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Drivers of Degradation Report

ASSAM PROJECT ON FOREST & BIODIVERSITY CONSERVATION

AFD AGENCE FRANÇAISE DE DÉVELOPPEMENT

"DRIVERS OF DEGRADATION AND DECREASE IN FOREST COVER OF ASSAM"

Prepared for

Assam Project on Forest and Biodiversity Conservation Society (APFBCS)

The Energy and Resources Institute

...towards global sustainable development

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List of Abbreviations

AFPBS	Assam Project on Forest and Biodiversity Conservation Society
FCD	Forest Canopy Density
FFV	Forest Fringe Villages
FIRMS	Fire Information for Resource Management System
FPI	Fire Point Intensity
FRP	Fire Radiative Power
GIS	Geographic Information System
IMD	India Meteorological Department
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
ISFR	India State of Forest Report
IUCN	International Union for Conservation of Nature
LULC	Land Use Land Change
MDF	Moderately Dense Forest
MODIS	Moderate Resolution Imaging Spectroradiometer
NGO	Non-Governmental Organizations
NRSC	National Remote Sensing Centre
NTFP	Non-Timber Forest Produce
OF	Open Forest
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RFA	Recorded Forest Area
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SD	Standard Deviation
SEA	Socio-Economic Assessment
SPI	Standardized Precipitation Index
VDF	Very Dense Forest
WLS	Wildlife Sanctuary

1. INTRODUCTION

Forests in India are vital ecosystems that cover a significant portion of country's land area, providing numerous ecological, economic and social benefits (Envistat, 2022). Forests not only harbours a vast array of floral and faunal species but also provide numerous ecosystem services such as recreation and ecotourism, flood protection, water purification, erosion control, and climate regulation through carbon sequestration (Hassan, R.M., Scholes, R. and Ash, N., 2005). Subsequently, forests are essential to the livelihood of local communities, they serve as a wellspring of resources that contribute to their sustenance and economic well-being. The diverse array of benefits from forests, including timber, non-timber products, and medicinal plants, forms the backbone of their subsistence and income generation. Fuelwood extracted from forests is still a primary source of energy in rural household. Beyond practical utility, forests hold cultural and spiritual significance, shaping the identity and cohesion of communities.

The rising population of India significantly contributes to the increased dependency on forests to meet various needs and demands. This drives urbanization and expansion of agricultural activities, leading to the conversion of forested areas into settlements or agricultural land. This increased reliance on forests for essential resources exacerbates the strain on these ecosystems, disrupting their natural balance and contributing outwards climate change (Rudel, T.K., Coomes, O.T. et. Al., 2005). This heightened pressure on forests and its resources intensifies forest degradation and deforestation. Forest degradation is marked by declining health and quality and is often a consequence of various anthropogenic activities. Whereas deforestation is the irreversible conversion of forest land for non-forest purposes.

Forest ecosystems are intricately connected to climate change; they are affected by climate change in both direct and indirect ways, with various feedback loops. Deforestation releases stored carbon into the atmosphere, significantly contributing to GHG emissions and amplifying the global warming effect. This process weakens the ability forests to sequester carbon, disturbing their vital role in mitigating climate change. Concurrently, climate change induces shifts in temperature, precipitation, weather patterns, directly impacting the health and composition of forests. Extreme weather events, intensified by climate change pose a threat to the biodiversity of forests.

This interconnected web establishes a feedback loop where the degradation of forests contributes to climate change, while climate change, in turn, exacerbates deforestation and forest degradation. Breaking this cycle necessitates comprehensive strategies, for which identification of drivers of deforestation and forest degradation is required. The report aims to identify different drivers that leads to deforestation and forest degradation. It will also help to enhance the current knowledge about these drivers and recommend appropriate climate change adaptation and mitigation strategies. The report intends to support the work of Assam Project on Forest and Biodiversity Conservation Society (APFBS), as well as related deforestation and forest degradation strategies, to formulate a robust decision-making process leading to climate change mitigation and adaptation.

The synthesis provided in this report is built up on scientific literature, available national and regional data, primary survey, and stakeholder consultation. It contains an assessment of key drivers of deforestation and forest degradation, to improve upon the existing knowledge on their roles in different regions. The report will supplement the implementation of relevant policy decisions for addressing the drivers. Furthermore, the report will aid identifying steps required to enhance the efforts for climate change mitigation and adaptation. Based on the analysis from this report several recommendations can be made to support on-going practices and provide state and/ or region level interventions to combat climate change.

1.1 Deforestation and Forest Degradation in India's Forests

Forests play a vital role in providing livelihood to billions of people across the globe, by providing several ecosystem services, and protecting biodiversity. From the year 2014 to 2018 the world has lost almost 10.4 lakh sq. km. of forest (Ken et al., 2020). This has been due to overexploitation of forest resources, for meeting the demands of rising population or for development activities. The dynamics of deforestation and forest degradation can be complex with interrelations between several factors such as agricultural expansion, infrastructure development, pressures of burgeoning population, natural hazards etc. Although in the Indian context, degradation is prominent, and deforestation is controlled, there is still degradation observed throughout the country. In a recent study it was observed that approximately 40% of forests in India are over-exploited and degraded, 55% are fire prone, and 70% have observed reduction in natural regeneration (Patra et al., 2022).

As per the ISFR 2021, a marginal increase of 0.22% has been observed in the forest cover of the country but a closer analysis of the report reveals that the quality of India's forest has deteriorated across 15,200 sq. km of forest area. Further analysis from year 2015 to 2021 reveals that, the quality of forests has degraded over a total area of 74,457 sq. km. Forest lands have been diverted for development objectives such as industrialization, roadways, and irrigation projects, resulting in significant forest loss. India has lost 1.5 million hectares of forest area for development since 1980, with most of this loss occurring after 2000. In the North-eastern states, which together account for 23.75 per cent of India's total forest cover, the forest cover has undergone a decrease 1,020 sq. km between 2015 and 2021 (ISFR, 2021). As per ISFR, the total forest cover of Assam in very dense and moderately dense forest has decreased by 1,509 sq.km. from year 1999-2021.

1.2 Drivers of Deforestation and Forest Degradation

The dynamics and causes of deforestation and forest degradation are multi-faceted, complex and vary from place to place. Literature has classified drivers of deforestation and forest degradation into direct (i.e., proximate) and indirect (i.e., underlying). "*Proximate or direct drivers of deforestation and forest degradation are human activities and actions that directly impact forest cover and result in loss of carbon stocks. Underlying or indirect drivers are complex interactions of social, economic, political, cultural and technological processes that affect the proximate drivers to cause deforestation or forest degradation"* (Kissinger et al., 2012). Direct drivers are generally place-specific and prominent, such as expansion for agriculture and settlement purposes, infrastructure development, mining, resource extraction (timber, fuelwood, fodder, minor forest produce etc.). The direct drivers are influenced by various socio-economic, political, institutional factors that function at various scales, from local to global level. These may include weak governance, market forces, institutional capacities etc. (Geist and Lambin, 2002; Kissinger et al., 2012).

Both the direct and indirect drivers include a combination of natural and anthropogenic drivers. For instance, certain direct drivers such as agriculture or infrastructure expansion are caused due to immediate anthropogenic actions that lead to forest loss. Forest degradation can also be caused due to abiotic or natural causes (floods, earthquakes or forest fires), biological (e.g., bark beetle) factors, in addition to anthropogenic factors. Natural drivers of forest degradation are factors that originate from processes and events. While human activities often play a significant role in forest degradation, certain natural factors contribute towards the decline in health of forest ecosystem. Some of the key natural drivers are depicted in the figure below (Philip G. Curtis et. al., 2018). Anthropogenic factors, driven by human activities, play a significant role in forest degradation. These activities often lead to the direct or indirect deterioration of forest ecosystems.

