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Assessing the Ecological Consequences: Biodiversity Decline in Gopalganj, Bangladesh, under Climate Change

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Abstract

This research critically examines the alarming case of biodiversity loss in Gopalganj, Bangladesh, focusing on identifying the causes of this decline and assessing its long-term impact on ecosystems and communities. The main reason is anthropogenic activities, including land conversion, and infrastructure using a comprehensive approach. This research employs a combination of primary and secondary data analysis techniques, encompassing surveys, focus group discussions, interviews, and field surveys. Findings: A staggering biological decline in ethnic diversity seems predictions point in the direction of it is an alarming trend that will take place by 2054. At the same time, the study reveals a worrying decline in vegetation and a dramatic expansion of built-up areas. In light of these findings, this paper strongly emphasizes the urgent need for immediate and coordinated conservation efforts. The proposed measures include conservation and restoration of critical areas, strong measures to reduce greenhouse gas emissions, proactive climate adaptation planning, promotion of sustainable agricultural and forestry practices, and strong public awareness campaigns to emphasize the critical importance of biodiversity conservation. Collectively, these actions are pivotal in safeguarding Gopalganj's rich biodiversity and ensuring a sustainable future for the region and the planet at large.

Keywords

Climate Change, Biodiversity Loss, Ecology, Adaptation, Future Prediction

1. Introduction

Biological diversity or its common abbreviation, biodiversity, has been defined

as "the totality (numbers) and variability (types) of living organisms in the ecosystem, region and the environment" (Butler, 2006). The Convention on Biological Diversity defines biodiversity loss as the loss of the components of biodiversity that include biomes, habitats, and ecosystems; species and populations; and genetic diversity (CBD COP 7 Decision VII/30). In other words, biodiversity loss is a reduction in the variety of life on Earth. South Asia is the most vulnerable region of the world to climate change impacts (McCarthy et al., 2001). Among the developing countries, Bangladesh is the worst suffering country for climate change. It is part of the largest river delta in the world (CIA, 1997).

Gopalganj is a District of Dhaka Division, Bangladesh. It has about 1,172,415 civilians and a surface area of 1490 Km^2. The most important metropolis of the district is also known as Gopalganj City. It is situated on the bank of the Madhumati River and is positioned between 22˚50' and 23˚01' North Latitudes and between 89˚40' and 90˚02' East Longitudes. It is surrounded by Narail District on the West, Pirojpur, and Bagerhat District on the South, Madaripur, and Barisal District on the East, and Faridpur District on the North. There are 5 Upazila in Gopalganj District, e.g. Gopalganj Sadar, Kashiani, Kotalipara, Muksudpur and Tungipara. The position of the district is in the South-Central part of the country (Shaibur et al., 2019). There has not been any new study done in Gopalganj on the biodiversity loss caused by climate change, therefore, it's time to consider it.

Numerous studies have reiterated that one of the most important drivers of the current loss of biodiversity is climate change (MEA, 2005; Brook et al., 2008; Guo et al., 2017a). The rise of temperature and carbon dioxide (CO_2) levels has been associated with global climate changes. These effects give rise to several potentially major changes in hydrologic cycles (precipitation and evaporation) and an increased magnitude and frequency of extreme weather such as floods, cyclones, and droughts that will have a profound negative impact on biodiversity (Rinawati et al., 2013).

Biodiversity loss in the 21st century could rank among the major drivers of ecosystem change (Hooper et al., 2012). It was found that the world's ecosystem changed more rapidly in the second half of the twentieth century than at any time in human history. Over the past few hundred years, humans have increased the species extinction rate by as much as 1000 times over the planet's history (Habibullah et al., 2022). In Gopalganj City, the number of plants, animals, birds, fish, and other species is steadily declining, which is concerning given the city's population. Humans are struggling with issues such as a shortage of diverse food supplies and amenity value, as well as changes in the ecology. Biodiversity loss is a great threat to the productivity and sustainability of the ecosystem.

Planned climate change adaptation policies and actions are necessary and the Government of Bangladesh (GoB) already prepared a national adaptation plan such as the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) of 2009. The fundamental requirement for implementing this action plan is to cha-

racterize the impacts because adaptation is highly context-dependent. Therefore, different communities may require different adaptation plans for climate change impacts (Huq et al., 2018a).

The study aims to assess biodiversity loss in Gopalganj, Bangladesh, pinpoint its causes, and examine its ecological and societal repercussions. It delves into the decline of various species categories over three decades, attributing it to human activities and climate change. The goal is to heighten awareness of Gopalganj's biodiversity crisis, understand its root causes, and advocate for conservation measures to safeguard its rich biodiversity.

2. Materials and Methods

2.1. Tools

GPS Logger mobile application has been used to obtain the exact location of the data collection area. Also, used Excel and SPSS computer software for data analysis and ArcGIS software used for mapping study areas.

2.2. Study Area

Here, the data collection area is shown through the map. There are three upazilas in Gopalganj District, such as Gopalganj Sadar, Tungipara, and Kotalipara. The location of the data providers in each area is confirmed through 59 GPS points which define data collection points in this map (**Figure 1**).

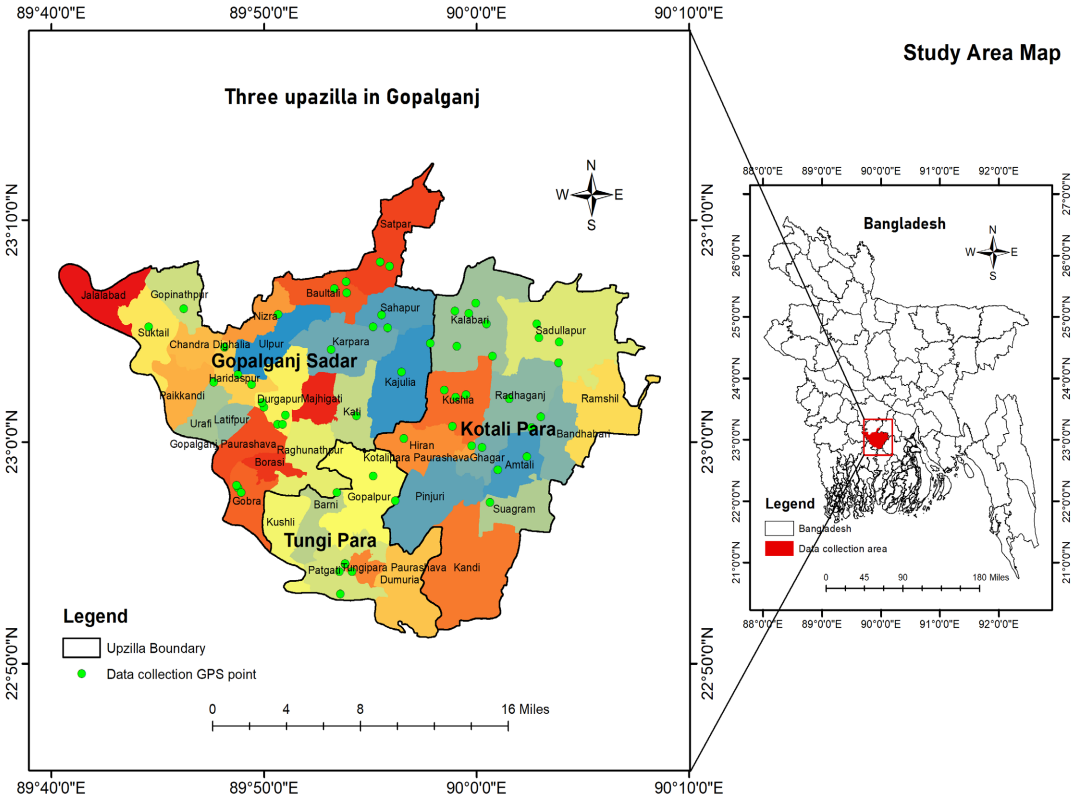


Figure 1. Data collection area Gopalganj.

