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WATER AND VEGETATION COVER CHANGE DETECTION USING MULTISPECTRAL SATELLITE IMAGERY: A CASE STUDY ON JHENAIDAH DISTRICT OF BANGLADESH

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ABSTRACT

Water and vegetation cover are the two most important land cover features of any natural setting. The Jhenaidah District of Bangladesh is known for its remarkable physical geography, featuring diversified vegetation cover and numerous oxbow lakes. Due to several anthropogenic causes this majestic land cover is degrading rapidly. This study examines the spatiotemporal water and vegetation cover change of the study area from 1990 to 2020. Freeware Satellite imageries from USGS data archive was used as the main secondary data source, ensuring consistency by collecting images of the dry season. In addition, open discussion with the residents provided valuable insights into the situation. Remote sensing (RS) based Soil Adjusted Vegetation Index (SAVI) was used to detect the water and vegetation cover from the preprocessed satellite imageries. Furthermore, the water and vegetation cover were classified based on a classification scheme developed by field observation and discussion with the residents. The analysis reveals an overall 84.47% decline in dense vegetation, 63.01% decline in deep water cover, 185.69% increase in shallow water cover and 16.08% increase in agricultural lands within the mentioned time frame. Almost all the upazila of Jhenauidah district experience the criticality of the land cover change. Among the upazila Shailkupa faced unprecedented decline in deep water (95.29%), Kaliganj faced heavy decrease in forested vegetation (92.40%) whereas shallow water expanded significantly in Sadar upazila (251.37%) and agricultural land experienced most increasing trend (32.70%) in Shailakupa Upazila.

INTRODUCTION

Bangladesh, a riverine and agriculture-dependent nation, is acutely aware of the paramount significance of water as the primary resource for agricultural sustenance (Huque *et al.*, 2013). The absence of this vital element can unleash a profound negative impact on agricultural production, thereby engendering potential shifts in the delicate balance of the ecosystem (van Schilfgaarde, 1994). Terrestrial vegetation, on the other hand, can play an important role in providing the environmental context and shaping the dynamics of regional and global ecosystem processes by meeting a variety of needs ranging from local uses such as cooking fuel to industrial utilization for construction materials. (Samrat *et al.*, 2023; Hérault & Piponiot, 2018; Lafleur *et al.*, 2018; Lee *et al.*, 2014; Sun & Liu, 2020). Jhenaidah, a region nestled in the southwestern part of Bangladesh, boasts a prominent expanse of *Baor*, which is considered one of the invaluable wetlands dotting the Bangladeshi landscape (Samad *et al.*, 2022) and is reputed for moderate to dense vegetation cover but urbanization causing deforestation. Anthropogenic factors also reduce the number of wetlands in this region has undergone a drastic decline over the past four decades (Mustafa *et al.*, 2010). Most of the areas in Bangladesh facing the changing trend of LULC and as a result the biodiversity is despoiling day by day. Furthermore, due to high industrialization, the water and vegetation cover declining rapidly not only in Bangladesh but also all over the world. Water availability and vegetation cover serve as pivotal

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components within Earth's intricate ecosystems, wielding significant implications for both ecosystem services and human well-being. Diminished water supply and vegetation cover can lead to drought conditions, adversely affecting the survival of plants, animals, and humans particularly in areas already grappling with the scarcity of this vital resource. The consequences of water scarcity can manifest in reduced crop yields, thereby unleashing serious ramifications for food security. According to a study by the United Nations, certain regions could experience up to a 50% reduction in crop yields due to water scarcity by 2050 (Mekouar, 2019). As the reduction in vegetation cover and the loss of wetland ecosystems are interconnected, LULC assessment can provide valuable insights into the dynamic change in nature, biodiversity, and the economic condition of the people and overall ecological health of the region.

The primary goal of this study is to evaluate the overall spatiotemporal water and vegetation cover change of the Jhenaidah district from 1990 to 2020 using multispectral satellite imageries. Additionally, this study tries to find out the upazila wise change dynamics focusing on the change magnitude of each vegetation and water cover. Furthermore, it also attempts to understand the possible causes behind the change. RS index-based method e.g., SAVI was applied to detect the water and vegetation cover from the preprocessed satellite imageries. Moreover, the water and vegetation cover were classified based on a classification scheme developed by field observation and discussion with the residents.

This article is divided into six major sections e.g., introduction, literature review, materials and methods, results, discussions, and conclusions. In the first section, background, justification, objectives, and brief information on methods is presented. In the literature review section, some latest relevant research is presented which helps to find out the research gaps and formulation of hypothesis. In the third section, detailed methodological framework is discussed sequentially which covers details of the materials and methods used. The result section represents the findings of the upazila wise LULC assessment and the discussion section explains the overall change dynamics of the study area. The last section represents the general summary of the findings, implications and recommendations, research limitations and suggestions for future research.

LITERATURE REVIEW

In the arid regions of Northwest China, alterations in water availability have been found to strongly correlate with changes in vegetation cover, highlighting the profound influence of water on vegetation extent (Gao *et al.*, 2017). Given Bangladesh's heavy reliance on agriculture and vulnerability to climate change, it presents an intriguing case study for investigating water and vegetation cover changes using multispectral satellite images. In a separate investigation, Uzzaman et al. (2020) utilized multispectral Landsat satellite imageries of 1991, 2001, 2011, and 2021 to identify transformations in water bodies and vegetation cover within the Sundarbans, an expansive mangrove forest in southwestern Bangladesh. The study revealed a decreasing trend of forest vegetation and a subsequent increase of water bodies during the study period, attributed to a combination of anthropogenic factors like deforestation, coastal accretion, and erosion. Water scarcity is a major global concern, inducing shifts in plant communities with some species attaining dominance while others face extinction (Jury & Vaux, 2007). Dhaka city has experienced significant reductions in wetland area (76.67%) and rivers and canals (18.72%) over the past three decades (Mahmud *et al.*, 2011). This undeniable alteration can be attributed to the relentless encroachment of agricultural pursuits and the relentless march of urbanization that has persistently ravaged the pristine wilderness (Hossain *et al.*, 2023). According to a study that employed NDVI and supervised classification approach, between 1989 and 2020, urbanization, agricultural activity, and weather condition changed about 49.25 percent of the vegetation cover in the Barguna district (Islam *et al.*, 2023; Morshed *et al.*, 2022). In Jhenaidah, a region in the southwestern expanse of Bangladesh, water and vegetation dynamics are of utmost importance due to its substantial expanse of *Baor*, an influential wetland (Kundu *et al.*, 2018; Mredul *et al.*, 2021). Regrettably, these vital wetlands have undergone a precipitous decline over the past four decades (Mustafa *et al.*, 2010), underscoring the need for meticulous analysis to understand the implications on nature, biodiversity, and socioeconomic well-being. According to Rahman et al. (2017), the rate of increase in urban areas in Jhenaidah is 0.25 km^2 /year leading agriculture and vegetation to a decline of 0.14 km^2 and 0.06 km^2 per year respectively. In a study conducted by Hasan et al. (2021), over 29 years, notable changes were observed in the urban area, woodland, water bodies, and vegetation cover. Water bodies and forest areas accounted for 9.20% and 3.86% of the total area, respectively. During this period, urban areas expanded, converting 5.18% of the land, which now comprises 6.27% of the total area. Additionally, there was a positive development in vegetation cover, increasing by 3.36%.