1.3 Linking Climate Change and Drivers of Deforestation and Forest Degradation

Climate change is one of the greatest challenges of the 21st century. Various anthropogenic activities lead to climate change which further magnifies the impacts of forest degradation and deforestation (IPBES, 2018). This generates various positive feedback loops between climate change, loss of biodiversity, loss of forest cover and quality, as given below:

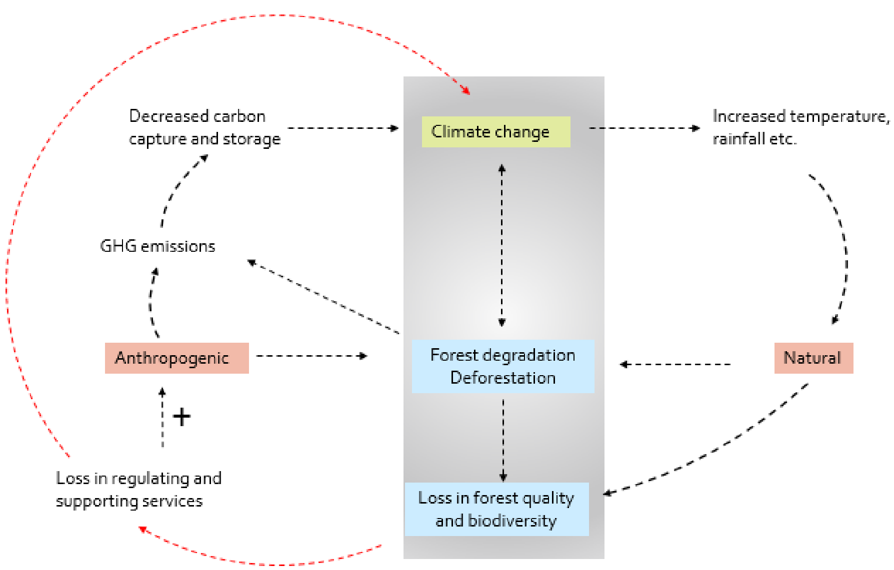


Figure 1: Positive feedback loop of forest degradation and deforestation accelerates climate change which in turn leads to further degradation.

2. METHODOLOGY

In order to understand and simplify the relevant direct and indirect drivers for Assam's forests, the study employs a four-way approach, as elaborated in the sections below.

2.1 Four-way Approach

We have implemented a four-way approach for the identification of drivers of deforestation and forest degradation in Assam. Each of the approach aims to identify different drivers, understand the interlinkages and correlation between them. The detailed approaches are as follows:

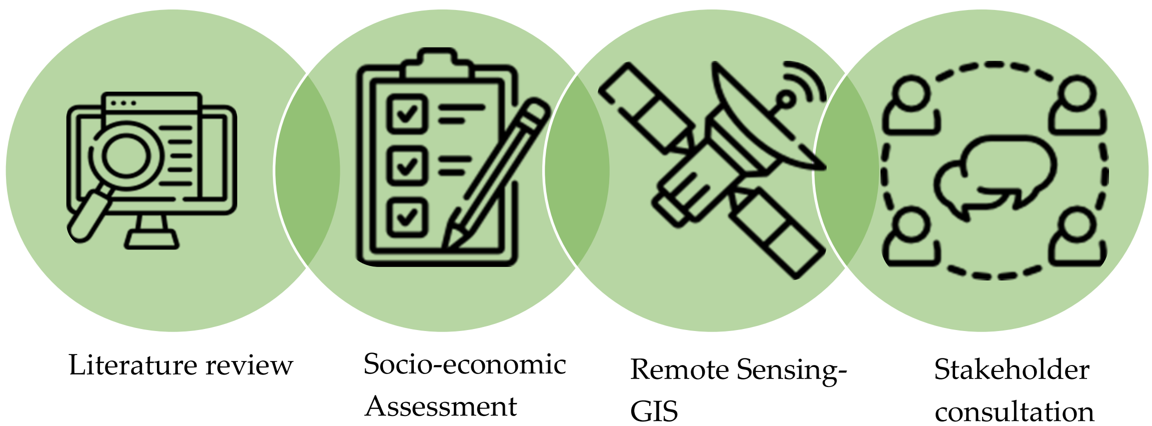


Figure 2: Four-way approach

2.1.1 Systematic Review of Literature

The methodology for the study adapted from the established protocol as specified in Pullin and Stewart (2007) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). The methodology consisted of the following steps:

It consisted of the following steps:

a) **Setting a search strategy:** For the systematic retrieval of peer-reviewed scientific publications, various databases were accessed. This included academic research databases (such as SCOPUS, Science Direct, JSTOR etc including Google Scholar), relevant grey literature, policy briefs and unpublished literature. Publications between the years 2000-2023 were screened and analyzed.
b) **Key-word strategy:** The search and retrieval of literature a keyword-driven approach. Since the study pertained to identifying the drivers relevant to state of Assam, the keywords included the words "Assam" AND "Deforestation"/ "Degradation" in combination with various plausible drivers such as "Shifting Cultivation" OR

"Resource Extraction" OR "Development Activities" OR "Illegal Activities" OR "Geopolitical Conflicts" OR "Encroachment" OR "Monoculture Plantations" OR "Natural Hazards" etc.

c) **Screening of Literature:** Following the search of the literature, the appropriate inclusion and exclusion criteria were applied (i.e. the study region, the type of drivers, relevance to the study objectives etc.) to all the potential literature at the title, abstract and full-text level to filter out the research papers which were not relevant to the study and its objectives.

d) **Data analysis:** The search strategy identified 3,506 publications by using the keyword driven strategy. On removal of the duplicates, 1,384 articles were further screened at the title level based on the inclusion and exclusion criteria. Following the screening, 472 articles were further screened at the abstract level which left 269 articles to be screened at the content level. Through this process, 159 articles relevant to the study objectives were selected for qualitative analysis.

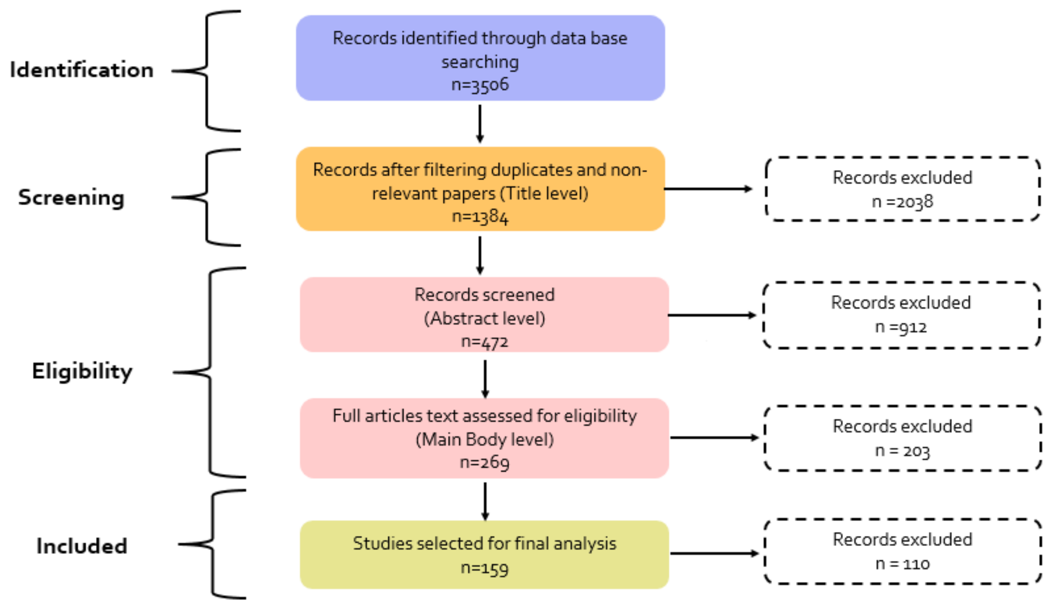


Figure 3: Systematic review of literature.