The data were collected from 101 responders at different 59 GPS locations in the study area of three upazila in Gopalganj District. Out of this, 26 respondents were from Gopalganj Sadar Upazila, 33 were from Tungipara and 42 were from Kotalipara Upazila. The 81 male and 20 female respondents ranged in age from 32 to 80 years. Among them, 38 can only sign and 22 completed primary education level, 21 have gone through secondary education, 3 people graduated and 17 are completely illiterate. Professionally, 38.6% of them are engaged in business, 34.7 percent in agriculture, 7 percent in daily wage labor, 2 percent in the teaching profession, and 17.8 percent of women are engaged in various household chores.

2.3. Methods

The study employed various data collection methods, including surveys, focused group discussions, individual interviews, and field surveys. GPS Logger mobile application was utilized to precisely locate data collection areas. The research focused on documenting changes in plant, animal, bird, fish, and vegetable/agricultural crop species. Collected data from 101 respondents across three upazilas were subjected to rigorous analysis using Excel, SPSS, and ArcGIS software. The percentage of species decrement was calculated for the past and estimated for future years (1992 to 2022 and projected to 2052) based on the collected data.

In this case, the following steps will be performed sequentially:

1) Primary data analysis

All the relevant data information has been collected and used from primary sources. Here, we have collected data mainly depending on surveys by the study consisting of 48 questions. We conducted focused group discussions, individual interviews, and field surveys and analyzed them to determine the exact results. Also, predict future conditions.

a) Comparison of relevant data between 30 years;

b) Measuring the percentage of decrement in the current situation;

c) Identifying the cause and effect;

d) Prediction of future decrement conditions and trend analysis by using the simple linear regression equation:

$$y = a + bx \tag{i}$$

where,

y = the dependent variable of the regression equation;

b = slope of the regression equation;

x = dependent variable of the regression equation;

b = constant of the equation.

2) Secondary data analysis

Used satellite images from the United States Geological Survey (USGS) and climatic data map from NASA for observation and to predict future conditions.

a) Vegetation index difference mapping from 1992 to 2022 by using Normalized Difference Vegetation Index (NDVI);

b) Built-up area index difference mapping from 1992 to 2022 by using Normalized Difference Built-up Index (NDBI);

c) Temperature and precipitation mapping according to a historical period (1970-2020);

d) Also, trend analysis for prediction future temperature and precipitation.

2.4. Abbreviations

The full form of GPS is the Global Positioning System and it is a satellite navigation system used to identify the ground position of an object. SPSS (Statistical Package for the Social Sciences) is a software program used by researchers in various disciplines for quantitative analysis of complex data. The full form of GIS is the Geographic Information System. It is a system designed to capture, evaluate, manipulate, handle, and view all forms of geographical & spatial information and data.

3. Result

The results of this study were based on two main types of data. Firstly, collect survey data from a total of 101 respondents. The survey consisted of 48 questions about the respondents' experiences with climate change, their perceptions of the future, and their willingness to take action. Secondly, also use satellite images from the USGS and climate data maps from NASA to observe the current state of the environment and predict future conditions. The survey data show that a majority of respondents believe that climate change is happening and that it is caused by human activities. The respondents also expressed concern about the future effects of climate change, such as more extreme weather events, and food shortages.

The satellite data and climate data maps confirmed the respondents' concerns. The data showed that the Earth's climate is warming, and that this warming is causing changes in the environment.

3.1 Primary Data Analysis

A comprehensive survey was conducted, gathering data from 101 participants. The survey encompassed 48 inquiries delving into participants' encounters with climate change, their outlooks on the future, and their inclination to engage in proactive measures. The collected data offers a valuable perspective on a wide range of climate-related concerns. The respondents' insights contribute to a deeper understanding of public sentiment and motivation surrounding climate change. This data-rich survey lays the foundation for informed decision-making and targeted initiatives aimed at addressing the challenges of our changing environment.

3.1.1. Plant Species

The following **Figure 2** shows that 30 years ago in 1992, 25 responders found

bushes, fruits, and flowers. Also, 9 responders found only trees, 14 responders found both trees and bushes, 20 responders found trees, bushes, and flowers, 26 responders found trees, bushes, fruits, and flowers, 5 responders found trees, bushes, fruits, and rice and 2 responders found trees, bushes, and rice were available. Therefore, the most common response was trees, bushes, fruits, and flowers, with 26 responders and the least common response was that trees, bushes, and rice were, with only 2 responders.

On the other side, currently, in 2022, 16 responders found only fruits, 60 responders found rice, 13 responders found trees and rice and 12 responders found fruits and rice are available. Therefore, the most common response is that only rice, with 60 responders and the least common response is fruits and rice, with only 12 responders. It is also worth noting that in 2022, no respondents mentioned the availability of bushes or flowers.

According to Figure 3 in 2022, 89% of people responded that plant species had decreased. In contrast, 8% of people believed that plant species had not decreased, and 3% were unsure about the situation.

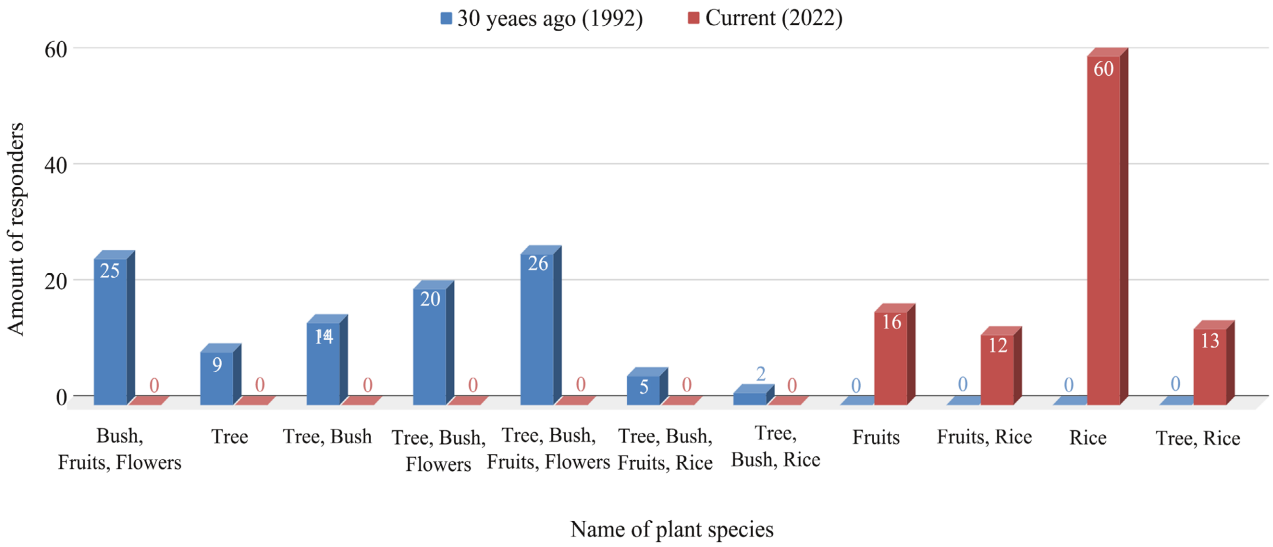


Figure 2. Plant species comparison between 30 years.

