CARBON CONSEQUENCES OF DEFORESTATION IN KHAGRACHHARI OF CHITTAGONG HILL TRACTS: A GIS AND REMOTE SENSING APPROACH

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ABSTRACT

The Chittagong Hill Tracts (CHT) in Bangladesh are ecologically significant for their role in carbon absorption and storage. However, in recent years, the CHT have faced severe deforestationand forest degradation due to various factors, including illegal logging, agriculture expansion, infrastructure development, and population pressure. This rapid loss of forest cover disrupts the region's rich biodiversity and ecosystems but also diminishes its capacity to sequester carbon. Thus, the primary objective of this study is to rigorously assess the profound impacts of deforestation on carbon storage within the Khagrachhari district of the CHT, spanning the past three decades, utilizing advanced remote sensing methodologies. Analysis revealed a surprising 40.50% reduction in forested land, with dense forest land decreasing by 21.11%, corresponding toannual deforestation rates of 36.49 square kilometers and 19.35 square kilometers, respectively, driven by population growth and urbanization. This resulted in a significant increase in carbon emissions, from 0.36 million tons per year to 3.18 million tons per year. In addition, there was a significant decline in carbon absorption capacity, declining from 5.26 million tons/year in 1990 toa mere 1.99 million tons/year in 2000. These revelations underscore the urgency of addressing deforestation in the CHT and emphasize the critical role of conservation efforts in mitigating the escalating carbon footprint associated with this ecological crisis.

Keywords: Land-use base carbon emission, NDVI dynamics.

1. INTRODUCTION

The degradation of hill and forest land is growing with time in hilly tracts of Chittagong regions, making the places more susceptible to natural disasters. Both urban and hilly areas are experiencing the harmful effects of population increase and urbanization (Barua & Haque, 2011).This is causing a significant change in the hilly areas' topography and land cover type (LCT). Changes in the environment have been brought about by the destruction of the most significant natural resources in Bangladesh's hilly regions, its forests. Throughout the past century, and particularly in the last several decades, issues including global warming, rising CO_2 and carbon emissions, and reduction in hilly regions' potential to absorb carbon have gotten worse. (Ahmed B., 2015). Although previous studies have shed light on landslide causes and effects in mountainous regions, research has largely overlooked the unique carbon emission dynamics of these areas. (Ahmed B., 2015) (Alam, et al., 2019) (Biswas, Swanson, & Vacik, 2020) (Hasan, Sarmin, & Miah, 2019). Notably, deforestation significantly impacts emissions patterns, but complex land cover changes in hilly regions have hampered existing studies' ability to accurately assess this interplay. This research pioneers a novel approach in the Khagrachhari district of the Chittagong Hilly Tracts by employing remote sensing and the Normalized Difference Vegetation Index (NDVI) to analyze land cover and carbon emission trends over three decades. By classifying satellite imagery at two-year and five-year intervals, this study enhances both carbon emission trend analysis and NDVI utilization, providing valuable insights into the interplay between land cover and emissions in this previously understudied region.

About 12% of Bangladesh is made up of mountains or hilly terrain. (Biswas, Swanson, & Vacik, 2020) (Ahmed, et al., 2021). Because of the population growth in the hilly parts, as well as the provision of food and shelter to this rising population, the terrestrial and environmental conditionsin Khagrachhari's mountainous areas are deteriorating (Rasul & Thapa, 2003) (Argha, Hasib, & Rahman, 2021). Similar to other hilly regions in Southeast Asia, the Khagrachhari district of the Chittagong Hilly Tracts are prone to deforestation, soil erosion, and land degradation as a result ofenvironmentally unsuitable human activities such as clearing forest land, shifting farming, zoom farming, and house construction. As such, there are less forests and more agricultural, urban, and grasslands than there formerly were (Duguma, et al., 2019), (Rasul, Thapa, & Zoebishch, 2004) (Chowdhury H.,2023). Any region's carbon emissions and absorptions drop when forest land declines and grassland cover expand. (Cui, et al., 2018), (Baniya, Tang, Huang, Sun, & Techato, 2018). The result is an increase in the net carbon output of Khagrachhari area. The population, housing stock, and infrastructural development in Bangladesh's hilly regions have all expanded, especially after 1991, according to the BBS report from 2011. Deforestation in the hilly regions has risen as a result since 1990. In the mountainous regions of Khagrachhari, this study evaluated the dynamics of land cover and carbon emissions from 1990 to 2020 (Chowdhury & Asiabanpour, A Smart Circular Economy for Integrated Organic Hydroponic-Aquaponic Farming., 2023) .