Table 1: Stages of the systematic review

Stages of review as per PRISMA guidelines	Methods	Approach
Data Identification	Various databases were accessed. This included academic research databases (such as SCOPUS, Science Direct, JSTOR etc including Google Scholar), relevant grey literature, policy briefs and unpublished literature. Publications between the years 2000-2023 were screened and analysed	Keyword driven approach (indicative): • assam + forest + degradation + fuelwood • assam + deforestation + encroachment • assam + deforestation + shifting cultivation • assam + deforestation + mining • assam + deforestation + plantation + tea/rubber/pineapple • assam + forest + degradation + biodiversity loss
Data Screening	1. Duplicates and non-relevant papers were removed. 2. Appropriate inclusion and exclusion criteria were applied at the title and abstract level	Inclusion Criteria: - Literature should be about Assam's Forest and biodiversity. - Should mention the relevant driver. Exclusion Criteria: - Reference to other North-eastern states - No attribution to the drivers
Data eligibility	Data were screened at the content/full body level appropriate to the inclusion criteria	
Data Analysis/ Inclusion	Selected literatures were analysed pursuant to the study objectives. The literature identified were identified qualitatively and categorised under various drivers.	

2.1.2 Socio-Economic Assessment

Along with secondary literature review, a household survey was also conducted. The aim of the survey was to understand the impacts of various drivers of deforestation and forest degradation in the state of Assam. Both quantitative and qualitative methods are deployed for collecting primary data from the selected sample villages for this study. The households selected for the primary survey is inclusive of different communities, economic backgrounds, gender, caste etc. A household survey was carried out to understand the socio-economic status of the forest fringe communities, their dependency on various forest resources and their perception about different drivers of deforestation and forest degradation in Assam. The questionnaire deployed for the household survey included 5 Sections (Annexure 1):

Section 1: It includes general information of the respondent's household.

Section 2: It includes socio-economic status of the respondent along with the facilities available to them.

Section 3: It includes questions on dependency of forest fringe villages on various forest resources such as fuelwood, bamboo, fodder, and NTFPs.

Section 4: It includes perception of respondents on forest, and various drivers of deforestation and forest degradation.

Section 5: It includes awareness of respondent about various forest management committees, and their participation level during skill development/ capacity building/ awareness generation workshops organized by various NGO or forest department.

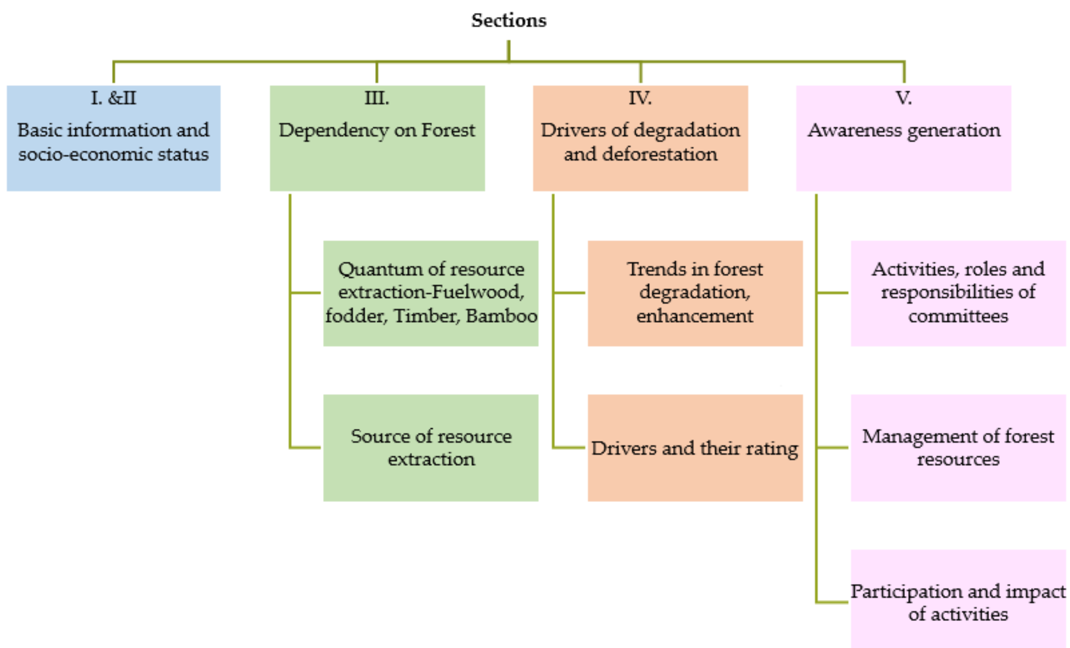


Figure 4: Sections of questionnaire.

Data collection and total number of samples

The data/information at the village and the household level has been collected by visiting the sample villages and households in the selected districts of Assam. The number of samples or sample size (n) for surveying the number of households in a district is derived using the statistical formula (Daniel, 1999) as mentioned below:

$n = S/(1+(S-1)/N)$

where,

n = Sample Size

S = Sample size for infinite population

N = population size (for maximum sample size estimation, maximum number of households was considered)

where,

S = (Z^2) * P * ((1-P)/M^2)

where,

S = Sample size for infinite population

Z = Critical value of normal distribution from the statistical table or the Z-score.

P = sample proportion (50% -It provides maximum sample size where the pilot is not conducted)

M = Margin of error

Using the above statistical formula, the sample size has been calculated for the households surveyed at a 97% confidence interval and margin of error 3.

Note: The Z-Score at 97 % confidence interval is 2.17.

Sampling Strategy

1. The strata are selected based on the proximity of the Forest Fringe Villages (FFV) from the forest. This selection is based on the consideration that people living nearer to the forest will extract a greater quantum of resources as compared to the people living farther away. The amount of distance that needs to be travelled for the collection of resources influences the consumption patterns. Thus, based on this we have classified the Forest Fringe Villages (FFV) into 2 categories:
   - Strata 1: FFV situated up to 1 km from the boundary of the forest.
   - Strata 2: FFV situated within 1 km to 3 km from the boundary of the forest.
2. After selecting the strata, we have identified the total number of households and population residing in the given strata along with the name of villages in which they fall under. All the districts in Assam have been divided into 5 zones based on the per capita forest cover within each stratum.
3. Districts are selected in each zone in consultation with the Forest Department based on the highest and lowest per capita forest cover of each district in their respective Zones.
4. The households and village in each district are then selected randomly in consultation with the Forest Department to remove any bias in selection.

The total number of households covered in stratum 1 is 828 and the total number of households covered in stratum 2 is 552. There are a total of 4,481 villages in stratum 1 and 5,584 villages in stratum 2.

Table 2: Sample household in each stratum

Description	Total sample household
Sample HH in Stratum 1	828
Sample HH in Stratum 2	552
Total HH Samples	1,380

Approximately 15 households are selected in each village randomly. A total of 91 villages have been covered out of which, 60 villages are covered in stratum 1 and 31 villages are covered in stratum 2.