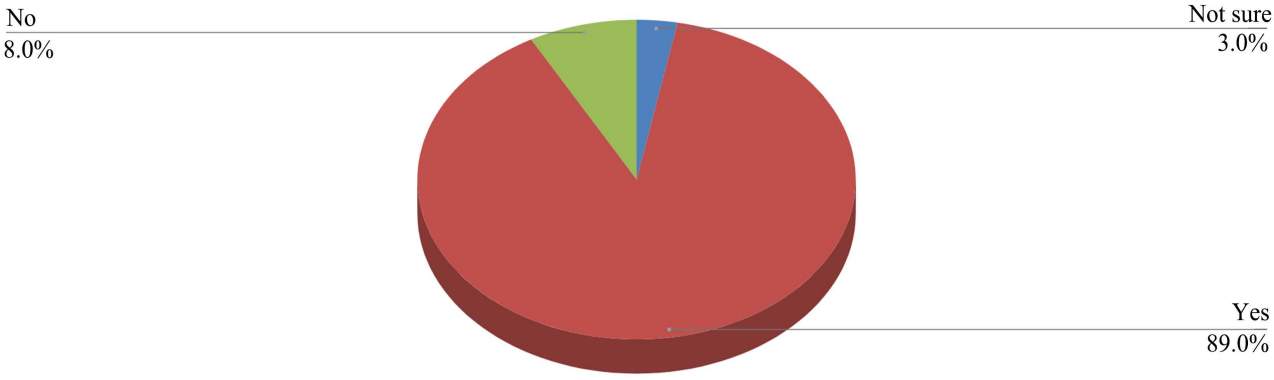


Figure 3. Public perception to decrease plant species in the current situation in 2022.

The reason for the decrease in plant species was that 9.9% of people believed it was due to the transformation of agricultural land by cutting trees. 45.5% of them believed it was caused by the construction of various infrastructures, including roads, highways, and buildings. 32.7% believed that both the transformation of land and the construction of infrastructure were responsible. Furthermore, 11.9% of people were not sure about this. As a result, 14.9% of them believed that the temperature was increasing, 24.8% believed that rainfall was decreasing, and 60.4% believed that temperature and precipitation were increasing and decreasing, respectively.

3.1.2. Animal Species

The following **Figure 4** shows that 30 years ago in 1992, 63 responders found both wild and domestic animal species in the study area. Also, 13 responders found only domestic animal species and 25 responders found only wild animal species. Therefore, the most common response was that both wild and domestic animal species were found, with 63 responders and the least common response was only domestic animal species, with only 13 responders.

On the other side, currently in 2022, 3 responders found wild and domestic animal species, 39 responders found only domestic animal species and 59 responders found nothing. Therefore, the most common response is nothing is found, with 59 responders. It is also worth noting that the number of responders who found both wild and domestic animal species decreased significantly from 63 to 3 over the course of 30 years.

According to **Figure 5** in 2022, 89.9% of people responded that animal species had decreased, while 6.1% believed that species had not decreased, and 3% of people were unsure about it.

The reason for the decrease in animal species was attributed to various factors. Among the respondents, 18.8% believed that it was due to the destruction of living areas. Additionally, 10.9% of people thought that the shortage of food supply was responsible. A majority of 58.4% believed that both the destruction of living

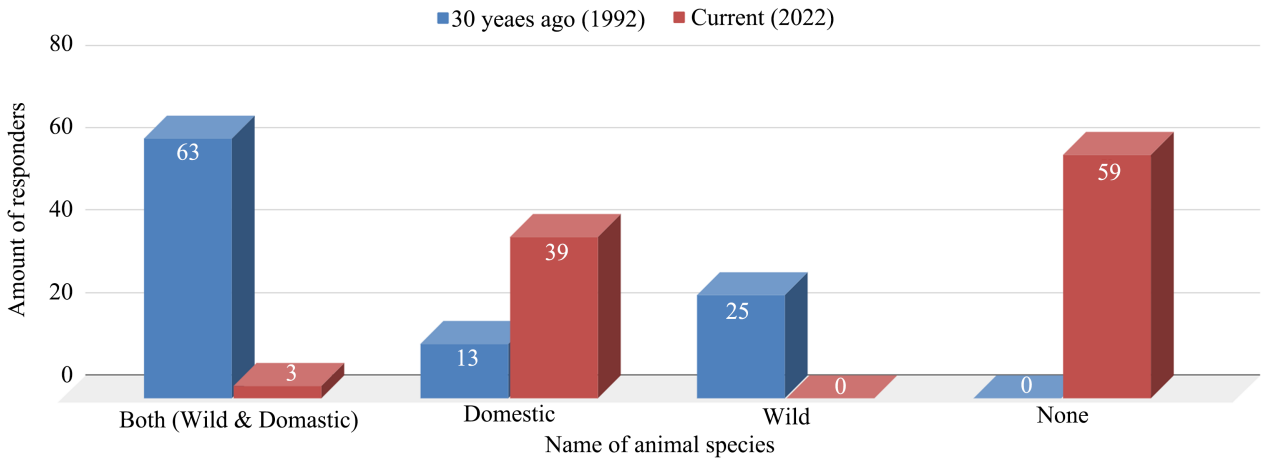


Figure 4. Animal species comparison between 30 years.

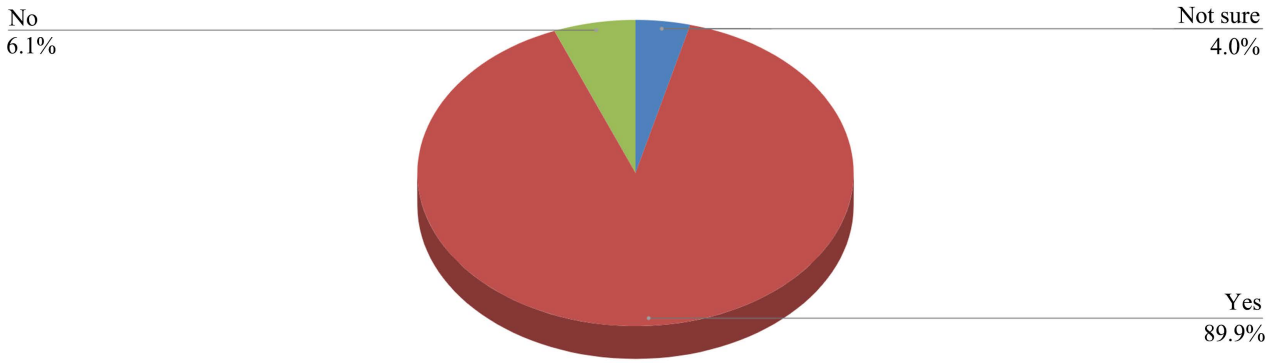


Figure 5. Public perception to decrease animal species in the current situation in 2022.

areas and the shortage of food supply contributed to the decrease in animal species. Furthermore, 11.9% of people were not sure about the reasons behind it. As a result, the perceived impacts were as follows: 19.7% of people believed that business and agricultural production had an effect, while 16.9% thought it was solely related to agricultural production. Additionally, 22% attributed the decrease to business activities. Some individuals, around 4%, felt that there was a shortage of nutrition. Moreover, 25.5% believed that both business activities and agricultural production played a role, and 11.9% were unsure about the specific effects on animal species.

3.1.3. Bird Species

The following **Figure 6** shows that 30 years ago in 1992, 58 responders found both migratory and domestic bird species, and 43 responders found only migratory bird species. Therefore, the most common response was that both migratory and domestic bird species were found, with 58 responders and the least common response was only migratory bird species, with only 43 responders.

On the other side, currently, in 2022, none found both migratory and domestic bird species at the same time. But 2 responders found only migratory bird species, 42 responders found only domestic bird species and 57 responders found nothing. Therefore, the most common response is nothing is found, with 57 responders. It is also worth noting that the number of responders who found only migratory bird species decreased significantly from 43 to 2 over the course of 30 years, while the number of responders who found only domestic bird species increased from 0 to 42.

According to **Figure 7** in 2022, 86.1% of people responded that bird species had decreased. In contrast, 2% of people believed that bird species had not decreased, and 11.9% were unsure about the situation.

