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# Impact of Species Invasiveness on Biodiversity: A Study in the Indian Context

**Susmita Mondal [a++] and Biswajit Pal [a#*]**

*[a] Department of Rural Studies, West Bengal State University, Barasat, West Bengal, Kolkata-700126, India.*

***Authors' contributions***

*This work was carried out in collaboration between both authors. Conceptualization, secondary data collection, and initial draft preparation was done by author SM. Conceptualization, methodology, data analysis, and report finalization was done by author BP. Both authors read and approved the final manuscript.*

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## ABSTRACT

Over the past few decades, anthropogenic activities have emerged as a significant contributor to the decline of indigenous species in their natural habitats. This paper presents an overview of the impact of Invasive Alien Species (IAS) and BT cotton cultivation on biodiversity in India. The methodology employed is rooted in secondary data sources, drawing from various government publications, reports, and BT cotton production records spanning 2002 to 2021. These data sources were carefully analyzed and compared with relevant research reports to fulfill the study's objectives. The findings reveal pronounced invasiveness of species across diverse ecosystems, disrupting ecosystem functions and services, ultimately leading to biodiversity loss with economic implications

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[++] *Research Scholar;*
[#] *Assistant Professor;*
**Corresponding author: Email: biswajit.pal22@gmail.com;*

and health risks. Moreover, BT cotton, introduced as a tool in the agricultural sector, acts as a form of biological invasion. However, it has shown negative repercussions on the environment by affecting non-target organisms and degrading soil health. This study underscores the need to comprehend and address the consequences of these anthropogenic activities for effective conservation and sustainable practices.

*Keywords: Biodiversity; BT cotton; crop; ecology; environment; invasive alien species.*

## 1. INTRODUCTION

Biodiversity is a term that defines the diversity of biological species in an area- the variety includes animals, plants, fungi even microorganisms present in the natural system. All these species work together in an ecosystem that is a natural phenomenon. In every part of nature, the different species contribute their way to sustaining and continuing the natural events. Any changes in the biological balance can disturb the overall ecosystem. The ecosystem is a geographic area where biotic (plant, animal, and other organisms) and abiotic (water, air, climate, etc.) parts work together to form a bubble of life. The ecosystem regulates essential ecological processes that are responsible for cycling the nutrient between biotic and abiotic elements. It also maintains the food chain with effective coordination and collaboration of different biotic (Producers, consumers, and decomposers) and abiotic elements (light, air, water). Human-driven anthropogenic activities are the major cause of biodiversity loss [1]. Different components of biodiversity play essential roles in ecosystems, so any kind of loss or change in biodiversity can cause threaten the ecosystem [2]. A fragile ecosystem is a threat to regulating the energy flow with the effective food chain and ecological pyramid.

### 1.1 Biodiversity and Ecosystem- a Relation

Biodiversity is very often termed as species diversity, and available species in a particular area or species richness of that area [3].The distribution of biodiversity is not uniform all over the earth [4]. Biodiversity is maintaining the health of the ecosystem. Biodiversity provides a good natural environment for living its different natural activities. It has a major role to fight climate change as well as reducing the impact of natural hazards.

Any loss in biodiversity decreases the level of productivity of the ecosystem. But every ecosystem can adopt the stress of some degree of change. In case of major species loss and beyond a critical point of species removal, the ecosystem becomes loses its stability and become collapses over a while. Most time-specific species are more vulnerable to this kind of biodiversity loss condition and they become extinct in long-term situations. With the loss of species, the ecosystem also loses its complexity and heterogeneity. An abundance of some species is not a good predictor of a good ecosystem; even relatively rare species can strongly influence the energy flow and ecological food chain.

### 1.2 Biodiversity Hotspot and Biodiversity Loss

On our earth, there are many places with biodiversity-rich and deeply threatened. According to Science Daily, “A biodiversity hotspot is a biogeography region that is both a significant reservoir of biodiversity and is threatened with destruction.” On our planet, 36 hotspots cover nearly 2.5% geographical area. The hotspot has to have lost more than 70 % of its native habitat. Rapid loss of biodiversity caused many species to become extinct and at risk of becoming endangered [5].