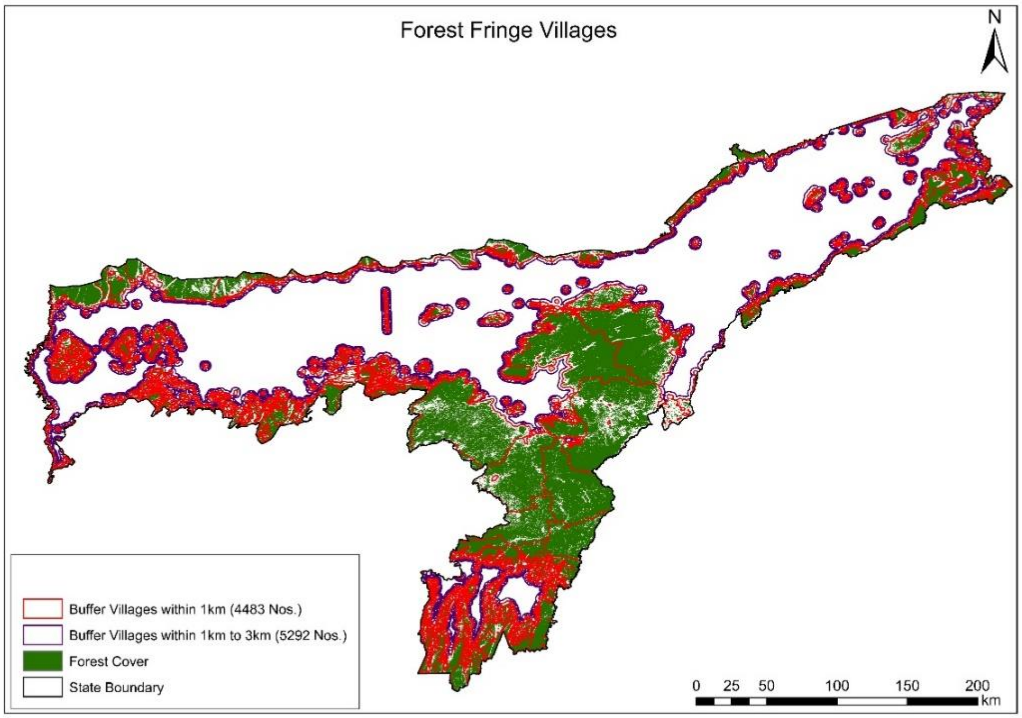


Figure 5: Forest Fringe Villages in two strata

2.1.3 Remote Sensing (RS) – GIS Analysis

Remote sensing and GIS have been used for the monitoring and analysis of forest degradation drivers. Several natural and anthropogenic drivers have been identified and analysed. Anthropogenic drivers include Forest Land transition (Derived from LULC) and Population Pressure. Climate change, earthquakes, forest fires, landslides, floods, and droughts are some of the natural causes of degradation. A machine learning based FCD model has also been used to track changes in the quality of the forest cover, and the impact on the carbon stocks due to forestland transition has been examined using LULC change matrix.

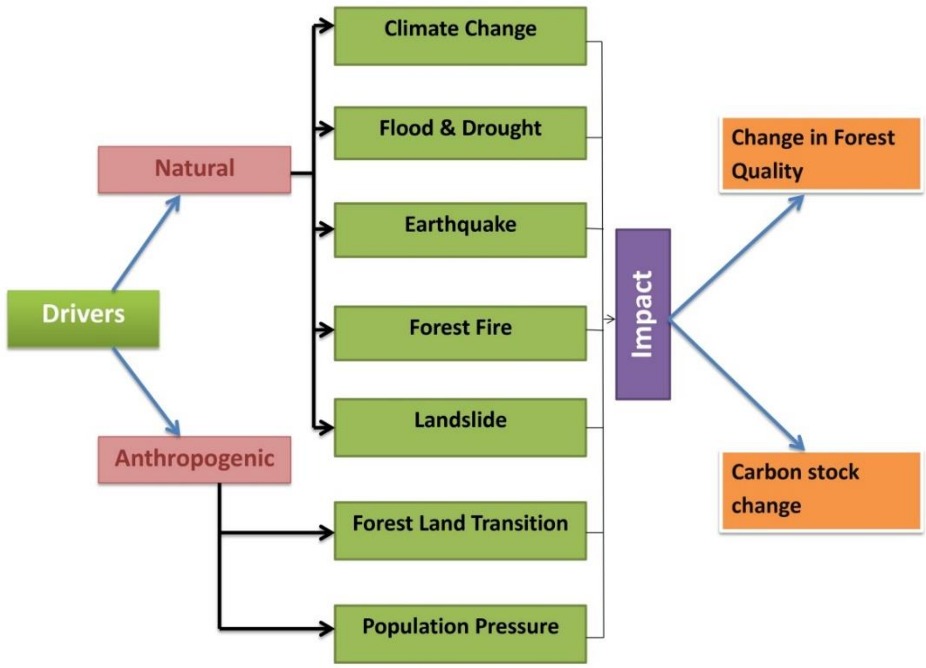


Figure 6: Drivers of deforestation and forest degradation

Data Sources

Various data used for mapping the spatial extent of the drivers like population, land use and land cover (LULC), fire, drought, earthquake, landslide, and flood have been tabulated below:

Table 3: Data sources used for RS-GIS analysis

S.No.	Parameter	Data Source	Temporal Coverage	Resolution
1	Fire Point Intensity (FPI)	MODIS Fire data (FIRMS) MODIS/FireDataset	2000-2022	1km
2	Standardized Precipitation Index (SPI)	IMD IMD/Rainfall	2000-2022	25km
3	Forest Canopy Density (FCD)	Landsat 5 and Landsat 8 earthexplorer.usgs.gov	2000, 2022	30m
4	Land Use Land Change (LULC)	Landsat 5 and Landsat 8 earthexplorer.usgs.gov	2000, 2022	30m
5	Landslides	Global Landslide Catalog GPM.NASA/landslides/data	2007- 2022	Point Location
6	Earthquake	USGS Earthquake Catalog USGS/Earthquake	1950-2022	Point Location

7	Flood	Sentinel 1 SAR data	2017-2023	10m
8	Climate Variability	CRU High-resolution gridded datasets (https://crudata.uea.ac.uk/cru/data/hrg/cru_ts_4.07/)	1951-2022	0.5°* 0.5°
9	Population	GlobalHumanSettlementLayer		1km

Methods

The drivers of deforestation and forest degradation can be broadly classified into two categories natural and anthropogenic. These drivers lead to either decrease in forest quality or loss in carbon stock or both. The extent of natural and anthropogenic drivers is assessed based on different parameters such as landslides, earthquakes, fire point intensity, droughts, floods, climate variability, land transition, population, forest canopy density, and carbon stock. The method used to analyse each parameter is as follows:

1. **Natural Drivers**
    a. **Landslides- L**andslides contribute significantly to the loss of forest cover, mainly through the displacement and uprooting of trees as well as disrupting the ecosystem. For the analysis, GPM NASA Landslide data has been used, which collects the rain-triggered landslides data post 2007. Using ArcGIS, a spatial distribution has been done to identify and map the areas prone to landslides.
    b. **Earthquakes-** Earthquakes trigger the forest degradation & deforestation through the widespread destruction and disturbance they cause in forested areas. The seismic activity can lead to the uprooting of trees, alteration of landscape, and changes in soil structure. For the analysis, the data has been obtained from USGS Earthquake data catalogue, and a spatial distribution map has been prepared based upon the number of occurrences and the intensity of the Earthquake.
    c. **Fire point intensity-** Fire can either be caused by human or natural factors. Here, the fire prone as well as the fire events affected districts in Assam state has been delineated through the FPI analysis. For the analysis, MODIS FIRMS dataset of spatial resolution of 1km has been used. Spatial distribution layers, providing information on the distribution of forest fire events and the intensity based on average Fire Radiative Power (FRP) score for each district over the period of 22 years have been developed.
    d. **Drought Assessment-** SPI plays a pivotal role in highlighting the variations in precipitation pattern which is useful to monitor the drought patterns. Here, SPI is used to analyse the dry weather pattern associated with drought across each district from the year 2000 to 2022.