The reasons given for the decrease in bird species were as follows: 50.5% of people believed it was due to the destruction of their living places. Additionally, 18.8% of people attributed it to a shortage of food supply. Some respondents, 15.8%, believed that both the destruction of living areas and the shortage of food supply were responsible. Furthermore, 14.9% of people were not sure about the reasons behind the decrease in bird species.

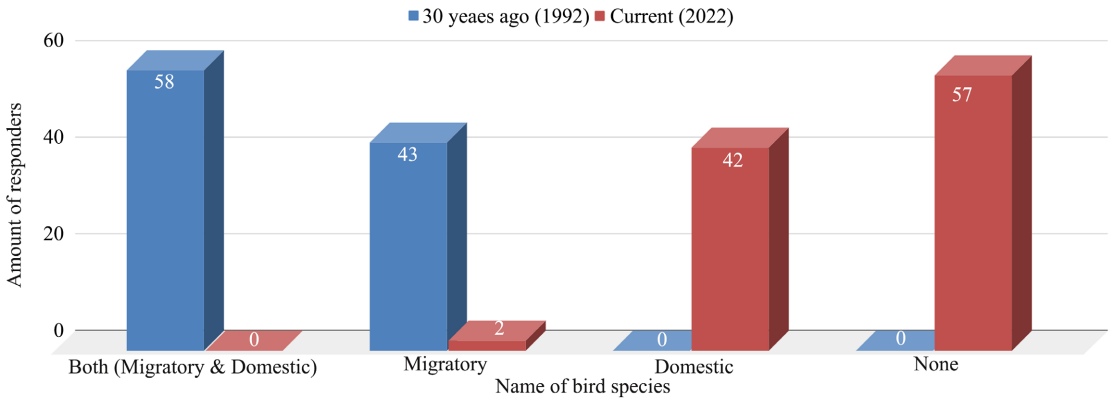


Figure 6. Bird species comparison between 30 years.

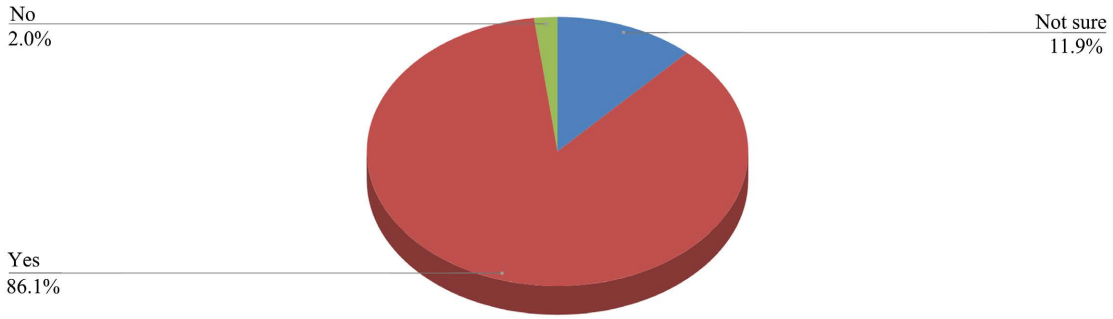


Figure 7. Public perception to decrease bird species in the current situation in 2022.

As a result of the decline, people identified various impacts: 36.6% believed that it led to a decrease in amenity value, while 31.7% thought it caused food scarcity and a decline in business. Additionally, 15.8% believed that the decrease in bird species had a combined effect of reducing amenity value, facing food scarcity, and decreasing business. Finally, 15.8% of people were unsure about the specific effects of the decline in bird species.

3.1.4. Fish Species

The following **Figure 8** shows that, 30 years ago in 1992, 30 responders found both riverine and farming fish species, 56 responders found only riverine fish species and 15 responders were not sure. Therefore, the most common response was that only riverine fish species were found, with 56 responders.

On the other side, currently in 2022, 12 responders found only riverine fish species, 75 responders found only farming fish species and 14 responders were not sure. Therefore, the most common response where only farming fish species were found, was stated by 75 responders. It is also worth noting that the number of responders who found only farming fish species increased significantly from 0 to 75 over the course of 30 years, while the number of responders who found only riverine fish species decreased from 56 to 12.

According to **Figure 9** in 2022, 74.3% of people responded that fish species had decreased. Conversely, 11.9% of people believed that fish species had not decreased, and 13.9% were unsure about the situation.

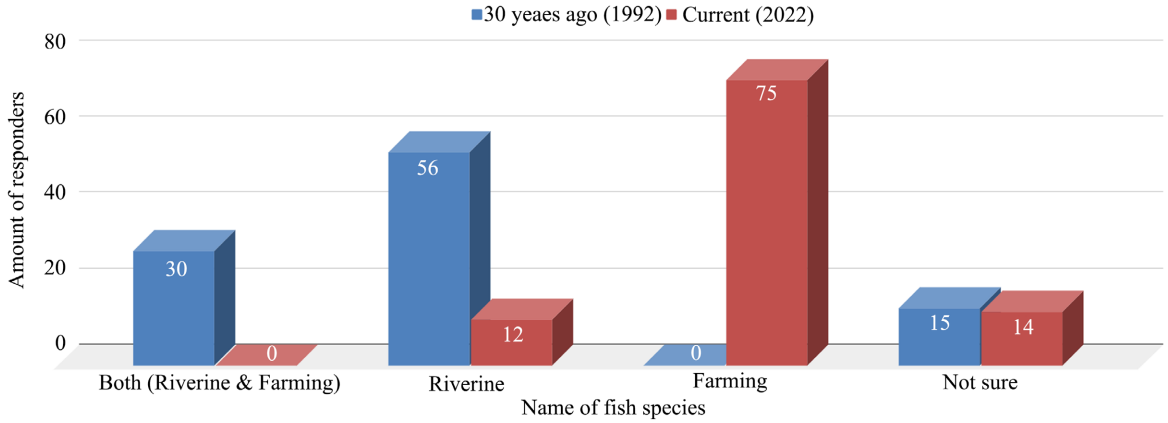


Figure 8. Fish species comparison between 30 years.

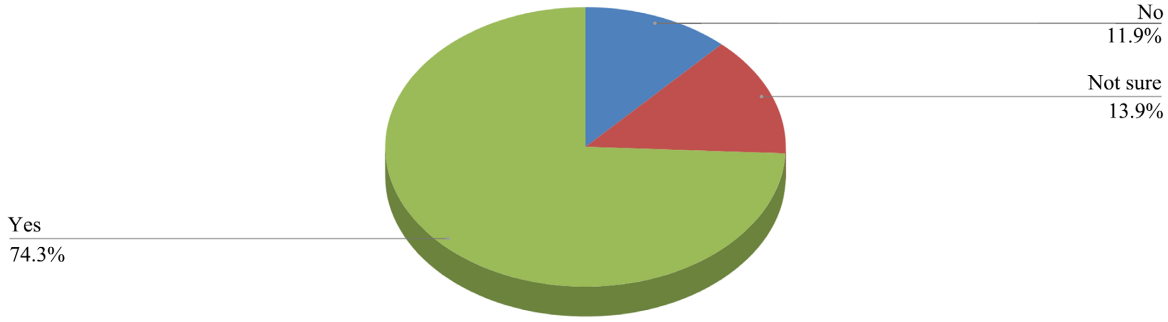


Figure 9. Public perception of decreasing fish species in the current situation in 2022.