It is evident that the study on vegetation and water cover is highly important in Bangladesh. While significant water and vegetation-related research has been conducted in adjacent areas, Jhenaidah remains unexplored in this regard. Furthermore, spatiotemporal change study on natural land cover using satellite indices is highly admissible throughout the world, which can help land use planners and policymakers in sustainable land use planning and development.

MATERIALS AND METHODS

Study Area

Jhenaidah District lies between 23º13´ and 23º46´ north latitude and between 88º42´ and 89º23´ east longitude. Jhenaidah is surrounded on the north by Kushtia and Rajbari districts, on the east by Magura district, on the south by Jessore district, and on the west by Chuadanga district and India (Fig. 1). The total area of the district is 1,964.77 sq. km (758.60 sq. miles) and is situated within the Ganges-Brahmaputra-Meghna delta region.

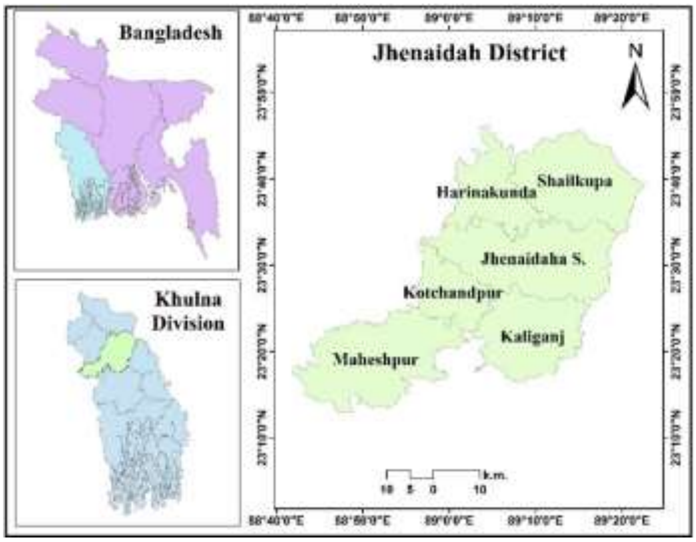


Figure 1. Study Area

Satellite image selection and preprocessing

Landsat satellite images are regarded as an effective tool for detecting and assessing environmental changes owing to their intermediate spatial resolution and accessibility to long-term data. In this study, high resolution multispectral Landsat 5 (TM) and Landsat 8 (OLI) satellite data were acquired from USGS satellite data archive (https://earthexplorer.usgs.gov/). The chosen images were in GeoTIFF format, Level-1 with a minimum percentage of cloud cover (less than 10%) and were projected to Universal Transverse System Zone 46 of the WGS 1984 (World Geodetic System). The details of the acquired satellite imageries are given in table 1. To obtain the bottom-of-atmosphere reflectance, the top-of-atmosphere (TOA) reflectance values of each image were converted by atmospheric modification.

Table 1. Details of acquired Satellite Images

Satellite ID	Sensor ID	Path/Row	Acquisition Date	Spatial Resolution	Image Quality
LANDSAT 5	TM	138/44	1990-01-30	30	9
LANDSAT 5	TM	138/44	2000-02-11	30	7
LANDSAT 5	TM	138/44	2010-02-06	30	9
LANDSAT 8	OLI_TIRS	138/44	2020-02-02	30	9

Spectral Index

In remote sensing, various indices such as NDVI, NDWI, NDBI, SAVI, NDSSI, etc. are used to perform change detection. These indices generate values ranging from -1 to +1. In this study, the soil-adjusted vegetation index (SAVI) was calculated using Equation 1. The SAVI is an index used to assess vegetation cover and health while accounting for variations in soil brightness. It was developed as an enhancement of the Normalized Difference Vegetation Index (NDVI) to minimize the influence of soil reflectance on vegetation measurements (Fatiha *et al.*, 2013). The SAVI is useful for a variety of applications, such as monitoring agricultural crops, assessing land cover changes, and estimating carbon stocks in forests.

Details of the bands used for SAVI analysis are presented in Table 2. The SAVI formula incorporates a soil adjustment factor, "L," which is determined based on the background soil brightness. Here, L is a soil-adjustment factor ranging from 0 to 1 that controls the influence of soil reflectance on the index. SAVI values typically range from -1 to 1, with higher values indicating denser and healthier vegetation reflectance on vegetation indices (Huete, 1988). The formula is as follows:

$$SAVI = ((NIR - Red) / (NIR + Red + L)) \times (1 + L) \quad \ldots\ldots (1)$$

Table 2. Spectral properties of the bands used in this study

Spectral Region	Landsat 5(TM)			Landsat 8(OLI_TIRS)		
	Band	**Wavelength (μm)**	**Resolution (m)**	**Band**	**Wavelength (μm)**	**Resolution (m)**
Red	3	0.63-0.69	30	4	0.64-0.67	30
Near Infrared (NIR)	4	0.76-0.90	30	5	0.85-0.88	30

Land cover change assessment using the SAVI index

Assessing land cover change using the SAVI can provide valuable insights into vegetation and water cover and changes in land cover over time. Four distinct land cover classes deep water, shallow water, agricultural land, and forested vegetation were determined by on-field observation and interviewing the local people. Then the SAVI values were categorized into four distinct classes by partitioning the threshold values using random classifier and specifying the thresholds for SAVI classification, which are represented in Table 3.