       Using ArcGIS, the rainfall data has been processed and SPI is calculated using the formula.

SPI= $(Pi - Pavg)$/ SD

Where Pi is annual precipitation in each station, $Pavg$ is average precipitation in each station, and SDx is the standard deviation.

The average SPI values across 22 years for each point are integrated into ArcGIS to perform the IDW interpolation. The result is the composite average SPI for the entire study area over 22 years. The SPI layer has been reclassified into four classes based on drought vulnerability. Higher risk regions were assigned a value of 4, while areas of lower risk received a value of 1.

e. **Flood Analysis-** A thorough assessment of post and pre-flood inundation has been conducted in this study. The information regarding the major disaster events has been sourced from various government reports (Assam State Disaster Management Plan, Assam State Flood Report, NRSC Flood Atlas) and National and Regional news articles since the year 2000. Based on the impact of floods (Impact on livelihood & Infrastructure, human casualties, and area destruction), as well as the availability of remote sensing data (both optical imageries & SAR Data), a total of 4 events of floods have been selected for the analysis. The analysis incorporates Sentinel-1 Synthetic Aperture Radar (SAR) images as well as sentinel-2 data, which have been available for the study region since February 2015 and November 2015 respectively. The flood inundated areas have been deduced by calculating the difference between the pre and post flood time and applying filtering and smoothing techniques.

f. **Climate variability-** To assess the decadal variability of major climatic parameters over the period of 72 years (i.e., 1951 to 2022), spatial distribution maps of average annual precipitation and air temperature have been prepared for each consecutive decade since 1951 to present. Decadal variability of major climatic parameters has been observed using the high-resolution CRU dataset (https://crudata.uea.ac.uk/cru/data/hrg/cru_ts_4.07/cruts.2304141047.v4.07/) having a monthly temporal resolution and spatial resolution of 0.5°.

2. Anthropogenic drivers

a. **Land Transition-** Analysis of Land Use and Land Cover Dynamics spanning over the period of 22 years (2000 to 2022) has revealed a visible trend of forest land conversion into other land use classes. The LULC for the year 2000 and 2022 has been developed using support vector machine algorithm. ArcGIS Pro has been used to process the change detection algorithm, and a change matrix has been developed. This change matrix provides a detailed representation of transition between land cover classes.

A table has been developed which delineates the net area conversion from forest to land cover classes. Furthermore, an additional table quantifying the annual rate of transition has been developed.

b. **Population-** Human settlement is identified by the presence of constructed man-made elements such as buildings, associated structures, and civil works. To calculate the human settlement in each grid cell, the built-up areas (Building footprint area) taken from the Landsat and Sentinel-2 imagery (upscaled to 30m). Raw census data with geometry of the Gridded Population of the World, version 4.11(GPWv4.11), from CIESIN/SEDAC Census population data with a resolution of 250m, has been factored into the analysis. The GHSL method is then applied to integrate information from population censuses, built-up areas, into a 1km grid. The final GHSL layer represents the presence and density of population. Each grid cell value represents the absolute number of inhabitants (https://ghsl.jrc.ec.europa.eu/ghs_pop2023.php).

The spatial raster dataset depicts the distribution of residential population, expressed as the number of people per cell. Residential population estimates between 1975 and 2020 in 5-year intervals and projections to 2025 and 2030 derived from CIESIN GPWv4.11 which were further disaggregated from census or administrative units to grid cells (spatial resolution-100 m).

Here, the spatial distribution of population in the state of Assam as well as within the recorded forest area (RFA) have been prepared for 6 corresponding epoch (1980 to 2030) using the GHSL population data having the spatial resolution of 100 meter to assess the variation in the spatial distribution of population numbers.

3. **Impact Assessment**

   a. **Forest Canopy Density (FCD)-** The examination of Forest Canopy Density (FCD) from 2000 to 2022 has unveiled a discernible pattern in the conversion of forest density, indicating transition from one density class to another.

      The FCD study has been carried out using Landsat 5 imagery for 2000 and Landsat 8 imagery for 2022. The change detection technique has been processed using ArcGIS Pro, which produced a change matrix as a result. This matrix provides an extensive illustration of the changes that take place between various Forest Density classes.

   b. **Carbon Stock Assessment-** Machine learning based temporal land use land cover change matrix have been used to compute the net variation in forest carbon stock due to transition of forest land into other land classes.

2.1.4 Stakeholder Consultation

A stakeholder consultation was carried out on 17th November 2023 in hotel Nakshatra, Guwahati (Assam). It included stakeholders from different domains and organizations such as NGOs, state forest department, academic institutes, researchers, State Disaster Management Authority and government officials from different ministries such as labour, panchayat, tribal affairs, and culture.

The purpose of the stakeholder consultation was to provide a platform for policymakers, government departments, and NGOs to collaborate and discuss about different drivers of deforestation and forest degradation acting in the state of Assam. The agenda and images of the stakeholder consultation is provided in Annexure 2.

The stakeholder consultation helped to understand the local region-specific drivers of deforestation and forest degradation, identify target areas for strategic recommendations and to understand the limitations in the current management practices in Assam.

An approach involving problem analysis was employed for designing the stakeholder consultation program. The existing drivers affecting forest and biodiversity in the state of Assam were mapped on the district map of Assam. The step-by-step approach for conducting the stakeholder consultation for understanding the role of drivers of deforestation and forest degradation is as follows:

1. **Explanation of project overview and current findings of the project –** The overall objectives of the stakeholder consultation and different activities planned were briefly explained along with the methodology adopted for implementation of the project. This was followed by the major finding of the vulnerability analysis to assess the impacts of climate change on forest and biodiversity of Assam.

2. **Group Activity:** In line with the objective of the workshop a group activity was conducted for the following:

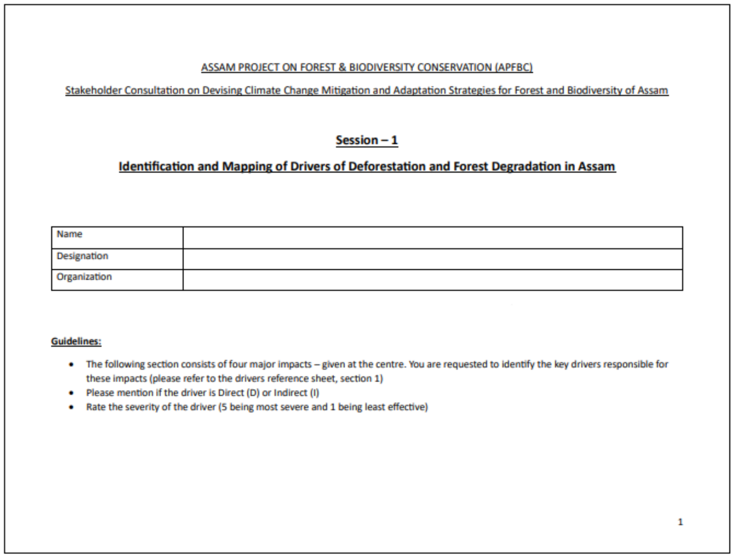
    - Identification of drivers of deforestation and forest degradation present in Assam and their categorization as direct or indirect drivers.
    - Mapping prominent drivers in the districts of Assam.