The Normalized Difference Vegetation Index (NDVI), considered as an indicator of vegetation activities is the normalized ratio of red and near-infrared(NIR) reflectance of satellite images (Piao,et al., 2003). At both regional and global scales, vegetation dynamics are detected using the NDVI.The various NDVI value ranges represent various land cover categories, which aid in determiningthe dynamics of an area's land cover. The range of values for the NDVI is ±1. A dense forest is indicated by an NDVI value greater than zero, and waterbodies are indicated by a value less than zero (Zhang, et al., 2013). The NDVI can be used to measure ecological factors like biomass, photosynthetic activity, plant productivity, tropical interaction, plant phenology, and the global carbon cycle (Zhao, Tan, Zhao, & Fang, 2011). NDVI can also be used to measure vegetation, which is the primary component of carbon cycles. The dynamics of forest energy, land degradation, drought monitoring, and land cover classifications have all been linked to NDVI (Stibig, et al., 2006). The objective of this research is to enhance comprehension of the NDVI dynamics and their effects on the carbon dynamics in Khagrachhari District of Chittagong Hilly Tracts between 1990 and 2020. In order to assess the existing and evolving paradigm of forest land, grassland, and carbon emissions in the hilly areas for better environmental and ecological management, the study was specifically developed to discover long-term NDVI trends in Khagrachhari. Overall, the study showed a connection between long-term NDVI changes and theimpact of carbon emission and absorption on land cover dynamics, which will increase scientific understanding of the climate and ecology of Khagrachhari District of Chittagong Hilly Tracts. The causes and effects of land sliding in Chittagong's hilly areas have been examined in previousstudies, (Rasul, Thapa, & Zoebishch, 2004), (Rabby & Li, 2020), (Alam, et al., 2019), (Sultana, 2020), (Ahmed B., 2015) along with suggestions for lowering the risk of land sliding. The land use patterns in Bangladesh's hilly regions have been demonstrated in a number of studies (Biswas,Swanson, & Vacik, 2020), (Hasan, Sarmin, & Miah, 2019), (Rai, Zhang, Paudel, Li, & Khandal,2017), (Islam, Hasan, & Chowdhury, 2006) However, no studies have been conducted to examinethe connection between carbon emissions and land cover patterns, and the associated impact on the environment. Land sliding has received special attention in these research. Even though severalresearch has concentrated on the hilly regions of Bangladesh, no studies have been done on the dynamics of land cover and deforestation in the Khagrachhari area. For improved environmental and ecological management in the Khagrachhari district of Chittagong Hilly Tracts, the study evaluated the long-term NDVI trends in Khagrachhari to determine the existing and evolving paradigm of forest land, grassland, and carbon emissions. Additionally, environmentaldeterioration and the reduction of GHG emissions are now major global concerns (Khan, Argha, & Anita, 2021). To prevent environmental degradation in Bangladesh's hilly regions, the assessment of the trend in carbon emissions and the research findings would provide valuable information.

2. METHODOLOGY

2.1 Study Area

The region of Khagrachhari is hilly. It is bordered by India's Tripura state on the north; Chittagong and Rangamati districts border it on the south; Rangamati district borders it on the east; and Tripura state and India's Chittagong district border it on the west. The district of Khagrachhari has eight upazilas. According to BBS (2011), the district has a total size of 2749.16 sq. km, or 8.9% of the entire area of Turmeric (Pranta, Ahmed, & KUMER, 2019) (Begum, Miah, Rashid, Islam, & Hossain, 2019).

Table 1: Study Area at Glance

Criteria	**2011**	**2001**	**1991**	**1981**	**1974**
Population	613917	525664	342488	278461	188975
Density (per sq.km)	223	195	127	103	70
Growth rate	1.54	4.38	2.09	3.95	3.41
Household	132503	105823	68972	47574	35721

(Source: BBS, 2011)

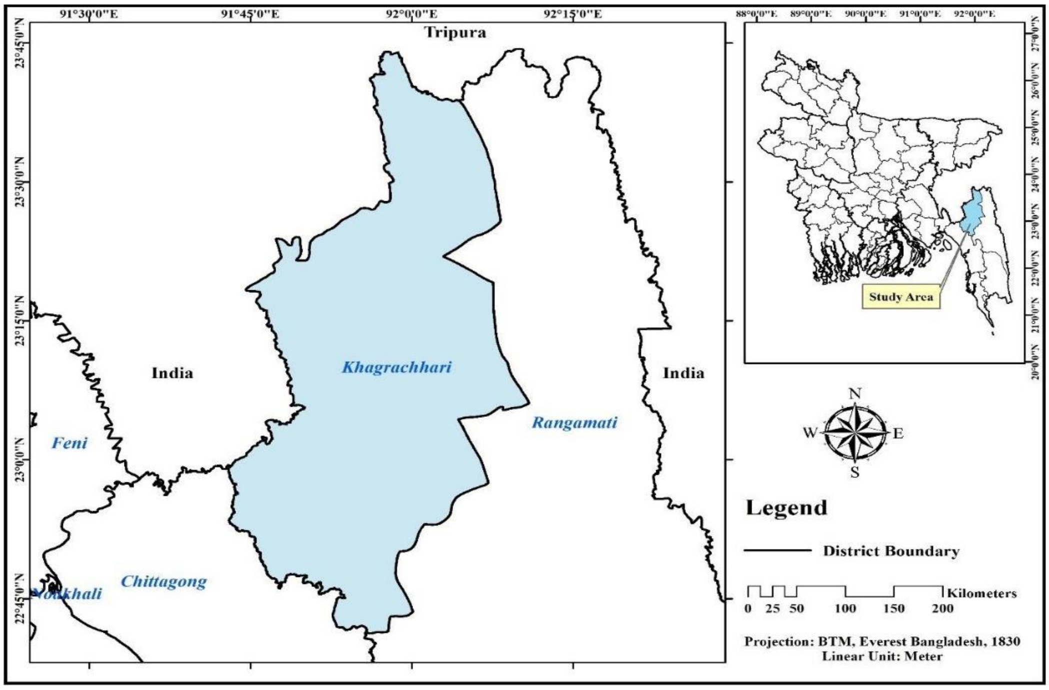

Figure 1: Study area map (Source: Author, 2020)