Table 3. The threshold value range used in SAVI classification and classification scheme

Types	Description	Threshold value			
		1990	2000	2010	2020
Deep Water	Perennial waterbodies such as- Rivers, Lakes, Beels, Boar	-0.08-0.03	-0.14-0.03	-0.08-0.03	-0.07-0.03
Shallow Water	Ephemeral water bodies and semi-inundated land	0.03-0.15	0.03-0.09	0.03-0.11	0.03-0.12
Agricultural Land	Crops, paddy, vegetable field	0.15-0.22	0.09-0.18	0.11-0.21	0.12-0.24
Dense/Forested Vegetation	Natural or manmade forests, Plantation	0.22-0.48	0.18-0.41	0.21-0.44	0.24-0.42

Accuracy Assessment

The validity of a defined land cover is determined by its accuracy. Accuracy assessment operations have typically been carried out using either ground truth data or, in contrast, using a few designated points on a previously classified map (Arifeen *et al.* 2021). To accomplish this assessment, approximately 100 random sample points were selected from each classified image (2001, 2011, and 2021). After that those sample points were validated through a reference map. In this study, Google Earth Pro was used as a reference map for assessing the ground truth. A proper examination of the results was carried out using a confusion matrix, which is designated as a powerful tool to ascertain key performance indicators such as user accuracy, producer accuracy, total accuracy, and the Kappa coefficient for every selective year (eq. 2-5).

$$\text{Overall Accuracy} = \frac{\text{Total Number of Corrected Pixel}}{\text{Total Number of Reference Pixel}} \times 100 \quad (2)$$

$$\text{User Accuracy} = \frac{\text{Number of correctly classified pixels}}{\text{Total Number of classified pixels (Row total}}) \times 100 \quad (3)$$

$$\text{Producer Accuracy} = \frac{\text{Number of correctly classified pixels}}{\text{Total Number of classified pixels(Column total)}} \times 100 \quad (4)$$

$$\text{Kappa coefficient} = \frac{(\text{TS}\times\text{TCS}) - \sum(\text{Column total} \times \text{Row total})}{(\text{TS}\times\text{TS}) - \sum(\text{Column total}\times\text{Row total})} \quad (5)$$

Where, TS is the total sample and TCS is the total corrected sample.

RESULTS

Accuracy Assessment Results

The validity of a classified land cover depends on accuracy evaluation. To validate the land cover class obtained from the SAVI for 1990, 2000, 2010, and 2020, the following validations were performed: overall accuracy, kappa coefficient, user accuracy, and producer accuracy. For the entire study area, a total of 100 arbitrary reference points were taken and visualized using Google Earth Pro. A kappa value greater than 0.75 indicates that the classification accuracy is very good, whereas a kappa value less than 40 indicates poor accuracy. (Rahman & Shozib, 2021; Congalton, 1991).

Table 4. Accuracy assessment result of the LULC map

Year	LULC Type	User Accuracy	Producer Accuracy	Overall Accuracy	Kappa Coefficient
1990	Deep Water	100%	96%	76%	0.68
	Shallow Water	65%	96%		
	Agricultural Land	75%	31%		
	Dense Vegetation	69%	88%		
2000	Deep Water	84%	100%	88%	0.84
	Shallow Water	92%	84.46%		
	Agricultural Land	88%	78.57%		
	Dense Vegetation	88%	88%		
2010	Deep Water	88%	95.65 %	90%	0.87
	Shallow Water	80%	86.96 %		
	Agricultural Land	96%	82.76 %		
	Dense Vegetation	80%	96%		
2020	Deep Water	85%	94.44%	88%	0.84
	Shallow Water	88.24%	96.77%		
	Agricultural Land	90%	69.23%		
	Dense Vegetation	88.46%	95.83%		

Upazila-based LULC Assessment

Shailkupa Upazila

The result of the change assessment of water and vegetation cover of Shailkupa upazila is presented in Figure 2 and 3. The analysis found that the dense vegetation cover decreased almost all over the area of Shailkupa. Much of the deep-water cover vanished from 1990 to 2020. Agricultural land expands rapidly in the western part of the Upazila and shallow water cover in the northern part of Shailakupa Upazila. The Kumar River and Nabaganga River in Shailakupa almost died. The main Madhumoti River is in danger. The LULC change statistics of Shailakupa Upazila are given below in Table 5 and Figure 4.

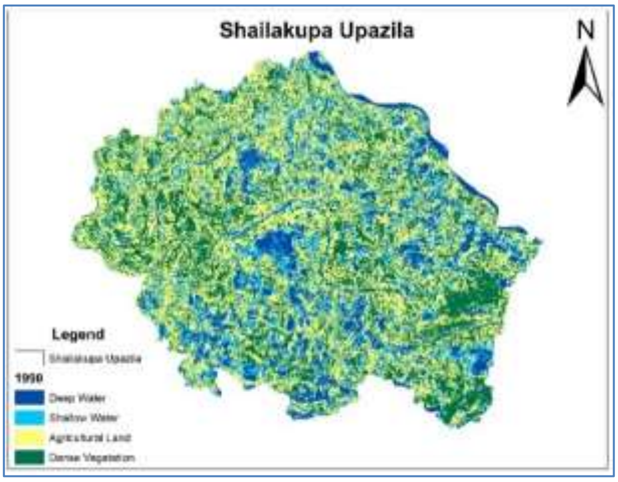


Figure 2. Shailakupa land cover in 1990

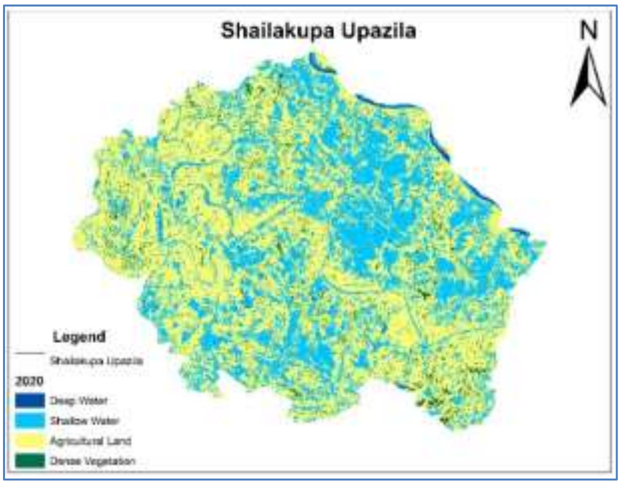


Figure 3. Shailakupa land cover in 2020

Table 5. LULC of Shailakupa Upazila

LULC type	**Change area (ac)**			
	1990	**2020**	**Change Area**	Percentage (%)
Deep Water	15476.82	727.93	-14748.89	-95.29%
Shallow Water	14929.94	34689.35	19759.41	132.35%
Agricultural Land	40772.98	54105.28	13332.30	32.70%
Dense Vegetation	21942.17	3580.01	-18362.16	-83.68%