    All the stakeholders were divided into five groups. To maintain heterogeneity and ensure brainstorming among the members, each group had a representative from different departments, organizations, and domain of work.

    Details of group activity-

    Task 1- Identification of drivers of deforestation and forest degradation acting in the Assam and their categorization as direct or indirect driver.

    This task was an individual activity. All members in a group were required to individually list out drivers based on four major impacts. Along with this the participants were also required to categorize the driver as direct or indirect and rate them based on severity (5 being most severe and 1 being least severe).



ASSAM PROJECT ON FOREST & BIODIVERSITY CONSERVATION (APFBC)

Stakeholder Consultation on Devising Climate Change Mitigation and Adaptation Strategies for Forest and Biodiversity of Assam

Session – 1

Identification and Mapping of Drivers of Deforestation and Forest Degradation in Assam

Name	
Designation	
Organization	

Guidelines:

- The following section consists of four major impacts – given at the centre. You are requested to identify the key drivers responsible for these impacts (please refer to the drivers reference sheet, section 1)
- Please mention if the driver is Direct (D) or Indirect (I)
- Rate the severity of the driver (5 being most severe and 1 being least effective)

1

Figure 7: Guidelines and participant detail sheet for Task 1

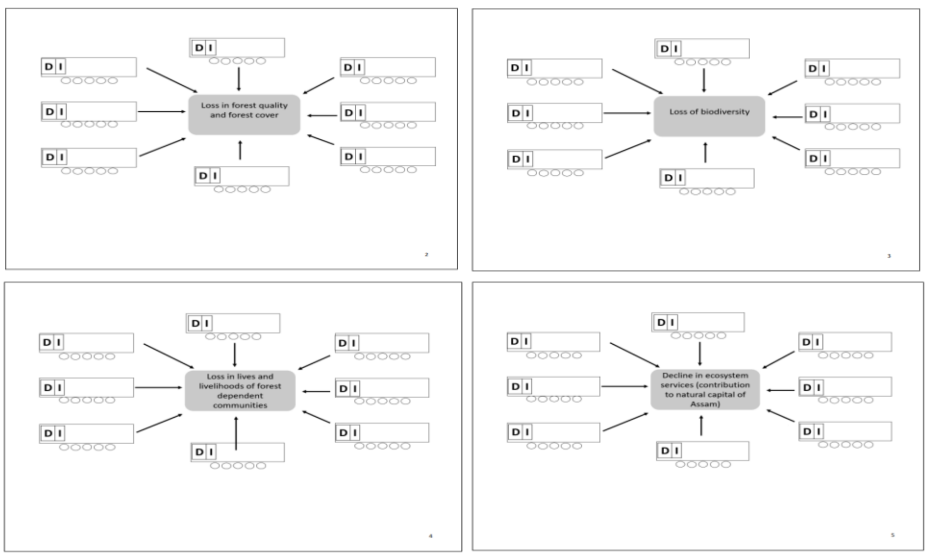


Figure 8: Activity sheet for Task 1

<u>Task 2-</u> Mapping drivers in the district map of Assam. (Group Activity)

Each group was encouraged to discuss the driver identified in the task 1. Based on their respective experience the groups were asked to conduct a spatial mapping of the identified drivers on the political map of Assam.

This was followed by a short presentation by the group leader of each group to showcase their findings to all the groups.

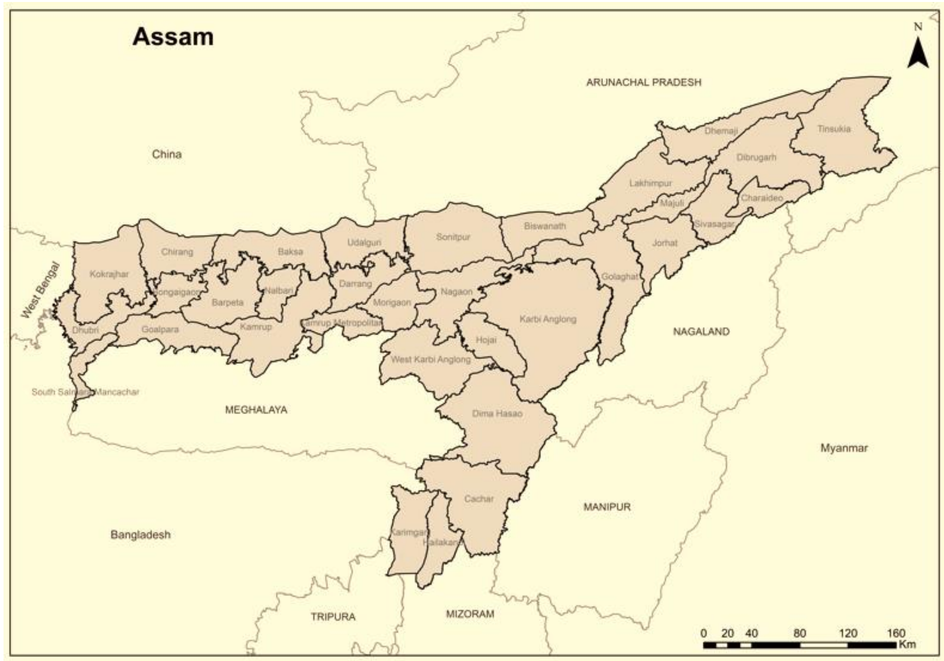


Figure 9: Political map of Assam for Task 2

An exhaustive coded driver's reference sheet was provided to each participant (Refer to Annexure 5). The purpose of list was to get unbiased opinions of all the stakeholders on whether a particular driver is direct or indirect.

3. TERI findings- A short presentation on findings of Socio-Economic Assessment (SEA), systematic literature review, and RS-GIS findings was also presented. This was followed by a group discussion.

3. FINDINGS

The findings of the four-way approach undertaken in the report to identify and assess the impacts of different drivers of deforestation and forest degradation are as below:

3.1 Systematic Review of Literature

The findings of systematic literature review are as follows:

3.1.1 Evidence from Systematic Review of Literature

The following section provides an overview of the drivers that are identified in Assam:

Resource Extraction and Illegal activities

Forests and its resources are indispensable to forest dependent communities for their livelihoods. The North-east region, including Assam is a repository of various forest resources which are extracted for various purposes (Heinen & Srivastava, 2009; Sharma and Pegu, 2011; Nath S.K., 2013; Dey et al., 2015; Hazarika & Kalita, 2019). Unsustainable resource extraction methods are also a contributing factor (Menzies and Rao, 2011). Resource extraction and its overexploitation (fuelwood, fodder, timber, and various minor forest produce etc.) has been cited has one of the leading drivers of forest degradation in Assam (Ramakrushna and Layek, 2012; Debnath et al., 2015; Das et al, 2016; Kumar et al., 2017). For instance, the forest in districts such as Karbi Anglong, and Joypur Reserve Forest in Dibrugarh district are overexploited for NTFPs such as bamboo and rattan (Nath et al., 2005; Teronpi et al., 2015).

Sengupta et al., 2010 states that the major threats to amphibians in Assam include its collection for consumption along with collection of forest produce, bamboo, dry wood, firewood, wild vegetables, etc. Badiya et al., 2020 has also mentioned the decline in diversity of the sacred forest due to overexploitation of forest resources by neighbouring human settlements. Zimmermann et al., 2009 has highlighted that the unsustainable extraction of forest products is one of the major reasons for human-wildlife conflict between elephants and people. Talukdar and Choudhary, 2017 and Talukdar et al., 2018 have reported overutilization of resources by nearby communities from the Barak valley (Karimganj, Hailakandi, and Cachar Districts). This exploitation has led to decline in the biodiversity of the valley. Forests in Karbi Anglong have been converted to another land use to meet the demands of broom grass (*Thysanolaena latifolia*) (Baidya et al., 2020).