The reasons provided for the decrease in fish species were as follows: 10.9% of people believed it was due to a decrease in the depth of rivers. Additionally, 12.9% attributed it to a decrease in the navigability of rivers. Some respondents, about 2%, thought that the decrease in fish species was a result of a decline in their habitat sources. Furthermore, 60.4% of people believed that the decrease in fish species was caused by a combination of decreasing river depth, navigability, and habitat availability. Lastly, 13.9% of people were uncertain about the reasons behind the decline. As a result of the decrease in fish species, people identified various impacts: 18.7% believed it led to a lack of nutrition and a shortage of fish meat. Another 25.8% thought that they were facing food scarcity and a lack of nutrition. Additionally, 39.7% believed that both of these impacts were occurring as a result of the decrease in fish species. Finally, 15.8% of people were unsure about the specific effects of the decline.

3.1.5. Vegetable and Agricultural Crop Species

The following **Figure 10** shows that 30 years ago in 1992, 48 responders found both 12-month and seasonal vegetable and agricultural crop species, 12 responders found only 12-month vegetable and agricultural crop species, 29 responders found only seasonal vegetable and agricultural crop species, and 12 responders were not sure. Therefore, the most common response was that both 12-month and seasonal vegetable and agricultural crop species were found, with

48 responders.

On the other side, currently in 2022, 2 responders found both 12-month and seasonal vegetable and agricultural crop species, 67 responders found only 12-month vegetable and agricultural species, 10 responders found only seasonal vegetable and agricultural crop species, 12 responders are not sure and 10 responders found nothing. Therefore, the most common response is only 12-month vegetable and agricultural crop species, with 67 responders. It is also worth noting that the number of responders who found only 12-month vegetable and agricultural crop species increased significantly from 12 to 67 over the course of 30 years, while the number of responders who found both 12-month and seasonal vegetable and agricultural species decreased from 48 to 2. Additionally, 10 responders reported finding nothing, which is not a response given in the data from 30 years ago.

According to Figure 11 in 2022, 84.2% of people responded that vegetable and agricultural crop species had decreased. In contrast, 11.9% of people believed that species had not decreased, and 13.9% were unsure about the situation.

The reasons provided for the decrease in vegetable and agricultural crop species were as follows, 14.85% of people believed it was due to an increase in the use of pesticides and fertilizers. Additionally, 3.96% thought that the decrease was a result of a reduction in cultivated land. Some respondents, 6.93%, believed that changing land patterns played a role in the decrease. Furthermore, 10.89% of people attributed the decrease to infrastructural development. A majority of 60.39% believed that both increased pesticide and fertilizer use, as well as other factors mentioned, contributed to the decrease in vegetable and agricultural crop species. Lastly, 1.98% of people were unsure about the specific reasons behind the decline. As a result of the decrease in vegetable and agricultural crop species, people identified various impacts: 35.6% believed that they were facing food scarcity. Additionally, 8.9% thought that there was a lack of nutrition. Furthermore, 11.9% of people were unsure about the specific effects of the decrease in vegetable and agricultural crop species.

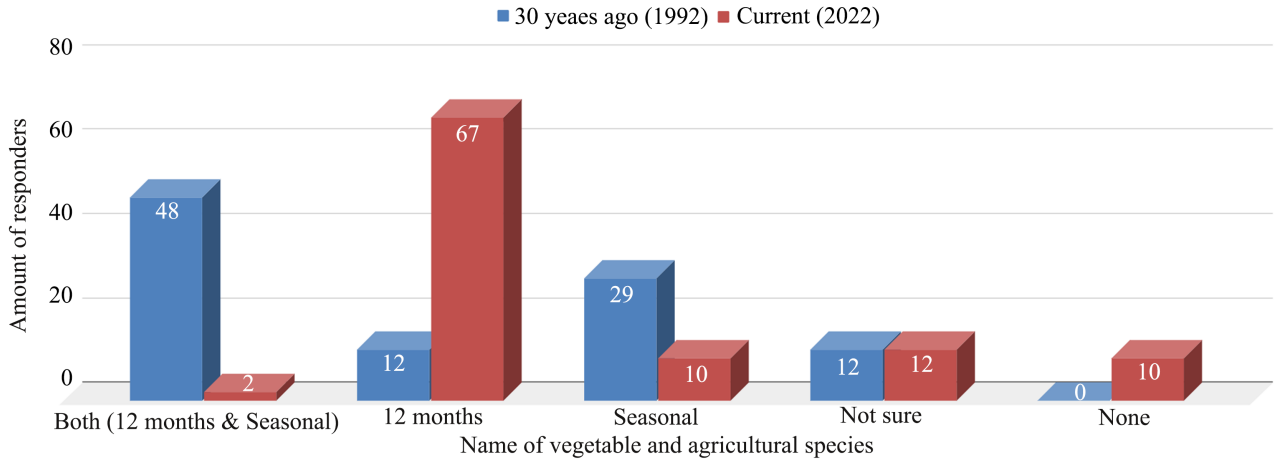


Figure 10. Vegetable and agricultural crop species comparison between 30 years.

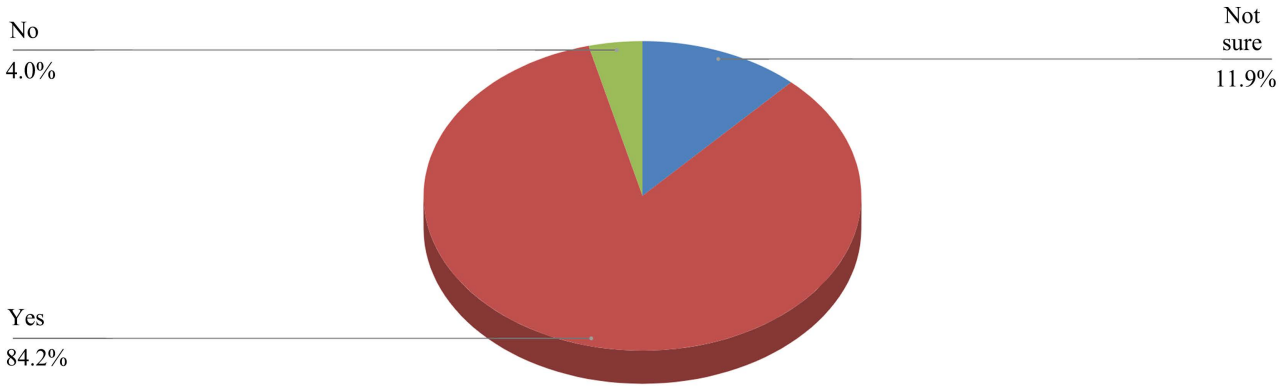


Figure 11. Public perception of decreasing vegetable and agricultural crop species in the current situation in 2022.

3.1.6. Predict the Percentage of Species Decrement in Future (2052)

The data in **Figure 12** are expressed as a percentage of future species decrement prediction based on field surveys. In this case, based on the data provided by people from 1992 to 2022, the future, i.e. the percentage of species decrease meant in 2052 has been estimated.

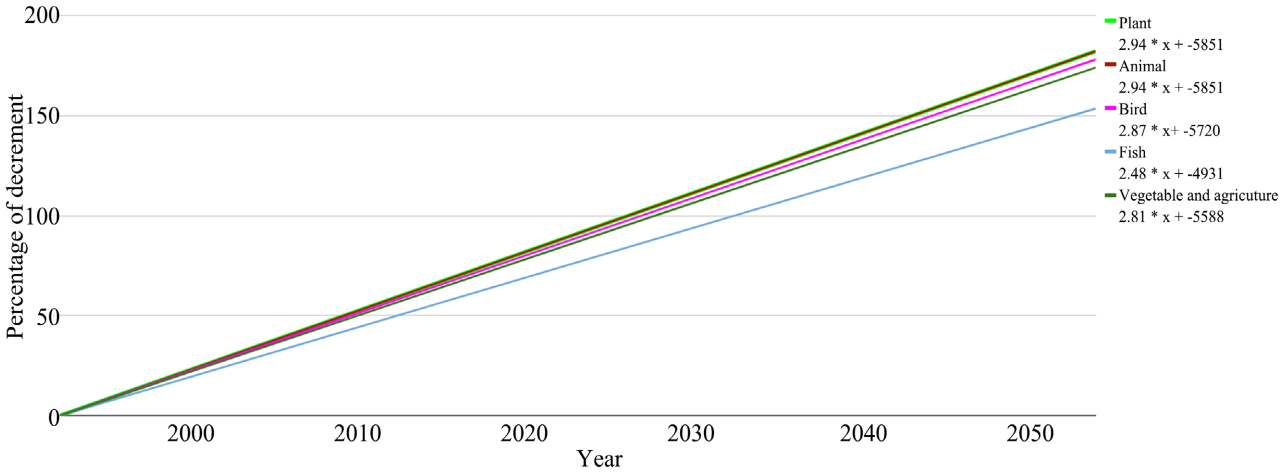


Figure 12. Predict the percentage of species decrement in future (2052).