The major cause of the loss of biodiversity is due to human interference. The human activities that directly caused the biodiversity loss or maybe indirectly changed the natural conditions that affect the life cycle of different species. Our actions of the last 50 years have been the cause of a large number of losses of species- that is ten to a hundred times more than the natural rate. Some of the anthropogenic causes are Changes in land use, direct exploitation of species, Climate change, Pollution of natural resources, and invasive alien species.

## 2. OBJECTIVES

Biodiversity is related to various kinds of Ecosystems; it maintains the health of an ecosystem. Loss of biodiversity decreases the level of ecosystem productivity. There are so

many direct or indirect reasons those are responsible for the loss of species in their habitat. Among them, anthropogenic activity over the past few decades is a strong cause of the decrease in indigenous species and affects their natural habitat. Therefore, this paper aims to portray a scenario about two anthropogenic actions that are IAS and BT cotton cultivation related to the loss of biodiversity in India.

## 3. METHODOLOGY

The methodology employed in this study involves a comprehensive gathering and examination of secondary data to investigate the intricate consequences of two prominent anthropogenic activities in India: Invasive Alien Species (IAS) and Bt cotton cultivation, both exerting significant impacts on biodiversity. The main objective is to provide a holistic portrayal of how these activities intricately contribute to the decline of native species and the degradation of their natural habitats. The data acquisition process for IAS relies on the facilitation of the National Biodiversity Authority (NBA) India, with prior validation through related studies. In parallel, data on Bt cotton cultivation, spanning from 2002-03 to 2020-21, draws from reports by authoritative bodies such as the Directorate of Economics and Statistics, DAC&FW, State Governments, and the Directorate of Cotton Development. The subsequent analysis explores the direct biodiversity impacts of IAS and the cumulative environmental consequences of Bt cotton, achieved through a synthesis of diverse research articles. This systematic approach is aimed to extract the complex relationship between these anthropogenic actions and their collective role in driving biodiversity loss, thereby contributing valuable insights for the development of well-informed conservation strategies. Moreover, as part of the data analysis, the collected information is structured according to the study's objectives. Utilizing tools like MS Excel, compare the percentage of invasive species' rate of invasiveness and their impact across different ecosystems, enhancing the precision of our findings and enriching the study's outcomes.

## 4. RESULTS AND DISCUSSION

### 4.1 Invasive Alien Species

These are animals, plants, fungi, and microorganisms that enter or are introduced to the environment from outside of their natural habitat. IAS is a threat to native species of any ecosystem. It impacts negatively on native biota causing decline or even extinction. IAS reproducing rapidly can out-compete the native species in the food chain and cause major biodiversity loss. According to the national biodiversity authority in India,presently173 most serious IAS are traced from various ecosystems among them 33% from the agricultural ecosystem, 32% from the terrestrial ecosystem,27%, and 8% from the major island ecosystem.

