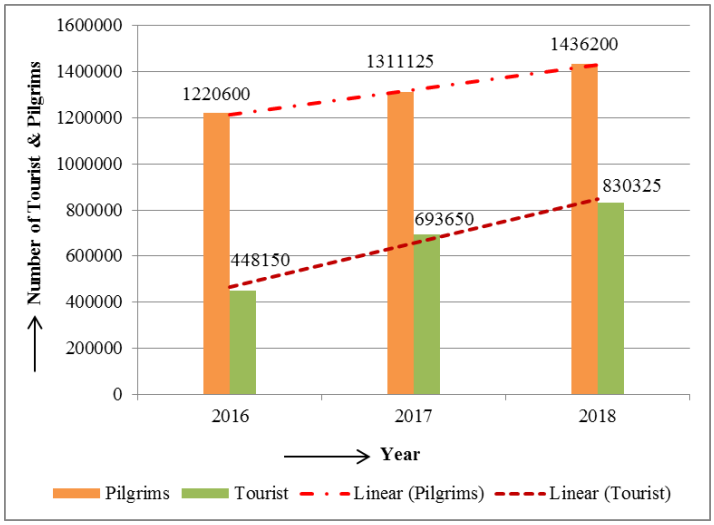

Fig. 13 Pilgrim and Tourist Traffic trends in Sagar Island from 2016-2018

C. Correlating LULC with visitations

An analysis of the annual rate of change of the LULC classes over the study period indicates two opposing trends of the two previously mentioned dominant classes in particular that have undergone a loss or gain of 1.0 km^2/ year or more (Fig.14). These are 'agriculture land' (-1.05 km^2) and 'settlement with vegetation' (+1.0 km^2) respectively. Each of these two variables of interest was separately compared with the annual rate of visitations, deduced from the tourist traffic data (Fig. 9) to ascertain their mutual association if any. This was done by using Pearson's correlation coefficient to measure the strength of the linear relationship between these variables.

In both cases, the value of R is close to one, indicating that the tourist visitations have a strong positive relationship with the settlement area (Fig. 15) and an equally strong negative relationship with the agricultural land (Fig. 16).

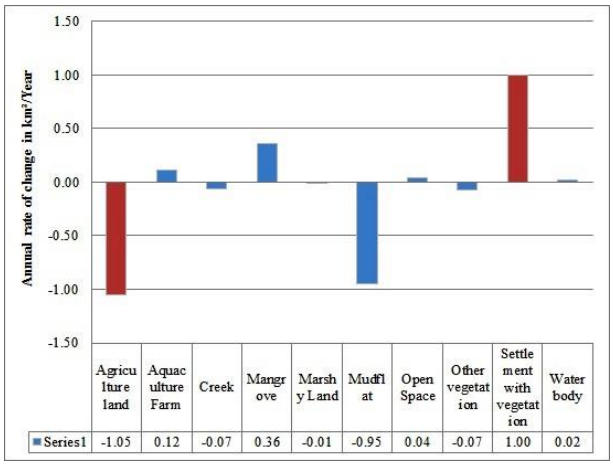

Fig. 14 Average annual rate of change in the LULC classes (1986 – 2014) in km^2/ year

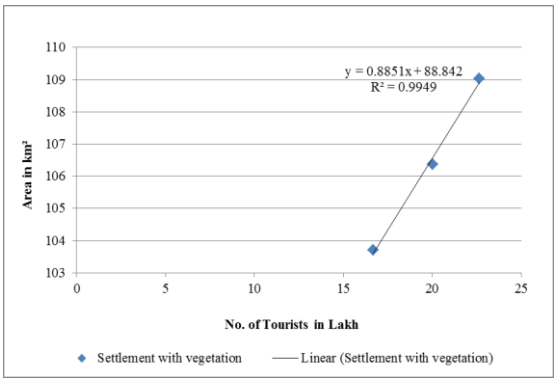

Fig. 15 Positive correlation between visitations and settlement with vegetation

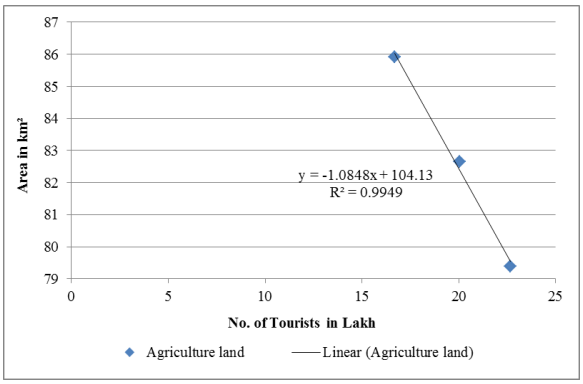

Fig. 16 Negative correlation between visitations and agricultural land

VII. CONCLUSION

Sagar Island is an indispensable part of the Ganges basin. As important as it is physically and economically, it is also one of the significant cultural sites in India. More than two million people actively and passively live on the

island. However, increased tourism volume and consequent environmental degradation are endangering the island. Natural resources and their sustainable use form the basis of any management strategy and require an understanding of the transformational dynamics of the existing land use and land covers of an area, which this paper tried to address. The total landmass of the island showed a diminishing trend, only to marginally pick up between 2006 and 2014. This is in conformation with the results of the precedent studies. The two LULC classes of 'settlement with vegetation' and 'agriculture land' were found to be the two predominant land uses in the Sagar Island, together constituting more than 75% of the total land area in 1986 and increasing to 80.2% in 2014. These two classes also register the highest average annual rate of change of $\geq$ 1.0 km^2/ year. The Pearson correlation coefficient test findings indicate a strong correlation between these two land use/cover changes and increased visitation, particularly in Gangasagar. This additional pressure also affects the quality of the natural ecosystems. The United Nations has demarcated the current decade 2021-2030 as that of ecosystem restoration, aiming '*to prevent, halt and reverse the degradation of ecosystems on every continent and in every ocean. It can help to end poverty, combat climate change and prevent mass extinction. It will only succeed if everyone plays a part*' [20]. Therefore, the concerned authorities, in consultation with experts as well as local communities, have to take the lead in preparing a sustainable roadmap for the Island. Planning tools such as Land Use Development and Control Plan (LUDCP) and appropriate resource management strategies need to be applied for regulating land use conversions, restoring damaged ecosystems, and investing in Green Infrastructure.

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