Since the data was collected from 1992, we assumed the species decrement for that year to be zero. On the other hand, it can be seen that in the space of 30 years, according to the current data obtained in 2022, plant species have decreased by 88.10%, animal species by 88.10%, bird species by 86.10%, fish species by 73.30%, and vegetable and agricultural species decreased 82.20%. As a result, it can be estimated that in 2054, plant species will decrease by 182.11%, animal species by 182.12%, bird species by 178.01%, fish species by 153.46%, and vegetables and agricultural species will decrease by 173.92%.

The data presented in the graph highlights a concerning trend of decreasing species across multiple categories. The percentage of species decrease has been predicted based on field surveys, and it is estimated that this trend will continue in the future. The decrease in plant, animal, bird, fish, and vegetable/agricultural

species over the past 30 years is alarming and indicates a significant threat to biodiversity and the sustainability of our ecosystems. Urgent action is needed to address the underlying causes of species decline, including habitat loss, climate change, overuse of natural resources, and pollution. It is crucial to implement effective conservation measures and promote sustainable practices to prevent further species loss and ensure a healthy planet for future generations.

3.2. Secondary Data Analysis

The study combined survey findings (80% acknowledging human-caused climate change) with satellite imagery and NASA's climate maps, revealing congruence. Respondents' worries over climate impacts (extreme weather, food shortages) aligned with empirical data. Satellite and climate maps underscored a warming Earth, driving observable environmental shifts. The amalgamation of perceptions and evidence highlights the criticality of proactive climate actions.

3.2.1. Vegetation Index Difference Mapping

Here, **Figure 13** is clearly seen, that the difference is shown by vegetation indexing every 6 years from 1992 to 2022. In this case, the value of the vegetation index or NDVI of 1992, 1998, 2004, 2010, 2016, and 2022 respectively is −0.14 to +0.50, −0.35 to +0.54, −0.08 to +0.46, −0.08 to +0.43, −0.09 to +0.47 and −0.12 to +0.49. That means that the amount of vegetation has decreased.

3.2.2. Built-Up Area Index Difference Mapping

Here, **Figure 14** is clearly seen, that the difference is shown by build-up indexing every 6 years from 1992 to 2022. In this case, the value of the build-up index or NDBI of 1992, 1998, 2004, 2010, 2016, and 2022 respectively is −0.33 to +0.11, −0.29 to +0.14, −0.35 to +0.13, −0.29 to +0.16, −0.23 to +0.14 and −0.37 to +0.17. That means that the amount of build-up area has increased.

3.2.3. Temperature and Precipitation Mapping (1970-2020) and Trendline Analysis

In **Figure 15**, the left side part-a shows the annual average temperature in Gopalganj. The temperature range from 1972 to 2020 was +25.6 to +26.19 degree Celsius/year. On the other side, part-b shows the the annual average precipitation in Gopalganj. The precipitation ranges from 1972 to 2020 was +158.40 to +174.17 mm/year.

In **Figure 16**, the left side part-a shows the annual average temperature projection from 1991 to 2052 in Gopalganj. The temperature range +27.97 to +23.5 degree Celsius/year. And gradually temperature increased rate +0.877. On the other side, part-b shows the annual average precipitation projection from 1991 to 2052 in Gopalganj. The precipitation range +1.46 to +13.8 mm/year. And gradually precipitation increased rate +0.926. But these temperature and precipitation rate moderately fall into a dangerous in condition because of the rural to the urban shifting.

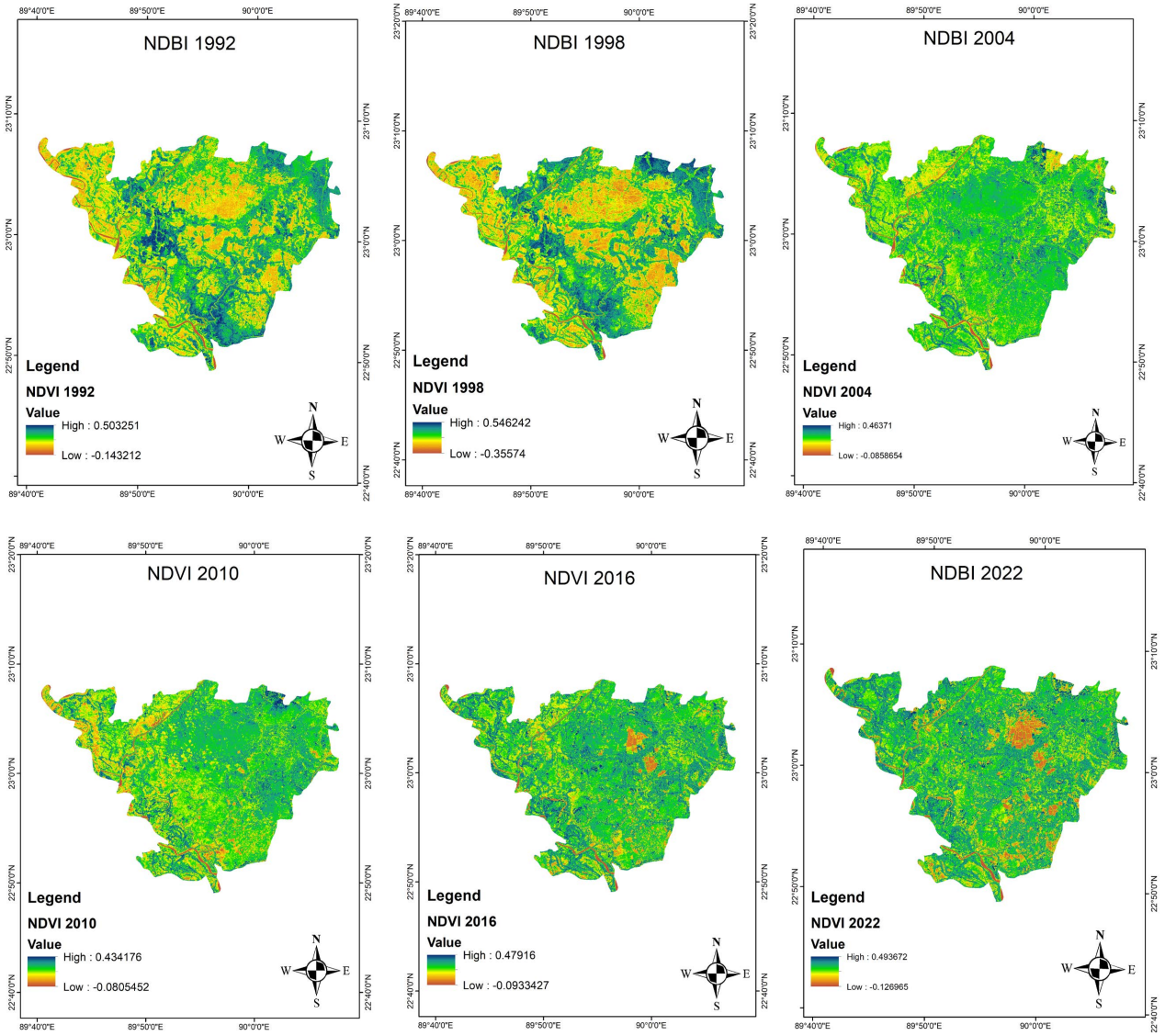


Figure 13. Vegetation index difference mapping from 1992 to 2022.