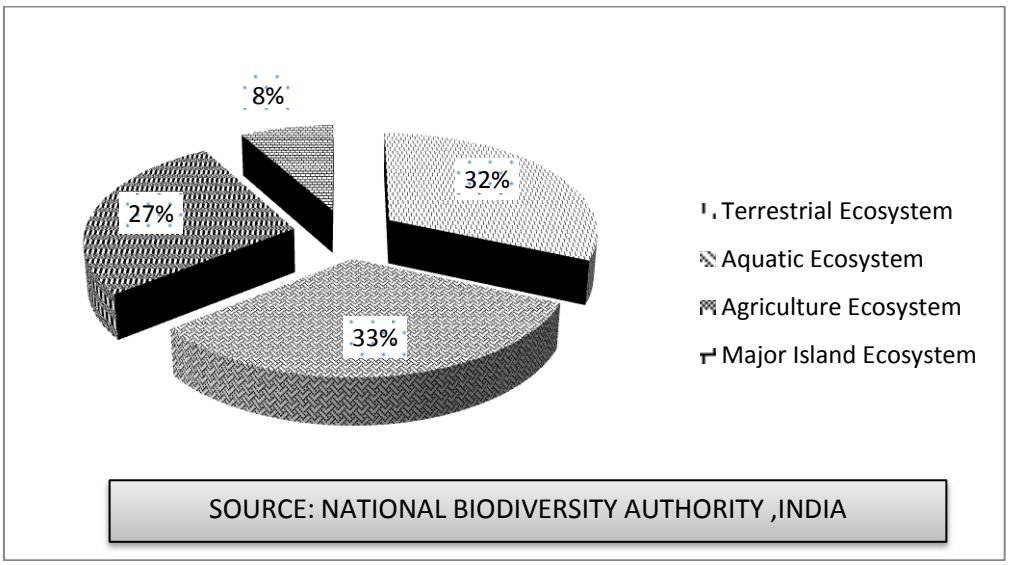


**Fig. 1. Distribution of IAS in India**

According to S.Sandhylan[6], Island's biodiversity ecosystem is directly impacted by IAS, and its effect on their economy, culture, and human health. In Andaman Nicobar Islands 3 snails, 4 insects, 13 marine species, and 566 plant species were identified as IAS. A study conducted in 2013-14 stated that in Andaman Nicobar Island spotted dear or chital create a potential threat to the present ecosystem because of their high degree of seeding, sampling, and overgrazing causing of extinction other native species along with its change in vegetation cover and zonation pattern. Another study revealed that from 2000 to 2013 Indian bullfrogs were introduced into Andaman Nicobar Island. This species is a prolific breeder with a short breeding season. Recent studies establish that the food preference of this frog significantly overlaps with several amphibian species, which triggers competition for food among native species. Besides this, it consumed several native species.

Invasive mammalian predators are the most affected group of global biodiversity.30 species of invasive predators are implicated in the extinction or endangerment of 738 vertebrate species and collectively contributeto 58% of all birds' mammals and reptiles' extinction. Cats, rodents, dogs, and pigs have the most vulnerable to invasive predators [7]. In the lower Shivalik region, Himachal Pradesh, there more than 20% of the vegetation area is covered by three invasive species that is *Ageratum, Parthenium, and Lantana.* Due to the invasion of three species' the alpha diversity of this area drastically reduced by 39.62%, 41.26%, and 41.03% respectively in the species *Ageratum, Parthenium, and Lantana* Invaded area [8].

In 1951 from Maharashtra the weed named *Partheniumhysterophorus*was first reported. it is an aggressive colonizer of exposed soil, fallow wasteland, and roadside. It is considered a noxious weed because of its prolific seed production and fast-spreading effect,allelopathic effect on other plants. It also creates health hazards to humans, like respiratory problems, dermatitis, and asthma, and it's highly allergenic. It is also a threat to animal health and a strong competitor for the crop [9].

*Lantana* was introduced in India in 1809; it's a native tropical American plant species that spread rapidly in farms and forestland*. Lantana Camara*has several negative impacts like its disrupted succession cycle, displacing native biota which results in loss of biodiversity, and their density in forest increase allelopathic interaction resulting in species richness [10]. Apart from that it also has a secondary impact it gives shelter to some serious pests that as mosquitoes and test-fly that result in health issues [11].