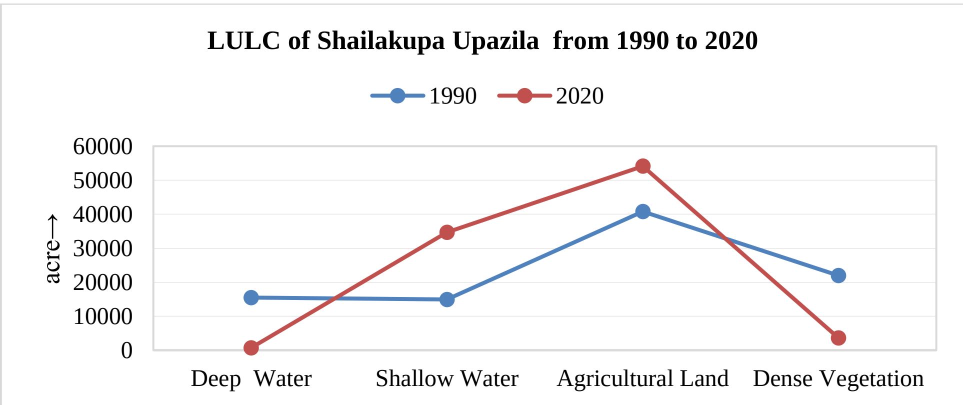
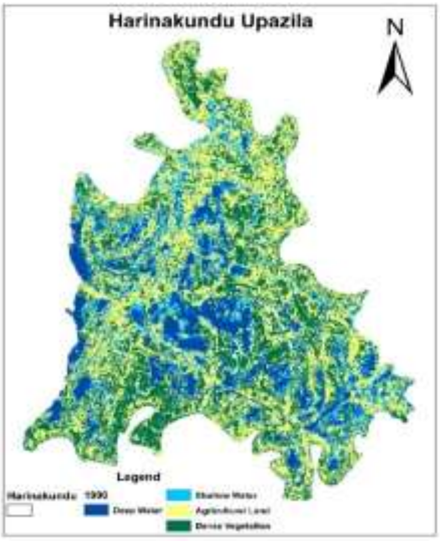


Figure 4. Water and vegetation cover change of Shailkupa Upazila

Harinakunda Upazila

Figure 5 and 6 show that the deep-water cover was replaced by shallow-water cover, and the dense vegetation cover decreased significantly in the whole Harinakundu Upazila. Agricultural land increased mostly in the eastern part of Harinakundu Upazila. The LULC change of Harinakundu Upazila is given below in Table 6 and Figure 7.



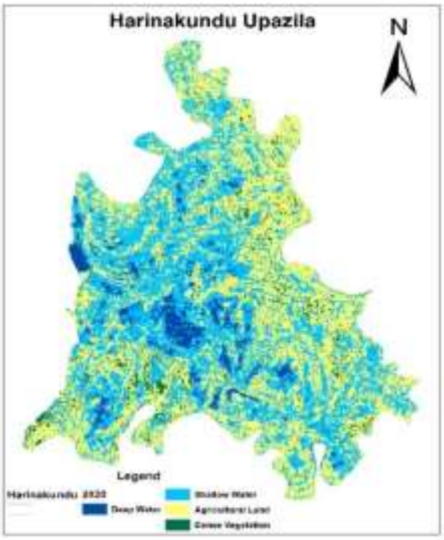


Figure 5. Harinakundu land cover in 1990   Figure 6. Harinakundu land cover in 2020

Table 6. LULC of Harinakundu Upazila

LULC type	Change area (ac)			
	1990	2020	Change Area	Percentage (%)
Deep Water	10854.88	3420.561	-7434.32	-68.48%
Shallow Water	8466.95	24808.31	16341.36	193%
Agricultural Land	22853.65	25940.59	3086.94	13.50%
Dense Vegetation	14054.71	2064.29	-11990.42	-85.31%

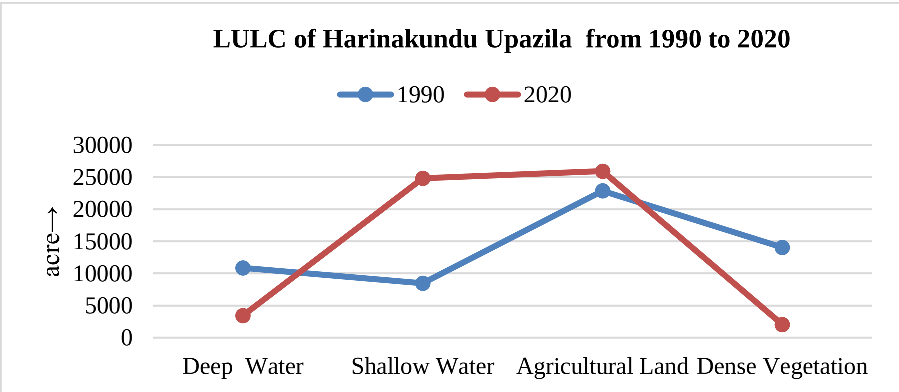
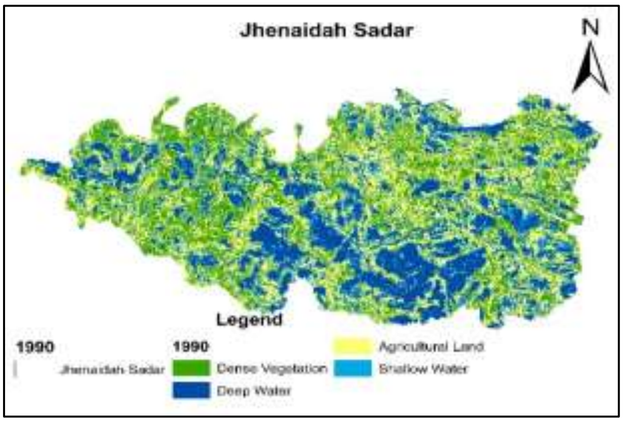


Figure 7. Water and vegetation cover change of Harinakundu Upazila

Jhenaidah Sadar Upazila

Figure 8 and 9 show that the deep-water cover was replaced by shallow water cover, and the dense vegetation cover decreased significantly throughout Jhenaidah Sadar Upazila due to extensive urbanization and industrialization. Agricultural land increased mostly in the eastern part of Jhenaidah Sadar Upazila. The LULC change in Jhenaidah Sadar is given below in Table 7 and Figure 10.