4. Discussion

The findings presented in the results underscore the urgency and importance of preserving biodiversity in Gopalganj, Bangladesh. The region's loss of plant species can have severe implications for the local ecosystem and beyond. The reduction in plant diversity disrupts ecological balance, affecting climate patterns and precipitation distribution. As a result, extreme weather events may become more frequent and severe, impacting agriculture, water resources, and human settlements. The destruction of habitats not only affects plants but also leads to a decline in animal and bird species. The loss of natural habitats disrupts ecosystems, forcing wildlife to adapt or perish, which can have cascading effects on the entire food chain. Moreover, the decline in fish species due to river shallowing and habitat loss threatens the livelihoods of communities dependent on fisheries, affecting food security and economic stability.

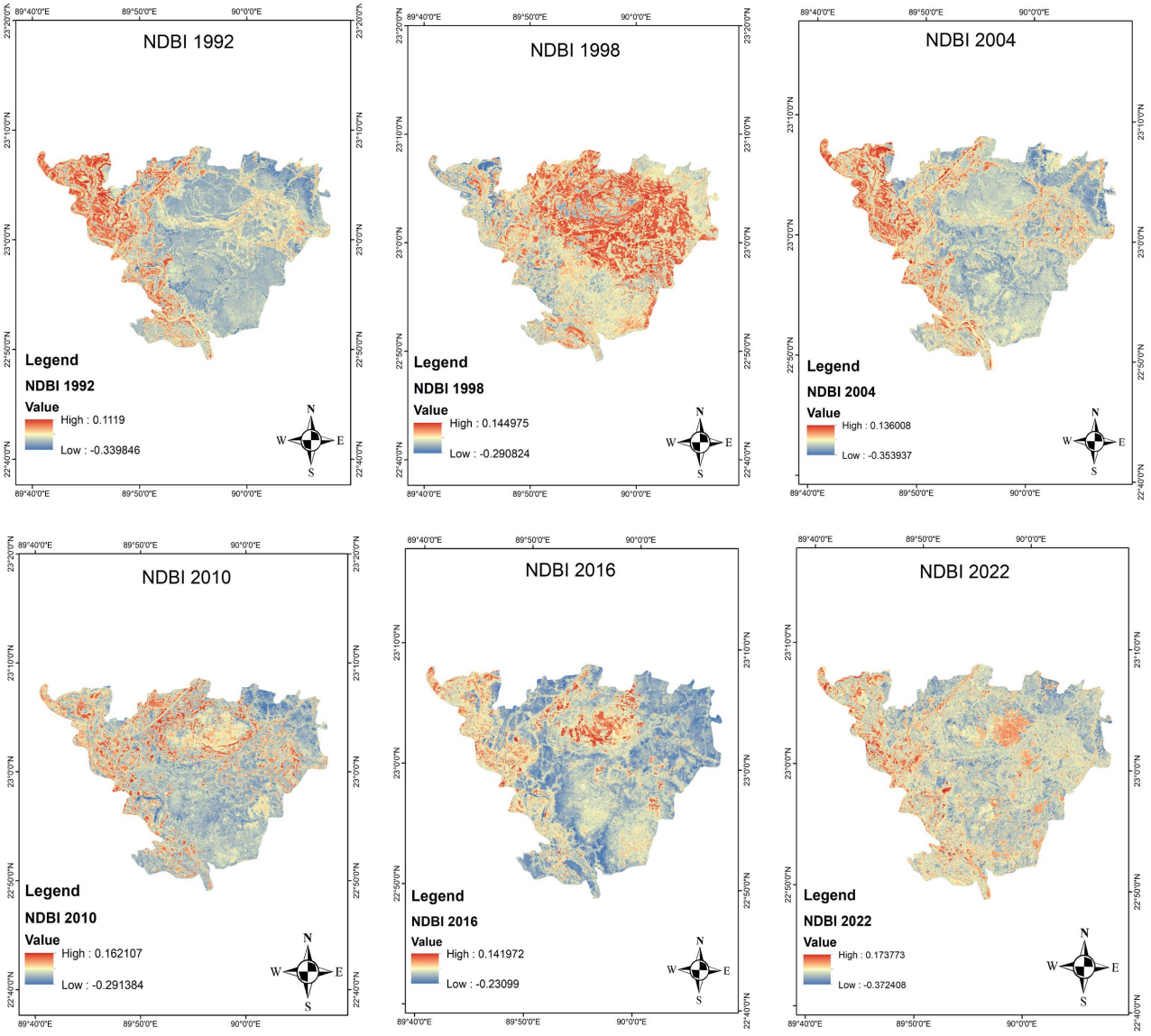
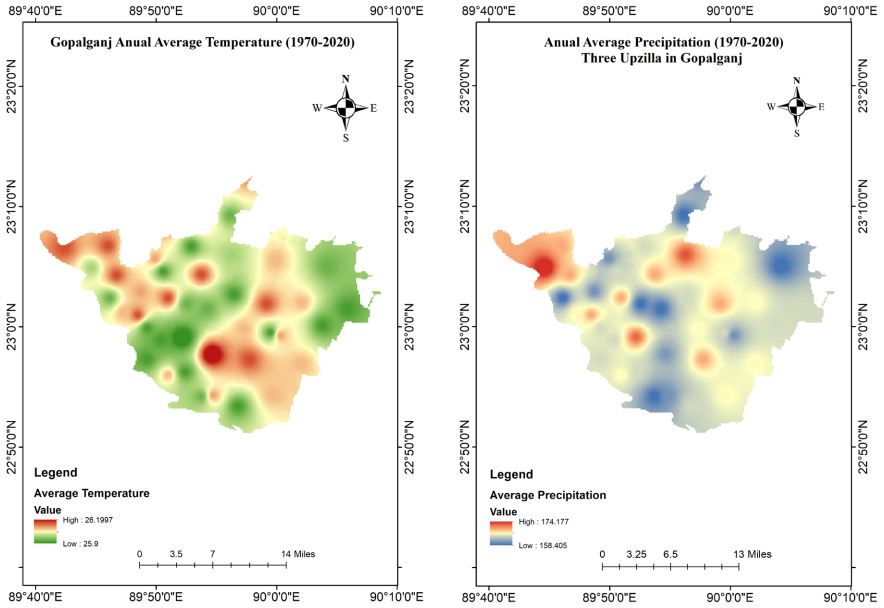


Figure 14. Build-up index difference mapping from 1992 to 2022.