Overdependence on forest resource such as medicinal plants have put them under risk of being threatened leading them to be categorized under the IUCN red list. As per Jiji, 2015, dependence on medicinal plants in Sivasagar district by various tribal communities have led to a decline in many high value medicinal plants. Barbhuiya et al., 2008 has also reported the overexploitation for medicinal purposes in Barak Valley, where 150 medicinal plants are used by local people and tribes.

Exploitation of forest resources is also prevalent in the form of overgrazing. Assam is home to the one- horned rhinos and excessive livestock grazing has led to their loss in habitat. Increase in cattle population, as reported by Sarma et al., 2009, has led to excessive grazing in the Pobitora Wildlife Sanctuary (WLS).

Also, activities such as illegal extraction of timber and poaching are also major issues in the state of Assam (Kumari et al., 2014; Mathur et al., 2005; Murthy, 2013; Sharma and Sarma, 2014; Sarma, 2015; Talukdarand Choudhary, 2017). Kaziranga National Park, one of the prime habitats for rhinos is subjected to the threat of poaching (Puri & Joshi, 2018; Hazarika & Kalita, 2019). Poaching is the major threat to the rhinos in Pobitora WLS as well, with 50 animals poached between 1988 and 2006 (Sarma et al., 2009). The Nameri National Park and Tiger Reserve have also witnessed an increase in poaching of wildlife and forest degradation due to ethno-civil conflicts, facilitated by easy access to weaponry used for poaching (Velho et al., 2014). Habitat loss of Asian elephants in Assam has been attributed to illegal felling of timber for commercial purposes (Aaranyak, 2008). Illegal timber logging has also caused large scale destruction in the Inner Line RF, Katakal RF, Longai RF, Singla RF of the Barak Valley, leading to habitat loss and fragmentation (Talukdar et al., 2018). Talukdar & Choudhury, 2017 rank illegal capturing and domestication for trade of ivory amongst the primary factors for decline of Asian elephants in Barak Valley.

Lack of education and poverty amongst the communities is considered as some of the major reasons for this unsustainable extraction of forest resources. (Hazarika & Kalita, 2019; Islary & Nautiyal, 2021).

Shifting Cultivation

The North-eastern region is prominently known for shifting cultivation or *jhum*, which has also been attributed as a driver of deforestation in Assam (Mathur et al., 2005; Upadhya and Saiki, 2010; Murthy and Sharma, 2013; Jiji, 2015; Ramkrushna and Layek, 2018; Khanum, 2021; Deka and Kumar, 2023). Approximately 0.45 million people living in the North-eastern states practice *jhum* with the total affected area of 44,000 sq. km (Lele and Joshi, 2009). Decline in the forest cover in the districts of North Cachar Hills, Karbi Anglong, Karimganj, and Hailakandi has been primarily attributed to shifting cultivation. As per a study by Phangchopi et al., 2017, *jhum* ranks first, as a major driver of large scale clearing of forests in the Karbi Anglong district. *Jhum* contributes to 12.5 % to the degradation of the Singhason landscape (Teronpi et al., 2015) and has led to habitat fragmentation, creation of gaps in the canopy cover and decline in forest cover in Barak Valley (Talukdar et al., 2018).

Earlier the land parcel under *jhum* was used after 20 to 25 years, but nowadays the *jhum* cycle has reduced to 4 to 5 years (Tamuli, J., & Choudhury, S., 2009). As per other studies, the rotation period of shifting cultivation which was earlier 6-7 years, has now reduced to 1-2 years, which is leading to deforestation-induced soil erosion and sedimentation of rivers (Deka and Kumar, 2023). Due to government limitations and an increase in human population, the *jhum* cycle has severely decreased, often lasting just two to three years, thereby creating pressure on the land.

While shifting cultivation is intricately linked with the culture and social fabric of tribal communities, it also has detrimental consequences on the ecology in terms of depleting soil fertility and causing soil erosion in higher catchments (Chaterjee et al., 2006; Bhuyan, 2019).

Encroachment (Agriculture, and Settlement)

Rapid urbanization for various purposes has significantly altered land use change, globally (Ifatimehin and Ufuah, 2006). This includes, and is not limited to commercial, industrial, residential, institutional, and recreational land uses (Acharjee et al., 2012). Expansion for agriculture and settlement purposes, due to population growth, migration and urbanization is one of the leading causes for forest degradation in Assam (Ramkrushna and Layek, 2018; Ranjan, 2019; Hussain and Goswami, 2019; Das et al., 2020; Goswami et al., 2020). Among all the states in India, Assam has the largest area under encroachment (Saikia et al., 2013). There has been a 7.47% decline in forest cover between 1990 and 2000, and a 7.11% loss between 2000 and 2010 due to encroachment in the districts of Sonitpur and Udalguri (Mahato et al., 2021). As per another study (Mahanta & Das, 2013), the districts of Sonitpur and Golaghat experienced one of the highest rates of deforestation between 1990 and 2001.

Literature of the past decade indicates growth in settlement and agricultural area and thereby, degraded forests too. The Reserve Forest areas across various districts of Assam have also witnessed the reduction in dense forest cover due to expansion of agriculture and settlement areas, driven by urbanization, population growth and migration issues (Devi, 2013; Saikia and Saikia, 2020). This is evident in the Dulung and Kukoi Reserve Forest areas of the Lakhimpur district and Rani Reserve Forest area of the Kamrup district (Goswami et al., 2020). Studies conducted in the Nagaon and Karbi Anglog regions also note a marked decrease and increase in the dense and open forest covers, respectively, from 1992 to 2010. (Le moine, 2012; Deka et al., 2013). Between 1974 and 2005, the Reserved Forest Area in Jorhat and Golaghat district decreased by 458.8 sq. km and 176.68 sq. km, respectively (Acharjee et al., 2012). As of 2022, encroachment in the forest area is around 3,64,145.02 ha. (SHA, 2022). Assam accounts for around 45% of the total encroached forest land in India (PTI, 2024)

The impacts are not bereft of its implications on the wildlife. Heavy encroachment in the reserve forests in the Golaghat district have impacted the habitats of the Asian Elephants which once served as a prime. Only 167.94 sq. km (16.18%) of the 1,037.94 sq. km of the forest remains undisturbed which have led to fragmentation of elephant habitats (Aaranyak, 2008). Similarly, in Joypur Reserved Forest, the core area remains protected while the peripheral areas of forest are encroached by the local people for tea plantations (Saika & Devi, 2011). In the Nalbari district of Assam, human encroachment has led to reduction in the number of snake fauna due to increased interaction and irresponsible killing of snakes by humans (Baishya & Das, 2018). Sengupta et al., 2010 mentions encroachment for plantations as one of the main reasons for habitat destruction of amphibians as it results in drying up of forest floor, depleting its microhabitat. Encroachment in Pobitora WLS, Laokhowa WLS, Patharia Hills and Barak Valley has impacted the habitat for rhino and has led to loss in forest cover (Sarma et al., 2009; Nath S.K, 2013; Talukdar et al., 2017; Talukdar & Chaudhary, 2017). Encroachment in Sonitpur district has led to the erection of electric fences leading to human-wildlife conflicts and loss in life. It was observed that 138 elephants died in a span of 13 years (from 2003 to 2016) due to electrocution from electric fences, & sagging powerlines (28%), retaliation via poisoning, poaching, & shooting (23%), natural deaths (18%), accidental deaths (14%), and other unknown reasons (17%) (Kalam, Baishya, & Smith, 2018).