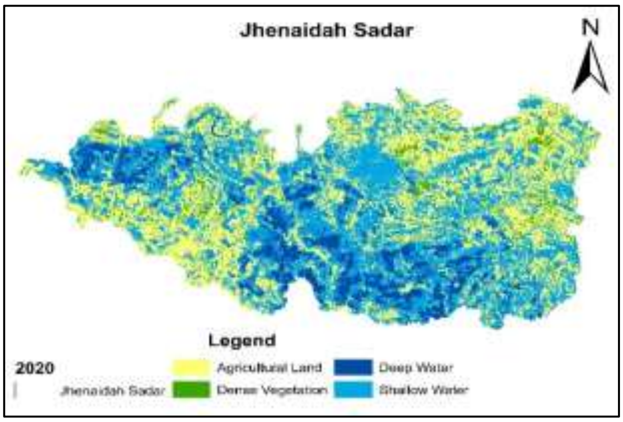


Figure 8. Jhenaidah Sadar land cover in 1990   Figure 9. Jhenaidah Sadar land cover in 2020

Table 7. LULC of Jhenaidah Sadar Upazila

LULC type	Change area (ac)			
	1990	2020	Change Area	Percentage (%)
Deep Water	31581.15	14138.83	-17442.32	-55.54%
Shallow Water	14851.91	52185.55	37333.64	251.37%
Agricultural Land	42516.47	45100.06	2583.93	06.07%
Dense Vegetation	26411.81	3927.65	-22484.16	-85.13%

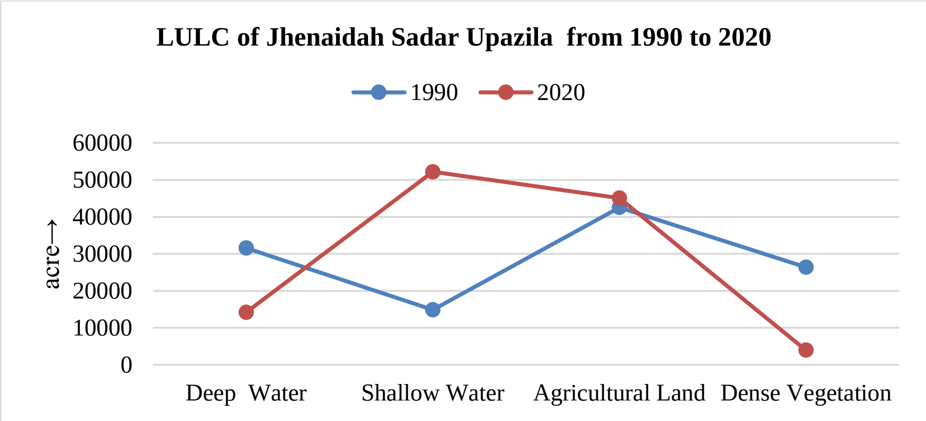


Figure 10. Water and vegetation cover change of Jhenaidah Sadar Upazila

Kaliganj Upazila

Figure 11 and 12 show that the deep-water cover was significantly replaced by the shallow-water cover, and the dense vegetation cover decreased significantly throughout Kaliganj Upazila due to extensive urbanization and industrialization. The dense vegetation cover almost vanished in Kaliganj Upazila. The largest *baor* (Oxbow Lake) **"Marjad *Baor*"** in Bangladesh (Alam & Jahan, 2014) is also in an alarming situation. The agricultural land in Kaliganj Upazila decreased by 2624.07 acres over the last 3 decades. The LULC change in Kaliganj Upazila is given below in Table 8 and Figure 13.

Table 8. LULC of Kaliganj Upazila

LULC type	Change area (ac)			
	1990	2020	Change Area	Percentage (%)
Deep Water	20489.02	10321.35	-10167.67	-49.62%
Shallow Water	11038.83	37217.13	26178.30	237.15%
Agricultural Land	31721.02	29096.95	-2624.07	8.27%
Dense Vegetation	14486.56	1101.51	-13385.05	-92.40%