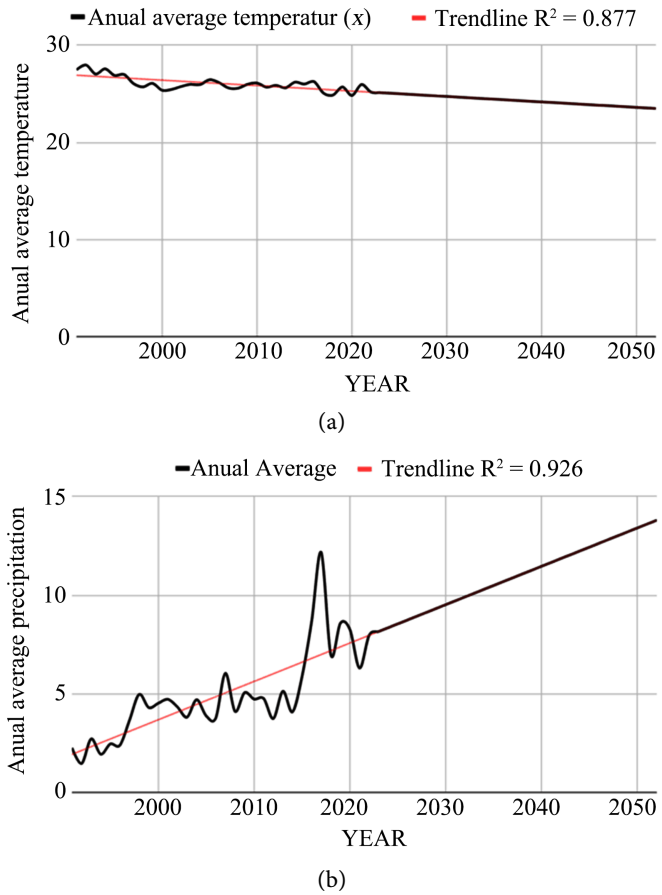
The diminishing variety of vegetables and crops raises serious concerns about food security and nutrition in the region. A decrease in crop diversity can make agriculture more vulnerable to diseases and pests, reducing yields and nutritional content. This, in turn, may lead to malnutrition and health problems among the local population. The comprehensive data spanning from 1992 to 2022 provide a robust foundation for understanding the extent of biodiversity loss and projecting future trends. These data help establish a clear picture of the urgency of the situation and underscore the need for immediate action to prevent further degradation.

To address the challenges posed by biodiversity loss, multiple measures are necessary. Conservation initiatives should be prioritized to protect natural habitats and promote the recovery of endangered species. Restoring degraded ecosystems can help create healthier environments for both wildlife and humans.



(a) (b)

Figure 15. Temperature and precipitation mapping (1970-2020): (a) Temperature mapping (1970-2020); (b) Precipitation mapping (1970-2020).



(a)

(b)

Figure 16. Temperature and precipitation projection (1991-2052): (a) Temperature; (b) Precipitation.

Additionally, addressing climate change is crucial for preserving biodiversity. Implementing measures to reduce greenhouse gas emissions, such as promoting renewable energy and sustainable land use practices, can help mitigate the negative impacts of climate change on the region's flora and fauna. Efforts to combat resource depletion and pollution are equally vital. Sustainable practices should be adopted in agriculture, fisheries, and industry to ensure the responsible use of resources and minimize pollution.

The findings of this study highlight the urgent need for comprehensive conservation and adaptation strategies in Gopalganj to mitigate biodiversity loss and its associated impacts. Climate change emerges as a major driver of species decline, necessitating efforts to reduce greenhouse gas emissions and promote sustainable land-use practices (Brook et al., 2008). Additionally, conservation initiatives should focus on protecting natural habitats and restoring degraded ecosystems to foster ecological resilience (Hooper et al., 2012).

Furthermore, integrating climate change adaptation into national policies and local planning is essential for effective response strategies (Huq et al., 2018b). Collaboration between the government, local communities, and international organizations is crucial to pool resources and expertise for successful implementation. Engaging local communities in decision-making processes is vital, as their traditional knowledge can complement scientific approaches (Rinawati et al., 2013).

Sustainable practices in agriculture, fisheries, and industry should be promoted to alleviate pressure on natural resources and reduce pollution (Guo et al., 2017b). Encouraging the adoption of renewable energy sources and organic farming can enhance resilience to climate change and biodiversity loss.

Collaboration between governments, local communities, and international organizations is essential to achieve meaningful and lasting results. By working together, we can pool resources, expertise, and knowledge to effectively combat biodiversity loss in Gopalganj, Bangladesh, and secure a sustainable future for generations to come.

Also, to address the decline of species and promote biodiversity, we need to develop sustainable land use plans, implement conservation measures for wildlife, increase public awareness and education, promote sustainable agriculture, and promote sustainable fishing practices. These recommendations address the root causes of biodiversity decline, such as habitat loss, overexploitation, and pollution. By implementing these recommendations, we can work to protect and restore biodiversity for the benefit of people and the planet.

Problem Statement

Biodiversity loss in Gopalganj District, Bangladesh, presents a pressing concern for the region's ecosystems and communities. Over the past three decades (1992 to 2022), the decline in various categories of species, including plants, animals, birds, fish, and vegetable/agricultural crops, has been observed. This research aims to comprehensively analyze the extent of biodiversity loss, identify the drivers behind this phenomenon, and assess its impact on the environment and local

populations.

Research Problem

This research will investigate the magnitude of biodiversity loss in Gopalganj District over the past 30 years, the main drivers of biodiversity loss, such as habitat destruction, climate change, and infrastructure development, and the ecological and social impacts of biodiversity loss, such as the disruption of ecosystems and the loss of food security. The research will also examine the specific impacts of climate change on biodiversity in Gopalganj District, assess the level of public awareness and perception of biodiversity loss, and propose conservation initiatives and climate change adaptation policies to mitigate biodiversity loss. Finally, the research will project the potential percentage of species loss in Gopalganj District by 2052.

5. Conclusion

The findings of this research provide a comprehensive assessment of the biodiversity loss in Gopalganj District, Bangladesh, over the past three decades (1992 to 2022). The study reveals a concerning trend of declining plant, animal, bird, fish, and vegetable/agricultural crop species, indicating a significant threat to the region's ecosystems and communities. The reduction in plant species diversity poses critical ecological challenges, impacting climate patterns, precipitation distribution, and overall ecosystem health. Habitat destruction, often driven by infrastructure development and land transformation, emerges as a major driver behind the decline of various species. Climate change, including rising temperatures and altered precipitation patterns, exacerbates the situation, leading to severe consequences for both wildlife and human populations. The loss of animal and bird species, particularly migratory birds, indicates a disruption in their natural habitats and raises concerns about the resilience of local ecosystems. Similarly, the decline in fish species due to river shallowing and habitat loss poses a significant threat to the livelihoods of communities dependent on fisheries and raises questions about food security.

The decreasing variety of vegetables and agricultural crops highlights the vulnerability of agriculture to diseases and pests, affecting yields and nutritional content, and potentially leading to malnutrition and health problems among the local population. To address the urgent challenges of biodiversity loss, immediate and coordinated efforts are necessary. Conservation initiatives must focus on preserving natural habitats, restoring degraded ecosystems, and promoting the recovery of endangered species. Climate change mitigation measures, including reducing greenhouse gas emissions and adopting sustainable land use practices, are crucial to mitigate the impacts of climate change on biodiversity.

Sustainable practices should be embraced in agriculture, fisheries, and industries to ensure responsible resource management and minimize pollution. Collaboration between governments, local communities, and international organizations is vital to mobilize resources and expertise for effective biodiversity con-

servation. Based on data trends, projections suggest an alarming increase in species decrement by 2052 if urgent action is not taken. The predicted percentage of species decrease underscores the urgent need for comprehensive conservation and adaptation strategies to protect the region's ecosystems and ensure a sustainable future for generations to come.

In conclusion, this research emphasizes the critical importance of addressing biodiversity loss in the Gopalganj District. By understanding the drivers and impacts of species decline, we can formulate evidence-based policies and actions to protect biodiversity, foster sustainable development, and enhance the well-being of both the environment and local communities. Urgent action and collaborative efforts are essential to safeguard the rich biodiversity of Gopalganj and contribute to global conservation efforts in combating the ongoing crisis of biodiversity loss.

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Availability of Data and Materials

All data generated or analyzed during this study are available for sharing when the appropriate request is directed to the corresponding author.

Conflicts of Interest

The authors declare that they have no competing interests.

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