2.2 Managing Remotely Sensed Images

Tracking changes in land use and cover, as well as NDVI, NDMI, NDBI, and LST changes, has shown to be a benefit of using remote sensing photos (Parvin & Abudu, 2017), (Sahana, Ahmed, & Sajjad, 2016), (Xu, 2006), (Grigoraș & Urițescu, 2019) (Roy, et al., 2020). The United States Geological Survey (USGS) website provided the Landsat 5TM and Landsat 8 OLI photos (30m resolution) that were utilized in this work to detect NDVI changes. The photos were downloaded from March to April in order to prevent the seasonal shift. Even though there was less than 10% coverage of land clouds and scene clouds, atmospheric and radiometric correction was carried outto prevent environmental impacts on the photos.

Table 2: Landsat Image Used in the Study

Year	Sensor	Path/ Row	Acquisition Date		
1990- 2012	Landsat 5TM	136/44	1990/03/30, 1996/02/18, 2004/03/19, 2008/03/06,	1992/03/13, 1998/03/27, 2005/02/26, 2010/02/08,	1994/03/16, 2000/02/13, 2006/02/28, 2012/02/27,
2014-2020	Landsat 8OLI	136/44	2014/03/19, 2018/03/27,	2015/03/26, 2020/02/04,	2016/03/01,

2.3 Calculating Normalized Difference Vegetation Index (NDVI)

Landsat's multi-spectral sensor's near-infrared and red spectral bands are used to determine the NDVI. (Grigoraș & Urițescu, 2019). The idea of NDVI estimation is based on the highest reflectionof light in the near-infrared (NIR) spectral band and the absorption of radiation in the red (R) spectral band.

$$NDVI = \frac{NIR\ Band - RED\ Band}{NIR\ Band + RED\ Band} \quad \text{(i)}$$

The vegetation index (NDVI) ranges from -1 to +1, where values near -1 indicate minimal vegetation and values near + 1 indicate abundant vegetation. Variations in NDVI levels correspondto different types of land use. (Piao, et al., 2003), (Cui, et al., 2018). To identify the various land use types in this study, the NDVI value range is split into four ranges with the same interval.

Table 3: NDVI Value Range for Different Land Cover Types

Range	Land Cover types	Range used in this study	Land Cover types
-1.0 to 0	Waterbodies	-1.0 to 0.0	Dense Waterbodies
0.1 to 0.2	Barren rocks/ sand	0.0 to +0.2	Grass land
0.2 to 0.5	Grasslands/ crops	+0.2 to +0.6	Forest
0.6 to 1.0	Dense Vegetation	+0.6 to +1.0	Dense Forest

2.4 Carbon Emissions

The study focuses on changes in land cover from 1990 to 2020 and the carbon emissions caused by deforestation. The carbon emissions from land usage may be estimated using the following formula. (Cui, et al., 2018).

$$Ei = \sum ei = \sum Si \times \delta i \times (\frac{M_{CO2}}{M_C}) \quad (2)$$

Where,

Ei = Carbon emissions from land use
i = land-use type
Si = Area of land i
δi = Carbon emission coefficient for land i
M_{CO2} /M_C = 44/12 = 3.6667

Positive values of δi imply carbon emissions, whereas negative values signify carbon absorption. (Cui, et al., 2018). Through the use of the NDVI calculation, several land use types were discoveredin this study, and earlier studies have suggested a value for the land use type's carbon emission coefficient. The majority of Bangladesh's grassland is farmed in its mountainous regions. For the purposes of this study, cropland and grassland have been combined to become grassland. Table 4compiles the carbon emission coefficients from earlier research for the various land covercategories. (Fang, Guo, Piao, & Chen, 2007), (Cui, et al., 2018), (Hong-xin, Xing-min, Ying-long,& Ming-quan, 2012).

Table 4: Carbon emission coefficient for different land cover types

Land-use Type	Carbon Emission Coefficient (kg (C).$m^{-2}.a^{-1}$)
Dense water bodies	-0.0459
Grass land	0.0497
Forest	-0.0527