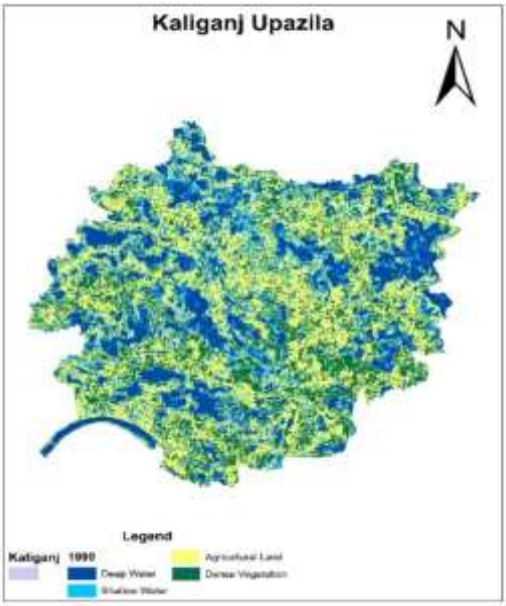


Figure 11. Kaliganj land cover in 1990

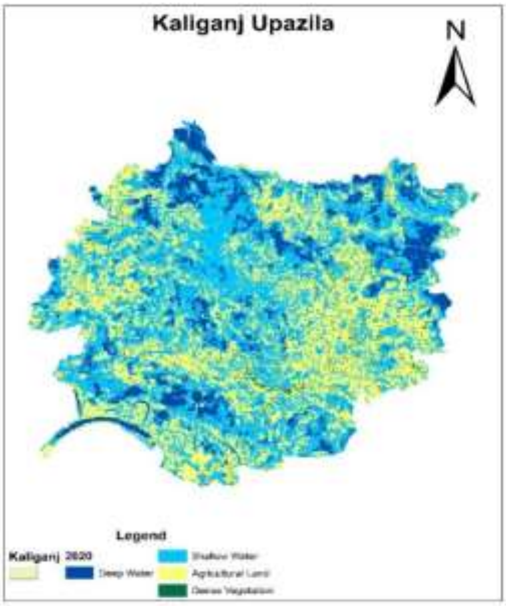


Figure 12. Kaliganj land cover in 2020

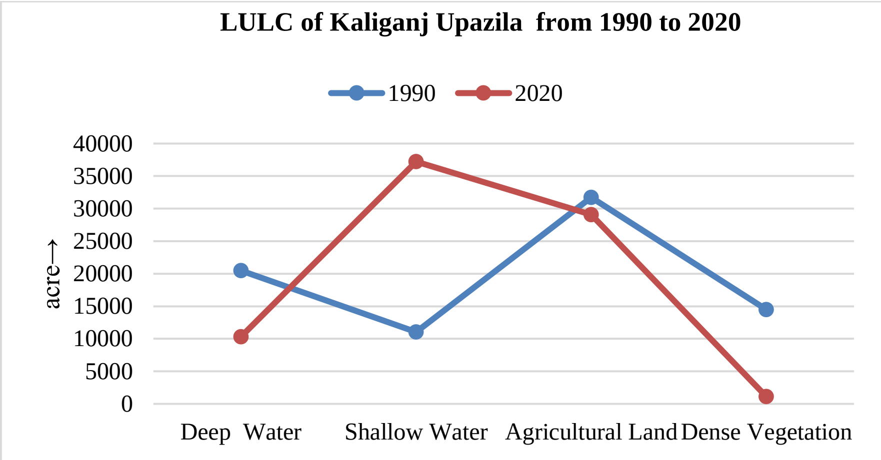


Figure 13. Water and vegetation cover change of Kaliganj Upazila

Kotchadpur Upazila

Figure 14 and 15 show that the deep-water cover was significantly replaced by shallow water cover, and the dense vegetation cover decreased significantly throughout Kotchapur Upazila due to extensive urbanization and industrialization. The dense vegetation cover almost vanished in Kotchadpur Upazila. The Joydia *Baor* and Boluhar *Baor* (Oxbow Lake) in Kotchadpur Upazila are also in an alarming situation. Boluhar *Baor* almost died in the last 3 decades. In the northeastern part of the Kotchadpur, Upazila had Beels that almost died and were replaced by shallow water cover. The agricultural land in Kotchadpur Upazila increased mostly in the western part of Kotchadpur Upazila. The LULC change in Kaliganj Upazila is given below in Table 9 and Figure 16.

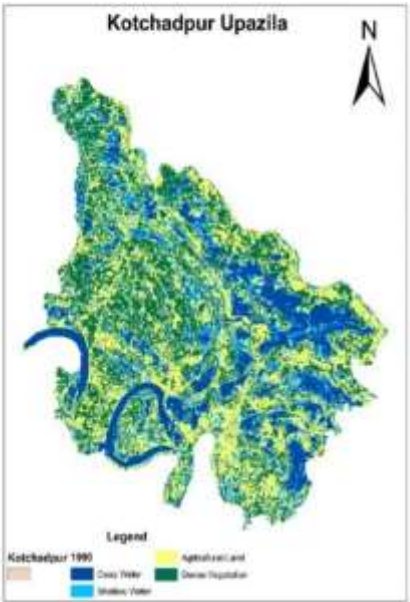


Figure 14. Kotchadpur land cover in 1990

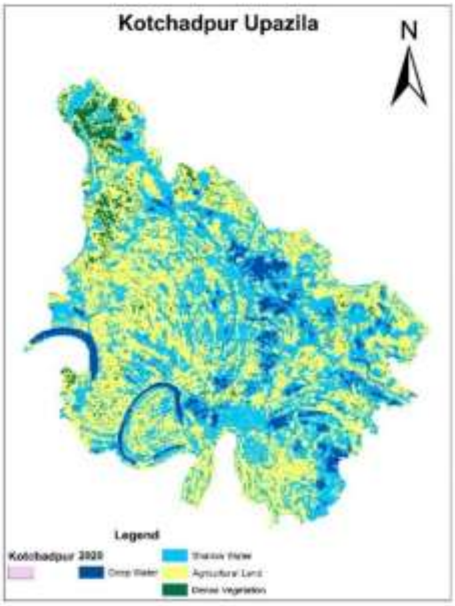


Figure 15. Kotchadpur land cover in 2020

Table 9. LULC of Kotchadpur Upazila

LULC type	Change area (ac)			
	1990	2020	Change Area	Percentage (%)
Deep Water	9701.99	2924.56	-6777.43	-69.86%
Shallow Water	5695.16	17350.30	11655.14	204.65%
Agricultural Land	15854.98	20159.06	4304.08	27.15%
Dense Vegetation	10865.90	1684.83	-9181.07	-84.49%

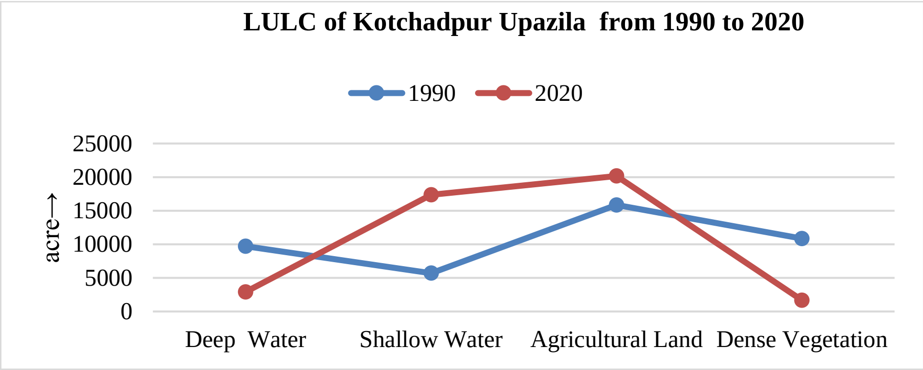


Figure 16. Water and vegetation cover change of Kotchadpur Upazila

Mohespur Upazila

Figure 17 and 18 show that the deep-water cover was significantly replaced by shallow water cover, and the dense vegetation cover decreased significantly throughout Mohespur Upazila due to extensive urbanization and industrialization. The dense vegetation cover almost vanished in Mohespur Upazila. Mohespur Upazila is very important for the *wetland area*, as there are many *baors and beels* situated in this Upazila. The Purapara *Baor*, Nostir *Baor*, Nepar *Baor*, Baghadangar *Baor*, Fatepur *Baor*, Chapatola-Vabnagar-Srinathpur *Baor*, Golla *Baor*, Mirzapur *Baor*, Katgara *Baor*, Khusolpur *Baor* (Oxbow Lake) in Mohespur Upazila and many smaller *baors*. The *beels* in Mohespur Upazila include Mailbariya *Beel*, Ukhri *Beel*, Talsar *Beel*, Dubli *Beel*, Pakrail *Beel* and many more. Those *Baors* and *beels are* also an alarming situation. From the mid to southwestern part of the Mohespur, Upazila is mainly in a wetland area, as there are many *baor* and *beels* situated, which almost died in the last 3 decades and were replaced by shallow water cover. Agricultural activity in the northeastern part of Mohespur Upazila increased. The LULC change in Mohespur Upazila is given below in Table 10 and Figure 19.