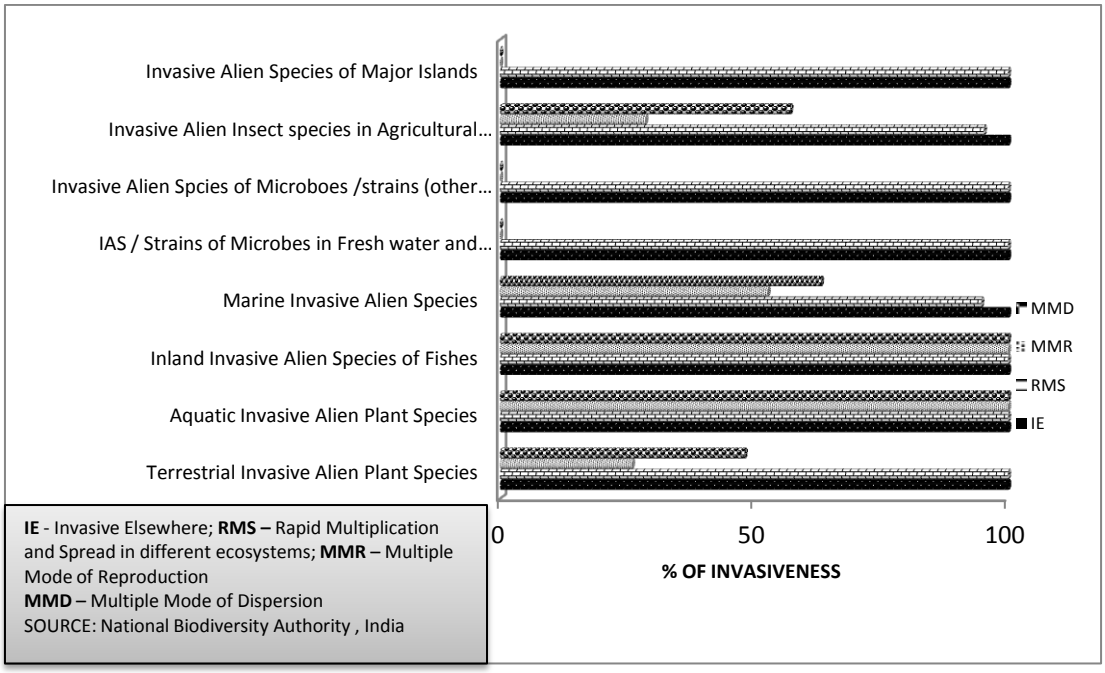


**Fig. 2. Invasiveness of species among different ecosystem**

### 4.1.1 Invasiveness among species

Fig. 2represents the invasiveness of the species in different ecosystems based on some adopted criteria like IE, RMS, MMR, and MMD. After analyzing data provided by the national biodiversity board of India it has been found that IE invasiveness of spices is 100% among all ecosystems. RMS invasiveness is 100% in terrestrial, aquatic, and inland microbes in fresh water and brackish water and microbes in the agriculture ecosystem. Approx. 95% RMS invasiveness was observed in marine IAS and alien insect species in agriculture.MMR or multiple modes of reproduction is 100% in IAS aquatic plant species and inland invasive alien species, 52% marine IAS, and 28% among IAS insects in the agricultural ecosystem. In another ecosystem like the island, microbes in agriculture have zero invasiveness in terms of multiple-mode reproduction or multiple-mode dispersions found in 100% of their total IAS population among aquatic IAS plant species and inland IAS of fishes, 63% among marine IAS species, 57% MMS invasiveness among insects in the agricultural ecosystem. IAS microbes in fresh & brackish water, agricultural microbe ecosystems, and in major islands represent zero percent of MMD invasiveness.

### 4.1.2 Impact of IAS on biodiversity

In different ecosystems, IAS species affect directly or indirectly for understanding their impact on biodiversity we take data published by the national biodiversity authority in India. In (Fig.3) B1-affecting ecosystem services and function, B2-biodiversity loss, and B3- economic loss and health hazard are three adopted parameters for analyzing IAS impact on biodiversity. It seems that 100% B1 impact is found in aquatic IAS, in-plant and inland IAS of fishes and in the territorial ecosystem, 96%, among marine invasive alien species impact 42%, Invasive Alien Insect species in Agricultural ecosystems Impact 9.5%. Loss of biodiversity or B2 among aquatic and inland ias100%.in marine alien invasive spices 57%'in terrestrial ecosystems 21%and in major islands 4%, IAS microbes in water and agriculture impact zero biodiversity loss.

B3 or Economic loss and health hazard impact is 100% in inland plant IAS, microbes in fresh and brackish water, and IAS insects in agricultural ecosystems .96%in IAS microbes in agriculture ecosystems .71% in the major island and 36%in marine 7% in terrestrial ecosystem.

So, after analyzing the data published by NBA India, it has been found that the percentage of species invasiveness is high among different ecosystems. Three parameters are taken to identify the degree of biodiversity loss by IAS, which shows that the percentage of impact on biodiversity varies from one ecosystem to another. Every IAS on the earth is to some extent responsible for the extinction of other native species.