Dense forest	-0.0645

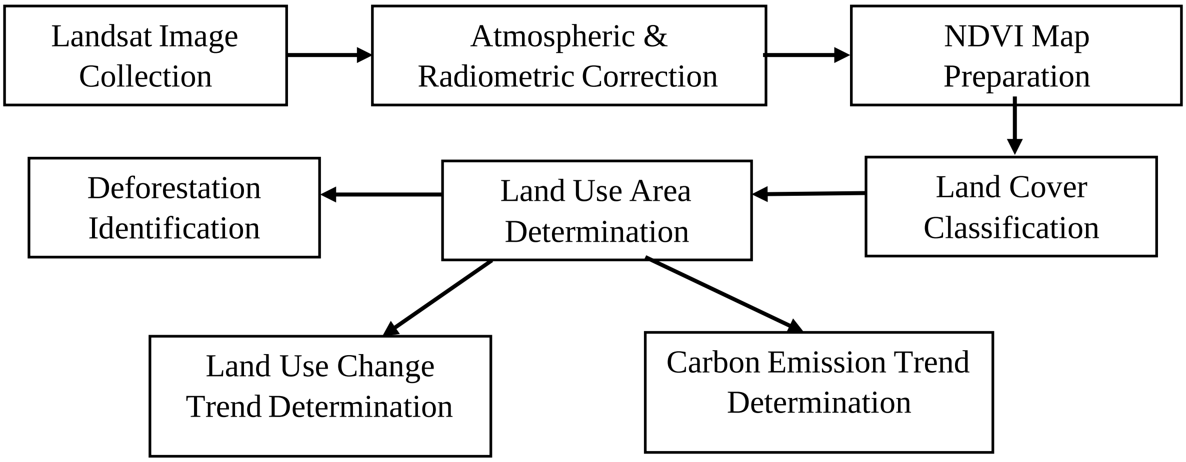

Figure 2: Procedural methodology framework of this study.

3. ANALYSIS AND INTERPRETATION

3.1 Vegetation Health Trends

The NDVI values range from -1 to +1. The densest forest or the area with the healthiest vegetationis indicated by an NDVI value greater than 0.6. Waterbodies are indicated by NDVI values less than 0, non-vegetative areas or grasslands by values between 0.01 and 0.2, and poor vegetation orforest land by values between 0.2 and 0.6. Figure 4 shows a decrease in Khagrachhari's dense forest area between 1990 and 2020. Over the course of the study, there has been a significant risein the grassland or non-vegetated cover area. The NDVI range was -0.255 to +0.977 in 1990, according to Table 5, but it progressively shrank over the course of the study and was between -0.316 and +0.601 in 2020. The NDVI trends in Chittagong's Khagrachhari hilly areas are displayedin Fig. 3. With a value of R2=0.5936, the NDVI's higher value has been greatly lowered. The NDVI upper value was less than 0.6 in 2008, 2016 and 2017.

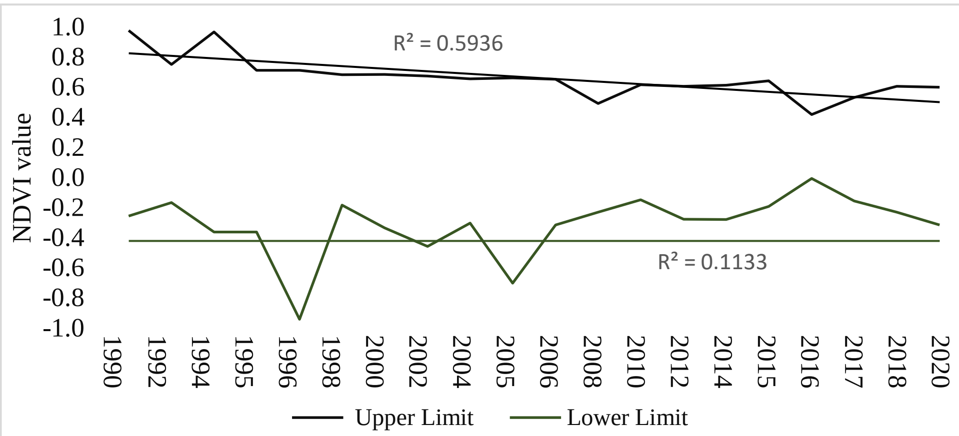

Figure 3: Khagrachhari's NDVI trends from 1990 to 2020 (Source: Author, 2020)

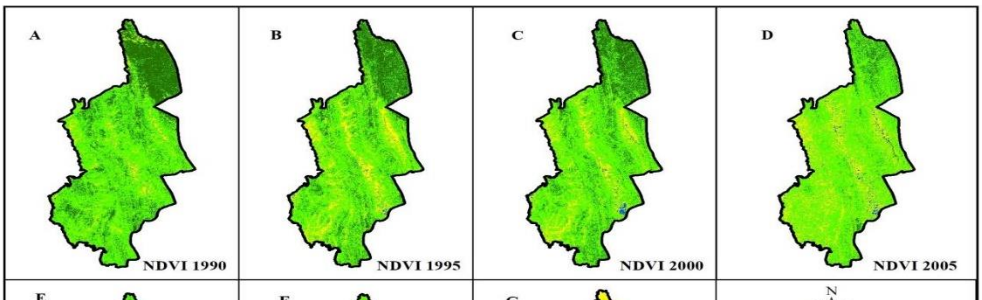

Figure 4: The NDVI map of Khagrachhari district for the years (A) 1990, (B) 1995, (C) 2000, (D) 2005, (E) 2010, (F) 2015, and (G) 2020 illustrates the classification of land cover types and the four NDVI classes according to the NDVI threshold values. (Source: Author, 2020)

Table 5: NDVI dynamics at Khagrachhari between 1990 to 2020

Year	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Higher Limit	0.977	0.712	0.686	0.662	0.618	0.642	0.601
Lower Limit	-0.255	-0.362	-0.333	-0.702	-0.147	-0.191	-0.316

(Source: Author, 2020)

3.2 Land Cover Change

Based on NDVI threshold values, four categories of land cover have been identified in this study to describe the dynamics of land cover in Khagrachhari district during the course of the study period. Table 6 and Fig.5 at 5-year intervals show the land cover percentage dynamics in the research area over the course of several years.