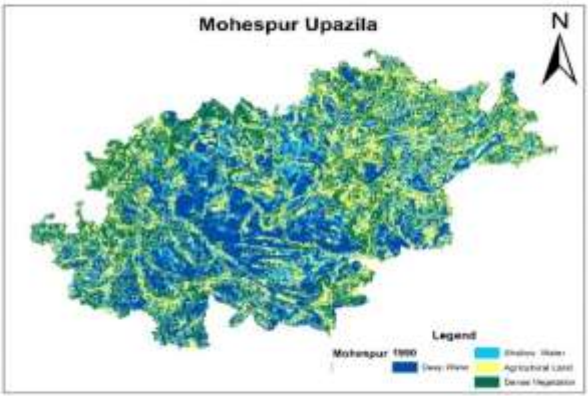


Figure 17. Mohespur land cover in 1990

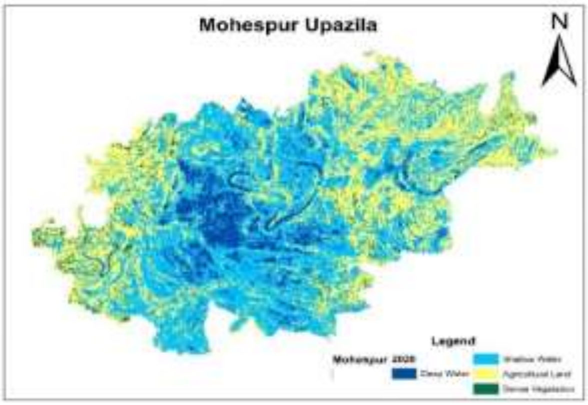


Figure 18. Mohespur land cover in 2020

Table 10. LULC of Mohespur Upazila

LULC type	Change area (ac)			
	1990	2020	Change Area	Percentage (%)
Deep Water	29401.04	10484.30	-18916.74	-64.34%
Shallow Water	15490.85	47665.86	32175.01	207.70%
Agricultural Land	32934.64	39673.48	6738.84	20.46%
Dense Vegetation	23202.22	3213.806	-19988.42	-86.15%

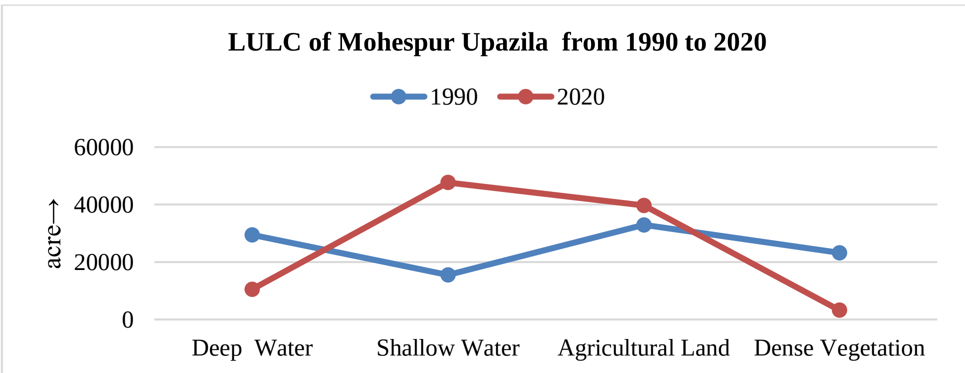


Figure 19. Water and vegetation cover change of Mohespur Upazila

DISCUSSIONS

Year-wise temporal LULC change of the study area is illustrated in Fig. 14 and the overall trend of change is presented in Figure 21. From the figure it is evident that the deep-water bodies and dense or forested vegetation are decreasing significantly whereas the shallow water bodies and agricultural lands are following the opposite trend. The graph shows that from 1990 to 2020, the deep-water cover decreased by 63.01%, and the dense vegetation cover decreased by 84.47%, which is alarming for the environment and biodiversity. In the meantime, shallow water cover and agricultural land increased by 185.69% and 16.08%, respectively.