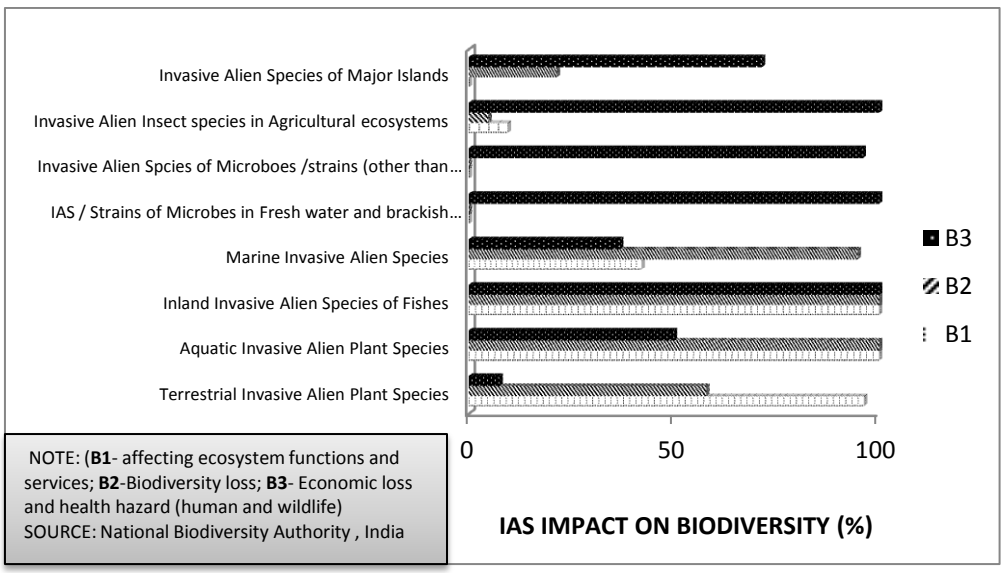


**Fig. 3. IAS impact on biodiversity among different ecosystem**

## 4.2 Genetically Modified Crop: BT Cotton

Cotton or white gold is an important commercial crop in our country; it consumes more than 45 % of the total use of pesticides in India cotton production is affected by many pests, whitefly, and sap sacking. One of them is American bollworm, which reduces 45-75% yield. It is an insecticidal protein whose gene has been derived from the soil bacterium *Bacillus thuringiensis*.

During crop growth full stage BT cotton can protect crops from bollworms, for this reason, it is successfully developed in the USA later other countries like China, Australia, Mexico, South Africa, Argentina, and India started to cultivate BT cotton commercially. In 2002 three BT cotton hybrids were approved for commercial cotton cultivation which was a breakthrough step for the cotton industry.

**Table 1. Showing area under BT cotton and production, 2002-2021**

| Years | Area under cotton* (in lakh hectare) | Area under Bt. cotton** (in lakh hectare) | Production (in lakh bales) | Yield (kg per hectare) |
|---|---|---|---|---|
| 2002-03 | 86.24 | 0.29 | 86.21 | 191 |
| 2003-04 | 75.98 | 0.92 | 137.28 | 307 |
| 2004-05 | 87.87 | 4.85 | 164.29 | 318 |
| 2005-06 | 86.78 | 12.34 | 184.99 | 362 |
| 2006-07 | 91.44 | 33.53 | 226.32 | 421 |
| 2007-08 | 94.14 | 54.72 | 258.84 | 467 |
| 2008-09 | 90.07 | 66.69 | 222.76 | 403 |
| 2009-10 | 101.32 | 85.52 | 240.22 | 403 |
| 2010-11 | 111.23 | 96.32 | 330 | 499 |
| 2011-12 | 121.78 | 107.58 | 352 | 491 |
| 2012-13 | 119.77 | 105.43 | 342.2 | 486 |
| 2013-14 | 119.6 | 110.35 | 359.02 | 510 |
| 2014-15 | 128.19 | 119.4 | 348.05 | 462 |
| 2015-16 | 122.92 | 106.83 | 300.05 | 415 |
| 2016-17 | 108.28 | 89.43 | 325.77 | 511 |
| 2017-18 | 124.29 | 110.76 | 328.05 | 477 |
| 2018-19 | 126.58 | 117.81 | 287.08 | 386 |
| 2019-20*** | 125.84 | 117.47 | 322.67 | 436 |