Table 6: Land cover type scenario in different year at Khagrachori

Year	**Unit**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Water-bodies	Area(km^2)	10.83	15.74	25.94	41.49	41.49	64.71	139.56
	Percentage	0.39%	0.57%	0.94%	1.51%	1.51%	2.45%	5.08%
Grass land	Area(km^2)	197.84	433.35	364.71	589.17	1395.49	1082.77	1744.11
	Percentage	7.18%	15.76%	13.27	21.43%	50.76%	39.39%	63.44%
Forest	Area(km^2)	1776.27	1678.40	1771.52	1782.01	1159.05	1439.53	73.83
	Percentage	64.61%	61.05%	64.44	64.82%	42.16%	52.36%	24.78%
Dense Forest	Area(km^2)	764.58	621.66	586.99	336.50	153.13	159.45	184.19
	Percentage	27.81%	22.61%	21.35%	12.24%	5.57%	5.80%	6.70%

(Source: Author's calculation, 2020)

The ratio of dense forest and forest area has drastically decreased, as Table 6 illustrates. There hasbeen a reduction of about 39.83% of forest land and 21.11% of the densely forested area. With anR2 value of 0.8288, Fig.6 illustrates the notable decline in sense forest land. However, over the course of the study period, the grassland area and non-vegetated cover area have gradually risen. The amount of grassland cover has increased by roughly 56.36%, with a co-efficient of determination of R2 = 0.8453 (Fig. 6). After 2000, there has been a noticeable shift in the land cover. Between 2000 and 2010, there was a 9.11% decrease in the thick forest area and a 37.49%increase in the grassland cover area. The primary driver of this land cover dynamic in the Khagrachhari area has been population growth. These types of landforms pose a threat to the distinctive features of hilly regions. According to Table 1, the total number of houses in the Khagrachhari district more than doubled between 1991 and 2011, while the district's population expanded by around one lakh between 2001 and 2011. The significant decline in the amount of forest land in the study area can be attributed to the high rate of population expansion and the construction of more homes.

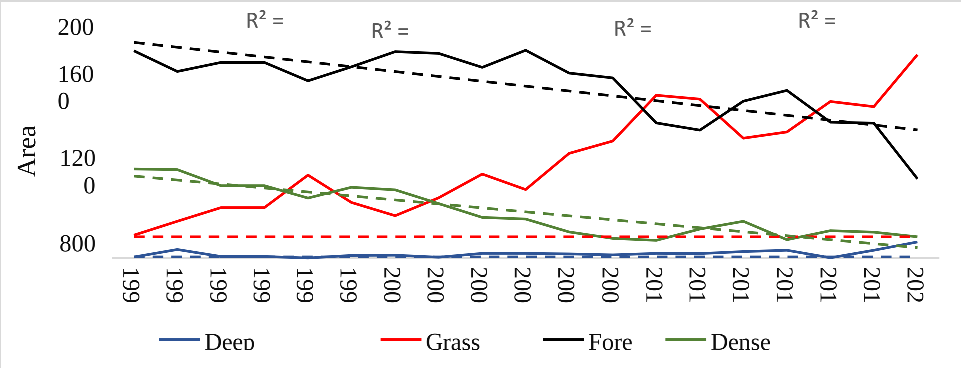

Figure 5: Different trends in how the land cover changes at Khagrachhari. (Source: Author, 2020)

The analysis displays the research area's deforestation scenario. At a pace of 36.49 sq. km/year, around 40.50 percent of forest land has disappeared. Over the previous three decades, there has also been a 19.35 sq. km/year loss in the dense forest area. The reason for this situation is the annual construction of houses to house the expanding population and the expansion of arable landfor food (Ahmed B., 2015). This extensive deforestation could have a negative impact on the environment and affect how the environment changes in the research area.

3.3 Land Cover Induced Carbon Emission

Based on the projected land use data in Table 5, yearly carbon emissions, adsorptions, and net carbon emissions (Table 7) were found. Positive numbers show places that release carbon, like grasslands, and negative numbers show places that take in carbon. More than 65% of all carbon uptake that happened each year happened in forests. However, because of huge changes in land cover, forest land has taken in less carbon over the last 30 years, going from 343.24x104 t to 131.65x104 t. Because the amount of dense forest land and forest land size has gone down, net carbon emissions have gone up. (table 7, Fig. 7). It is clear that grassland, which is the only land cover that contributes carbon, has grown a lot, as its carbon emissions have gone from 35.99x104t to 317.86 x104 t. As the area of grasslands has grown, carbon emissions have gone up by 281.87×104t, rising by an average of 9.396×104 t/year, while carbon uptake has gone down by 10.91×104 t/year. The bad news is that net carbon emissions have gone up, which means that greenhouse gas levels are rising and the world is getting worse.

Table 7: Carbon absorption, emission, and net carbon emissions by distinct land cover (unit:10^4t) and the Khagracchari contribution percentage for various years.