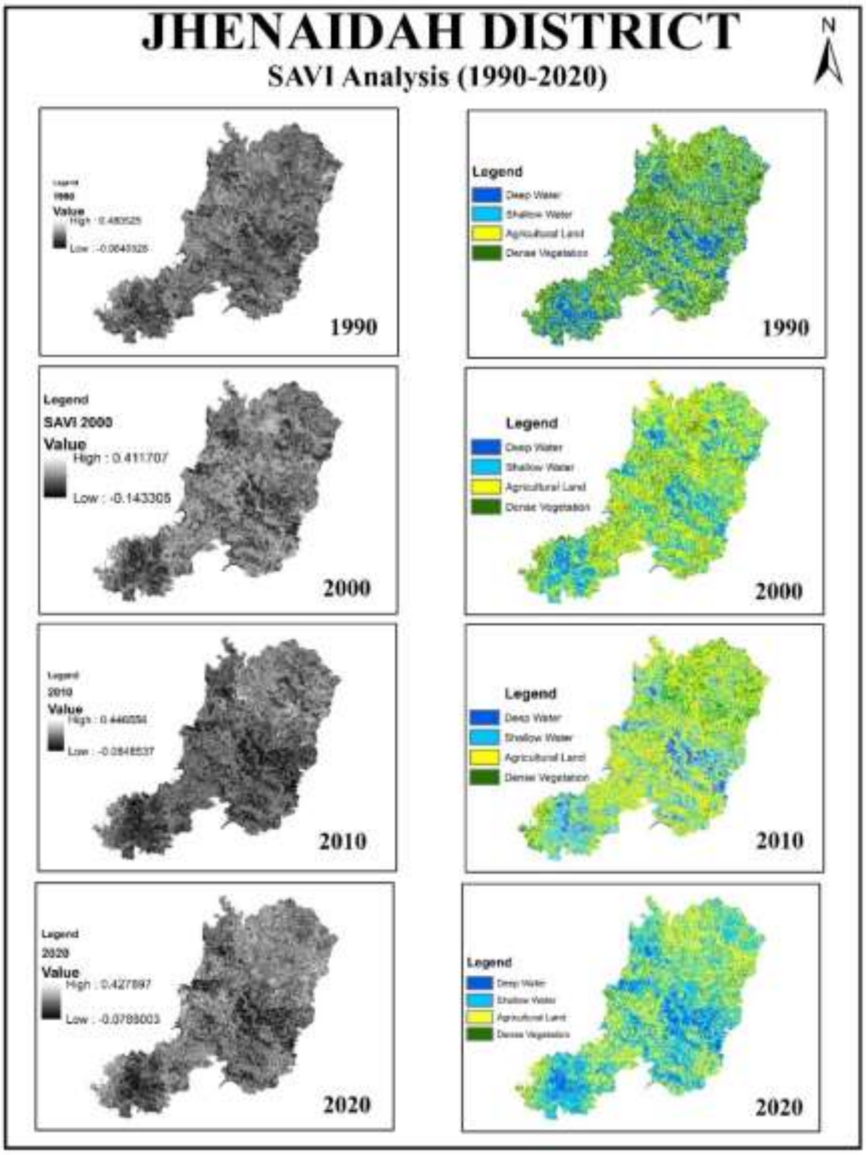


Figure 20. Area covered by different land cover features from 1990-2020

Table 11. Area covered by different Land Cover Feature from 1990-2020

LULC Category	1990		2000		2010		2020	
	Area in Acre	%	Area in Acre	%	Area in Acre	%	Area in Acre	%
Deep Water	116382.9	23.95	30280.59	6.23	26648.66	5.48	43045.38	8.86
Shallow Water	74773.09	15.38	153150.1	31.52	168868.3	34.75	213620.7	43.96
Agricultural Land	182484.1	37.55	251281.3	51.71	233254.6	48	211822.9	43.59
Dense Vegetation	112282.8	23.11	51211.04	10.54	57151.42	11.76	17433.96	3.59
Total Area	485921.97	100	485923.03	100	485922.98	100	485922.96	100

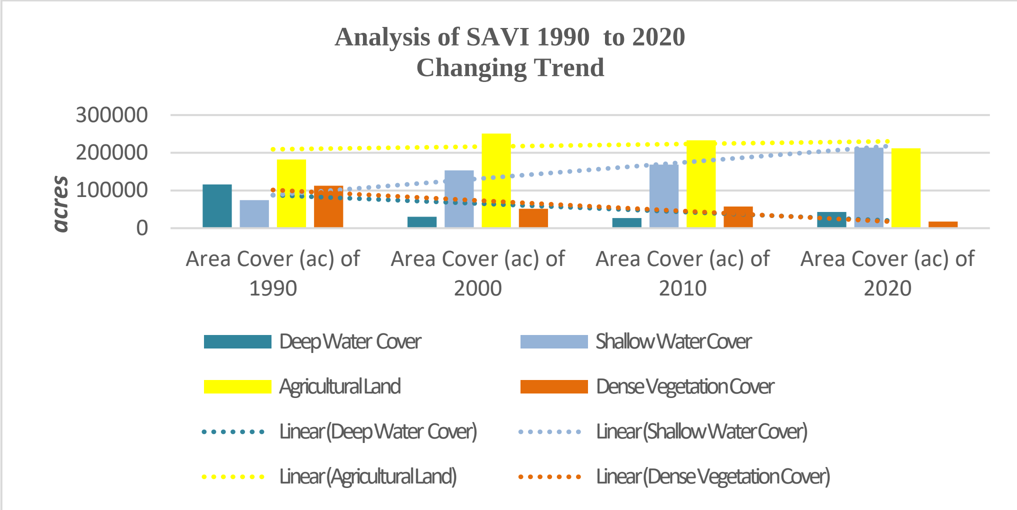


Figure 21. Area covered by different Land Cover Feature from 1990-2020

Table 11 summarizes the temporal magnitude of each land cover feature from 1990-2020, and Table 12 shows the overall temporal LULC change summary for each classified land cover. Most of the deep-water bodies decreased between 1990-2020 about 86100 acres, while shallow water bodies increased heavily about 78377 acres in the same time period. The residents of the study area blamed unplanned urbanization and extensive agricultural growth behind the widespread water cover change. The response of the locals also aligned with the results of the agricultural change as the table 12 shows around 68797 acres of agricultural land have been increased between 1990 and 2000. Most of the dense vegetation also decreased between the mentioned time period.

Table 12. Temporal LULC Change summary of each classified land cover.

LULC type	Change area (Ac)		
	1990 - 2000	2000 -2010	2010 - 2020
Deep Water	-86101.41	-3631.93	16396.72
Shallow Water	78377.01	15717.90	44752.70
Agricultural Land	68797.2	-18026.70	-21431.70
Dense Vegetation	-61071.76	5940.38	-39717.46

From informal interview with the locals, it was found that local government had taken some necessary steps such as extensive afforestation, riverbank management, *baor* conservation, agricultural innovation with mechanization and introduction of hybrid variety etc. after the year 2000. But the management system was not sustainable as the deep-water cover, especially the *baors* and forested vegetation found its declining trend.

CONCLUSIONS

The LULC analysis of Jhenaidah District from 1990 to 2020 demonstrates considerable changes in the landscape. Deep Water and Dense Vegetation coverage declined by 63.01% and 84.47%, respectively, while Shallow Water and Agricultural Land inclined by 185.69% and 16.08%, respectively. At the upazila level, Shailkupa experienced the greatest decline in Deep Water cover (95.29%) and Dense Vegetation (83.68%), while Kaliganj experienced a more modest decrease (49.62% and 92.40%, respectively). Jhenaidah Sadar saw the most increase in Shallow Water (251.37%), while Shailkupa saw the least (132.35%). Shailkupa also experienced the greatest increase in Agricultural Land (32.70%), whereas Jhenaidah Sadar experienced the smallest increase (6.07%). These shifts are mostly driven by growing food supply demand, which leads to increased agricultural land, gentrification, and river management behaviors, all of which contribute to an increase in Shallow Water coverage. Meanwhile, the abundance of built-up regions has reduced Dense Vegetation across Jhenaidah.

This research can be a cost-effective solution to land use land cover monitoring and management. Index based method assures reliability and accuracy as it consists of both automated and manual approach which is maintained in every step of this research. Furthermore, the calculated threshold values for water and vegetation cover identification might be applied to satellite-based vegetation and water cover delineation of similar landscapes.

One of the study's major weaknesses is its reliance on publicly available data sources for land cover research. The precision of the conclusions may be influenced by the accuracy and resolution of the data used. To increase accuracy, future studies could benefit from employing higher-resolution and more recent satellite images or combining ground-based data. While this analysis identifies significant changes in land cover, no direct causal links are established. Various underlying variables, such as socioeconomic advancements, policy initiatives, or climate fluctuations, could be driving these shifts. Further research using advanced modeling approaches or doing field surveys could aid in determining the underlying causes of the observed trends. The research is being carried out at the district level, which may obscure local-scale variability in land cover changes.

Future research should look into doing studies at a finer geographical scale in order to capture more localized trends and understand the variety of land use changes within the district. Extending the analysis to larger time frames could also provide a more complete knowledge of land cover patterns and their effects throughout time.

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