**Source: Directorate of Economics and Statistics*
*** DAC&FW, State Governments and Directorate of Cotton Development, Nagpur*
****First Advancement Estimate (Directorate of Economics and Statistics)*

### 4.2.1 BT cotton production in India from 2002-2021

According to data collected from the Directorate of Economics and Statistics, India has been showing that from 2002 to 2021 area under cotton cultivation and BT cotton cultivation increased. The growth rate of the Area under BT cotton was 2.17 % in 2003-04 next year it was 4.27 % which was the highest growth rate after that growth rate fluctuated over the period. In the year 2012-13, there was a negative growth rate in an area under BT cotton production. So, after analyzing the data, it was found that initially after 2002 farmers adopted new technology because production increased and it reduced the use of insecticide but in the later stage farmers reduce to the cultivation of BT crops which might be a reduction in yield, an increase in the price of BT seed.

### 4.2.2 Impact of BT cotton on biodiversity

According to P. Sadashivappa and M.Quim [12] over the first five years of BT cotton technology adoption, it achieves success in India with farmers benefiting from pesticide reduction, higher yields, and significantly higher profits. From 2007 to 08 India achieves record cotton with the help of adopting new technology whiles other countries faced a slowdown. The long-term scenario of BT cotton adoption primarily worked as a strong pesticide reducer. Later it showed that BT cotton has continued to control one major cotton pest but with BT resistance in another pest and a surging population of non-targeted

pests increased, as a result, farmers use more pesticides than earlier [13].

The reduction of pyrethroids and several conventional insecticides on BT cotton is presumed to have an enhanced intensification of non-targeted species like mealybugs and Spodopteralitura. The mealybugs were detected as new species found in cotton in India. The reason behind this is the excessive use of hazardous insecticides over the past two years for mealy bugs. It appears as panic to the scientific community because it rapidly increases all across India and caused damage [14].

Nutrient depletion in the soil is not directly related to BT technology but repeated cultivation of transgenic crops affects soil fertility because not initially but in a later stage, BT crop needs more use of insecticide than earlier to prevent pests, as a result, cotton crop shows a nutrient deficiency, especially in rain feed areas [14].

Refugee crops prevent the emergence of large amounts of resistant pests which need more chemicals. Thus, in the BT cotton field, it's required to cultivate non-BT cotton refuge crops because it supplies non-resistant insects. Therefore, BT seed companies provide a small amount of refugee crop seed with BT seed for cultivation. But less than 30 percent of farmers used this seed that is known for which purpose it was given. In Maharashtra, farmers used this seed and also sprayed it to protect seed from bollworms, and here it defected with the real purposes for which it was served. Most of the farmers refused to use refugee crops because of their lack of knowledge, and they feared more pest attacks which need more expenditure to control pests and yield reduction [15]. Deployment of the transgenic crop is a major concern because of its effect on the non-target organism. In crop plants, continuous availability of BT protein, their mode of release, and modified form prohibits. Based on the past safety record and insecticide spray, a simple inference was drawn about the safety of transgenic plants [16]. BT cotton indirectly affects some beneficial insects. Laboratory research has shown that consuming BT cotton parts results in the decline of the lacewing caterpillar population due to the toxic effects of Crylab protein. This is a major cause of the loss of food for attacking predators, pathogens, and parasites decreases [17].

There is a possibility about the large-scale deployment of transgenic crops for pest management, it might affect anthropoid diversity, natural enemies, and through different trophic level toxin flow among insect fauna, development of resistance in target insect pests, pollen flow in close relatives, antibiotic resistance [18].

K. Venkateshwarlu [19] pointed out questions concerning bio-safety because, in Adilabad and Khammam district, Andhra Pradesh several sheep and goat mortality were reported due to grazing on BT cotton fields. Before these same incidents occurred in the Warangal district in 2005 where 1800 sheep and goats perished according to Ngo's report. Therefore, some studies were taken by GEAC and biotech companies to check the toxicity level of BT cotton and the result revealed that it might occur due to hydrocyanic acid (HCN) and nitrates in BT cotton but there is no such report which strongly supports this argument. Many NGOs disagree with the GEAC and the company's observation because some biotechnical companies have tended to deny reports of livestock deaths or blame them on pesticide residues.