Year	Water-body	Grass Land	Forest	Dense Forest	Emission	Net Absorption	Net Emission
1990	-1.82	35.99	-343.24	-180.83	35.99	525.89	-489.89
	0.35%	100%	65.27%	34.38%			

1995	-2.65	78.98	-324.33	-147.02	78.98	474.00	-395.02
	0.56%	100%	68.42%	27.96%			
2000	-4.37	66.47	-342.32	-138.82	66.47	485.51	-419.04
	0.90%	100%	70.51%	26.40%			
2005	-6.98	107.38	-344.35	-79.58	107.38	430.91	-323.54
	1.62%	100%	79.91%	15.13%			
2010	-6.98	254.33	-223.97	-36.22	254.33	267.17	-12.84
	2.61%	100%	83.83%	6.89%			
2015	-11.35	197.33	-278.17	-37.71	197.33	327.22	-129.89
	3.47%	100%	85.01%	7.17%			
2020	-11.35	317.86	-131.65	-43.56	317.86	198.70	119.16
	11.82%	100%	66.26%	8.28%			

(Source: Author's calculation, 2020)

The trend study of carbon emissions and absorptions at Khagrachhari between 1990 and 2020 reveals a markedly increased carbon emission and a markedly decreased carbon absorption and net carbon emissions (R2 values of 0.8453, 0.8628, and 0.8551, respectively). The trend of hazardous carbon emissions in Khagrachhari Hilly areas can be attributed to factors such as population growth, urbanization, and rapid land cover change.

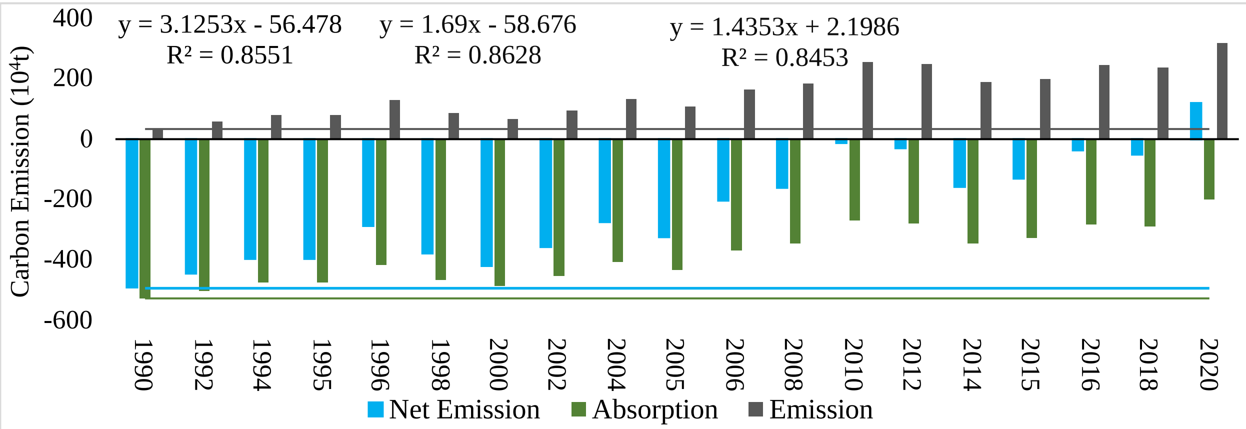

Figure 6: Trends in carbon emissions and absorption at Khagrachhari between 1990 and 2020.

(Source: Author, 2020)

3.4 Limitations of the Study

The study classified the land cover area only using the NDVI method rather of a supervised image classification approach, despite doing a time series analysis of land cover change and its impact on carbon emission in Bangladesh's hilly areas. From earlier research, the range of NDVI values for various land cover categories was gathered. Due to limitations in data collecting, the study hassolely computed the carbon emissions resulting from the land cover. The infrastructure, industrialarea, and build-up area were not taken into account by the study when calculating the carbon emission. The carbon emission coefficients for various land cover types were obtained from multiple research, wherein these coefficients were computed through a range of techniques. Further work is required to verify or enhance these coefficients.

4. CONCLUSION

The study focused on remote sensing base land cover change in the hilly areas and carbon emission prediction approach for the Khagrachhari district based on the last three decades from 1990 to 2020. The empirical findings of this study offer a novel perspective on the interplay between vegetarian health trends and land cover change with carbon emission. NDVI based carbon emission analysis shows the increasing of carbon emission and decreasing of carbon absorption capacity of the Khagrachhari. For optimal healthiest vegetation, the NDVI value consistently exceeds 0.6; however, during the initial period, the healthiest vegetation was selected that was greater than 0.6. But tragically, it decreased and crossed the border line of NDVI healthiest vegetarian trends in 2008, 2016, 2017 respectively. Additionally, tome forest and dense forest abruptly decreased as well as grassland cover increased due to cuttingdown of forest, jhum farming in land cover changed from 1990 to 2020. Hence, there was a notable reduction in carbon absorption. Moreover, net carbon emissions were low and net absorptions were high in1990 to 2015. On the contrary, there was a significant reversal: increased net carbon emissions and decreased net absorption which indicate a notable shift in the carbon balance in 2020. To sum up, As the increase of cultivable land and urbanization is influencing in the declination of forest land, necessary regulation policy should betaken by the responsible authorities such as use of hybrid seeds, planting trees and increasing awareness. Otherwise, the hilly areas will face a hostile environment in a few years. The overall study demonstrated the relationship between long-term NDVI changes, and the consequence of carbon emission and absorption for land cover dynamics which will help to provide a scientific knowledge about Khagrachhari concerning ecology and environmental management.