After analyzing BT cotton production data and some shreds of literature review, we can't directly say that BT cotton is responsible for environmental hazards. Because primarily when it started in India quantities of insecticide used in cotton cultivation were reduced drastically. That is a beneficiary from the perspective of the environment. In the later stage, it was found that the repeated use of transgenic crop cultivation creates a nutrient deficiency in soil apart from that it introduces another pest and disease. To control new pests farmers use more insecticides. As a result, the intense use of insecticide causes another species' extinction and creates a harmful impact on the environment.

## 5. CONCLUSION

Biodiversity is a part of nature and it contributes to the natural ecosystem. Any kind of external interference cost massive damage to this natural balance and compromises the sustainability of the environment. There is no confirmation that the bio-invasiveness process is one of the important key factors that lead to the destruction of native habitats and create ecological disturbances. This process takes place through the invasion of alien species or the adoption of new biotechnology in agriculture or another sector. It introduces through good, people movement or sometimes a requirement of mankind like in the agriculture sector adoption of BT cotton cultivation to control pests or

introduction of several exotic fishes into India for sport fishing and cultural activities which provide a livelihood for millions of people. Human action often triggered the process of biological intrusion which directly or indirectly impacts our biodiversity. Invasion of plants and species in a new area is negatively impacted by the habitat destruction of indigenous species, which triggers competition for food and disrupts the cycle of succession. In the case of invasive plants their rapid spreading effect, allelopathic effect on another plant, displace of negative biota, and has also given some secondary impact like creating health hazards to humans like respiratory problem, dermatitis, asthma, allergenic and also create a threat to animal health. On the other hand, invasion of new biotechnology like the cultivation of BT cotton for pest management initially,an active success for pest reduction but in later stages it creates some negative impact on the environment. In the Indian context cultivation of BT cotton increase the intensification of non-target pest and their pest resistance power, as a result, by introducing some new insect-like mealybugs to control these insects' farmers use more hazardous pesticide which is harmful to health. BT toxin effect pollen flows and disrupts natural enemies. sometimes goat and sheep death occur in BT cotton cultivated area some controversies arise that the toxicity of BT cotton is blamed for cattle death but there is no such reason BT cotton cultivation negatively impact animal health and controversies are still there. So in this area, there is a need for proper and bias less research and the government should promote proper cultivation methods among farmers and take various strategies to minimize its negative impact on the environment. Different kinds of protection measures from all of our ends need to be taken to protect the biodiversity that also protects our nature from massive loss and transform the fragile ecosystem into a stable one that is a sign of a sustainable environment.

Understanding and dealing with an invasive problem is a big challenge for us. We need to develop new strategies for handling the invasive alien issue. To meet this problem SCOPE (scientific committee on Problems of the Environment) was developed for a focused coordinated and broadly based approach. India recently needed to improve its understanding of ecology and invasive process, and knowledge about the environment to understand under what conditions species became invasive and their characteristics. It is realized that government should strengthen its quarantine authorization with the help of new legislation to prohibit the introduction of new species without consent, various government departments like the forest, agriculture, environment, veterinary, and public health should monitor the unauthorized introduction of wild animals, plants into a new region. These institutional approaches can lead long term success against the introduction of new species. To observe invaders' movement, status, rapid assessment, and their potential impact on the ecosystem we need to utilize our developing technologies like remote sensing and GIS through these we can track and manage invaded species. As well as most divesting invasive species most sensitive type of ecosystem distribution of the most abundant species map on a global scale is needed for quarantine assessment and status checking of invading species [20].

We need a sustainable environment for living so we should not disturb our ecosystem as it naturally controls energy flow and maintains the nutrient cycle. By managing the biodiversity loss we can ensure the natural ecosystem and prevent unwanted natural phenomena. The effective legislation and implementation of the law can check the accessibility of species, effective use of the land, and also control pollution. Demarcated areas for natural life like National parks have also taken important roles in this regard. Regular monitoring, research on lives, and effective collaboration of government-non-government sectors on these issues have also been effective to protect our nature and natural ecosystems. Educating people also has a significant role in key success in this regard because it aware people and the public become directly or indirectly involved to conserve their natural environment and influences their governmental representatives to take appropriate measures to protect nature.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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