REFERENCES

Rai, R., Zhang, Y., Paudel, B., Li, S., & Khandal, R. N. (2017). A Synthesis of Studies on LandUse and Land Cover Dynamics during 1930–2015 in Bangladesh. *Sustainability, 9*(10), 1866. doi:https://doi.org/10.3390/su9101866

Ahmed, B. (2015). *Land Cover Modeling of the Hilly Districts of Chittagong Division in Bangladesh.* Dhaka: BUET-Japan Institute of Disaster Prevention and Urban Safety .

Ahmed, M. A., Pranta, R. O., Shah, M. H., ARGHA, D. P., Datta, D., & Riyad, R. H. (2021). Recycling of cotton dust for organic farming is a pivotal replacement of chemicalfertilizers by composting and its quality analysis. *Environmental Research and Technology, 4*(2), 108-116.

Alam, T. A., Barua, G., Mahsin, M., Kamal, A., Mazumder, M. H., & Omi, F. R. (2019). ASTUDY OF THE RECENT LANDSLIDE IN RANGAMATI REGION: CAUSES, IMPACTS AND EXISTING SLOPE PROTECTION MEASURES. *nternational Conference on Disaster Risk Management, Dhaka, Bangladesh.* Dhaka.

Alsharif, M. H., Younes, M. K., & Kim, J. (2019). Time Series ARIMA Model for Prediction ofDaily and Monthly Average Global Solar Radiation: The Case Study of Seoul, South Korea. *Symmetry, 11*(2), 240.

Argha, D. B., Hasib, A., & Rahman, M. (2021). A comparative study on the variation of air quality index of Dhaka city before and after the nationwide lockdown due to COVID-19 .Sylhet: 6th International Conference on Engineering Research, Innovation and Education.

Baniya, B., Tang, Q., Huang, Z., Sun, S., & Techato, K.-a. (2018). Spatial and Temporal Variation of NDVI in Response to Climate Change and the Implication for CarbonDynamics in Nepal. *Forests, 9*, 329. doi:10.3390/f9060329

Barua, S. K., & Haque, S. M. (2011). Soil Characteristics and Carbon Sequestration Potentials of Vegetation in Degraded Hills of Chittagong, Bangladesh. *Land Degradation & Development, 24*(1). doi:10.1002/ldr.1107

Beaumont, C. (1984). Forecasting: Methods and Applications. *Journal of the OperationalResearch Society, 35*(1), 79. doi:10.1057/jors.1984.11

Begum, M. E., Miah, M. A., Rashid, M. A., Islam, M. T., & Hossain, M. I. (2019). EconomicAnalysis of Tumeric Cultivation: Evidence from Khagrachari District. *Bangladesh Journal of Agricultural Research, 44*(1), 43-58.

Biswas, S., Swanson, M. E., & Vacik, H. (2020). Natural resources depletion in hill areas of Bangladesh: A review. *Journal of Mountain Science, 9*, 147-156. doi:10.1007/s11629-012-2028-z

Chowdhury, H. (2023). Circular Economy Integration in Additive Manufacturing. *industrial and manufacturing engineering*. doi:https://doi.org/10.20944/preprints202310.0087.v1

Chowdhury, H., & Asiabanpour, B. (2023). A Smart Circular Economy for Integrated Organic Hydroponic-Aquaponic Farming. San Marcos, Texas: Texas State University.

Chowdhury, H., & Islam, M. (2015). Multiple Charger with Adjustable Voltage Using Solar Panel. Chittagong, Bangladesh: International Conference on Mechanical Engineering andRenewable Energy .

Colak, I., Yesilbudak, M., Genc, N., & Bayindir, R. (2015). Multi-Period Prediction of Solar Radiation Using ARMA and ARIMA Models. *2015 IEEE 14th International Conferenceon Machine Learning and Applications* (pp. 1045-1049). Miami: Institute of Electrical and Electronics Engineers (IEEE). doi:0.1109/ICMLA.2015.33

Cui, Y., Li, L., Chen, L., Zhang, Y., Cheng, L., Zhou, X., & Yang, X. (2018). Land-Use Carbon Emissions Estimation for the Yangtze River Delta Urban Agglomeration Using 1994– 2016 Landsat Image Data. *Remote Sensing, 10*, 1334. doi:10.3390/rs10091334

Duguma, L. A., Atela, J., Minang, P. A., Ayana, A. N., Gizachew, B., Nzyoka, J. M., & Bernard, F. (2019). Deforestation and Forest Degradation as an Environmental Behavior: Unpacking Realities Shaping Community Actions. *Land, 8*, 26. doi:10.3390/land8020026

Fang, J., Guo, Z., Piao, S., & Chen , A. (2007). Terrestrial vegetation carbon sinks in China,1981–2000. *Science in China Series D: Earth Sciences, 50*, 1341-1350. doi:10.1007/s11430-007-0049-1

Grigoraș, G., & Urițescu, B. (2019). Land Use/Land Cover changes dynamics and their effectson Surface Heat Island in Bucharest, Romania. *Int J Appl Earth Obs Geoinformation*. doi:https://doi.org/10.1016/j.jag.2019.03.009

Hasan, S. S., Sarmin, N. S., & Miah, M. G. (2019). Assessment of scenario-based land usechanges in the Chittagong Hill Tracts of Bangladesh. *Environmental Development*. doi:10.1016/j.envdev.2019.100463

Hong-xin, S., Xing-min, M., Ying-long, Z., & Ming-quan, L. (2012). Effects of Different LandUse Patterns on Carbon Emission in Guangyuan City of Sichuan Province. *Bulletin of Soil and Water Conservation, 32*, 101-106.

Islam, M. S., Hasan, G. M., & Chowdhury, M. A. (2006). Destroying hills in the northeasternpart of Bangladesh: A qualitative assessment of extent of the problem and its probableimpact. *Journal of Environmental Science and Technology, 2*(4), 301-308.

Khan, T., Argha, D. B., & Anita, M. S. (2021). An analysis of existing medical waste management and possible health hazards in Jhenaidah municipality . Sylhet: 6th International Conference on Engineering Research, Innovation and Education. SUST.

Mondal, A., & Hashemi, H. (2018, October). Intercomparison of trend analysis of Multisatellite Monthly Precipitation Products and Gauge Measurements for River Basins of India. *Journal of Hydrology, 565*, 779-790.

Parvin, N. S., & Abudu, D. (2017, April). Estimating Urban Heat Island Intensity using RemoteSensing Techniques in Dhaka City. *International Journal of Scientific & Engineering Research, 8*(4), 289- 298.

Piao, S., Fang, J., Zhou, L., Guo, Q., Henderson, M., Ji, W., . . . Tao, S. (2003). Interannual variations of monthly and seasonal normalized difference vegetation index (NDVI) inChina from 1982 to 1999. *Journal of Geophysical Research: Atmospheres, 108*(D14).doi:10.1029/2002JD002848

Pranta, R. O., Ahmed, M. A., & KUMER, A. (2019). An Overview of Hygiene Practices and Health Risks Related to Street Foods and Drinking Water from Roadside Restaurants ofKhulna City of Bangladesh. *Eurasian Journal of Environmental Research, 3*(2), 47-55.

Rabby, Y. W., & Li, Y. (2020). Landslide Inventory (2001–2017) of Chittagong Hilly Areas, bangladesh. *Data, 5*(4). doi:10.3390/data5010004

Raja, D. R. (2012, December). Spatial Analysis of Land Surface Temperature in DhakaMetropolitan Area. *Journal of Bangladesh Institute of Planners , 5,* 151-167.

Rasul, G., & Thapa, G. B. (2003). Shifting cultivation in the mountains of South and SoutheastAsia: regional patterns and factors influencing the change. *Land Degradation & Development, 14*(5). doi:10.1002/ldr.570

Rasul, G., Thapa, G. T., & Zoebishch, M. A. (2004). Determinants of land-use changes in theChittagong Hill Tracts of Bangladesh. *Applied Geography, 24*(3), 217-240. doi:10.1016/j.apgeog.2004.03.004

Roy, P., Ahmed, M. A., Islam, M. S., Azad, M. A., Islam, M. S., & Islam, M. R. (2020). Water supply, sanitation system and water-borne diseases of slum dwellers of bastuhara colony, Khulna. Khulna University of Engineering and Technology (KUET), Khulna: 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020) .

Sahana, M., Ahmed, R., & Sajjad, H. (2016, May 2). Analyzing land surface temperature distribution in response to land use/land cover change using split window algorithmto land use/land cover change using split window algorithm and spectral radiance model in Sundarban Biosphere Reserve, India. *Modelling Earth Systems and Environment, 81*(2).doi:10.1007/s40808-016-0135-5

Srivastava, P. K., Majumdar, T. J., & Bhattacharya, A. K. (2010, March 9). Study of land surface temperature and spectral emissivity using multi-sensor satellite data. *Journal of Earth System Science, 119*, 67-74. doi:https://doi.org/10.1007/s12040-010-0002-0

Stibig, H. J., Belward, A. S., Roy, P. S., Rosalina-Wasrin , U., Agrawal, S., Joshi , P. K., . . .Giri, C. (2006). A land-cover map for South and Southeast Asia derived from SPOT-VEGETATION data. *34*(4). doi:10.1111/j.1365-2699.2006.01637.x

Sultana, N. (2020). Analysis of landslide-induced fatalities and injuries in Bangladesh: 2000-2018. *Cogent Social Sciences, 6*(1). doi:0.1080/23311886.2020.1737402

Xu, H. (2006). Modification of normalised difference water index (NDWI) to enhance openwater features in remotely sensed imagery. *International Journal of Remote Sensing,27*(14), 3025-3033. doi:10.1080/01431160600589179

Zhang, Y., Gao, J., Liu, L., Wang, Z., Ding, M., & Yang, X. (2013). NDVI-based vegetation changes and their responses to climate change from 1982 to 2011: A case study in theKoshi River Basin in the middle Himalayas. *Global and Planetary Change, 108*, 139- 148. doi:10.1016/j.gloplacha.2013.06.012

Zhao, X., Tan, K., Zhao, S., & Fang, J. (2011). Changing climate affects vegetation growth in thearid region of the northwestern China. *Journal of Arid Environments, 75*(10), 946-952. doi:10.1016/j.jaridenv.2011.05.007