There has been degradation in protected areas such as the Manas National Park, Nameri National Park, Dibru-Saikhowa National Park, due to encroachment, population growth and other anthropogenic activities (TCP, 2014; Sharma and Sarma, 2014; Sarma, 2015; Shah and Shah, 2023.) For instance, the Dibru-Saikhowa National Park witnessed a forest cover loss of 8.23% from 2012 to 2021 (Shah and Shah, 2023). There has been immense pressure of encroachment and securing cultivable lands in the Nameri National Park which have led to degradation of forest cover and habitat fragmentation (Sharma and Sarma, 2014). Biodiversity of wetland regions, such as the Kapla beel in Barapeta district and Deepor beel have also faced significant losses due to illegal encroachment and cultivation of shallow beds of the wetland (Deka et al., 2015; Goswami et al., 2020). In a recent study it was revealed that encroachment and illegal felling has turned one-tenth of the area in Amchang Wlidlife Sanctuary under human settlement (Changkakati, T., 2017). Around 7.7 sq. km of the total forest area in Amchang WLS is heavily encroached (Purkayastha et al., 2020). According to Areendran et al. (2010), the protected areas in the districts of Karbi Anglong, Morigaon, Darrang and Sonitpur, Golaghat, Barpeta, and Kokrajhar, degraded forests and settlement areas have grown at rates (sq. km/yr) of 25.50 and 0.48, respectively, and forest areas are degrading due to deforestation at a rate of 0.98 sq. km/yr.

In Brahmaputra Watershed, between 1990-2023, the settlement and cropland area increased from 3.6% to 16.3% while the vegetation cover decreased from 48.7% to 35% (Haile et al., 2023). In Brahmaputra valley, between 1973-2021, the built-up area, barren land and cultivated land has increased by 384.99%, 20.28% and 7.60%, respectively, in contrast to the vegetation and water body cover which decreased by 19.48 & and 47.13%, respectively (Debnath et al., 2022). This study also simulated that urbanization and growing population would increase the built-up area up to 19.09% by 2050 and that the likelihood of conversion of land use classes into the forest class is lower than the likelihood of conversion into the cultivated land class.

Insurgency, in-migration and increase in population from neighbouring countries are attributed as major reasons for encroachment (Kushwaha & Hazarika, 2004; Chatterjee et al., 2006; Barbhuiya et al., 2008; Sarma et al., 2009; Sengupta et al., 2010; Dutta et al., 2016; Talukdar & Choudhary, 2017). For instance, Amchang WLS being close to city Guwahati bears the pressure of increasing population through immigration (Purkayastha et al., 2020). Talukdar et al., 2018 and Hazarika & Kalita, 2019 note that excessive influx of immigrants in Assam has resulted in the loss of biodiversity and human-wildlife conflict.

Geopolitical Conflicts and Governance

Since the late 1990s, insurgency and armed conflicts in Assam have not only prevented forest management and protection activities but has also led to habitat fragmentation and devastation of infrastructure (Kushwaha and Hazarika, 2004; Velho et al., 2014; Nath et al., 2023). Armed conflicts and insurgency in the state have also led to deforestation and loss of biodiversity (Vandekerckhove and Suykens, 2008; TCP, 2014). These conflicts have also aggravated encroachment in some areas. The Panbari and Betbari areas of the Manas National Park have been two areas where 15 sq. km of the area has been encroached, where few communities continue to clear forest lands (TCP, 2014). Mahanta and Das, 2013 note that both Sonitpur and Golaghat districts are located near the border of Assam state and are frequently disturbed by land disputes between indigenous people and immigrants. Migration of human population to Assam, especially from Bangladesh, has led to decline in man-land ratio, settlement problems, and food shortages (Narzary, 2017). Population explosion along with other factors such as ineffective forest policy, weak property rights, corruption, and poverty also leads to environmental degradation and loss of forest cover (Hazarika, B., & Bhattacharjee, N., 2022).

Ineffective forest management practices, lack of strict enforcement and mismanagement has also been cited as a contributing factor for weak forest governance (Chatterjee et al., 2006; Talukdar & Choudhury, 2017; Talukdar et al., 2018).

Development pressure

Development activities such as uncoordinated infrastructure development (Chatterjee et al., 2006), construction of cities and roads (Bharali & Boruah, 2023), etc. puts massive pressure on forests. Infrastructure development and construction of hydropower projects, while crucial in terms of energy and economic security, have also degraded the forests of Assam (Mathur et al., 2005; Mahanta, 2010; TCP, 2014; Hazarika, 2020). Land use and land use change (LULUC) and forest diversion due to various development activities has impacted the forests of Assam considerably in the past few decades (Sarma and Saikia, 2012).

Literature notes various cases, such as the establishment of the Numalighar Refinery in the Telgaram area and highway widening projects which have impacted the habitat of Asian elephants (Aaranyak, 2008). Linear infrastructure development such as the construction of the six-lane road and railway lines at Silchar has impacted the amphibian fauna (Dey et al., 2015). Amphibians are also threatened due to construction of residential complexes leading to loss of breeding grounds (Dey et al., 2015). Talukdar et al., 2018 states that development activities such as road construction, electrifying fringe area is responsible for habitat loss and restriction of free movement of animals in Barak Valley. Baishya and Das, 2018 have reported the killing of snakes in urban spaces by the residents. Upadhya and Saikia, 2010 report a decrease in the nesting and foraging areas of the Cotton Pygmy Goose due to development activities. Mendies and Rao, 2021 have also suspected that the road construction around Rangamati beel will negatively affect the rare species, Asian Small – Clawed otters in the future.

In addition to the urbanization and infrastructure development, extraction of coal, stones and oil exploration also affects forest and biodiversity. Rapid development activities combined with increased population pressure near hills of Khanpara-Bornihat (about 10 km from Guwahati City) has resulted in rapid land use change in recent times (Sarma and Saikia, 2012). Mining activities have been cited as a contributing factor in many studies, across various region in the state (Mathur et al., 2005; Lele and Joshi, 2009; Sharma and Sarma, 2014; Baruah et al., 2016; Reddy et al., 2016; Ranjan 2019; Lakhyajit et al., 2020; Hazarika, 2020; Chakravartty, 2021; Debnath et al.,2022). For instance, the Singhason landscape (Karbi Anglong) has witnessed a decline in the forest cover, habitat fragmentation and pollution through the mining of limestone and coal (Teronpi et al., 2015). Free ranging movement of elephants have also been minimized through extraction activities in the forests of Golghat district (Aaranyak, 2008). Oil and natural gas exploration activities have placed amphibians at risk (Sengupta et al., 2010). Talukdar & Choudhary, 2017 note that activities such as construction of roads, electricity, railway track to Tripura and establishment of ONGC (Oil and Natural Gas Corporation) etc. have impacted the migration of animals in Patharia Hills. As per Jiji, 2015, the drilling activities of ONGC inside forest area have impacted biodiversity. The forest of Amchang WLS is also affected by developmental activities such as stone and rock quarries, construction of dams, etc. (Purkayastha et al., 2020). Industrial activities have also led to the expansion of settlements in and around the activity areas, which is also a factor contributing to the degradation of forest and wetland areas (Baruah et al., 2016; Deka and Kumar 2023).

A study by Debnath et al, 2022, assessed the LULC in the Brahmaputra Valley, due to various factors, from 1973 to 2021. There has been a decrease in the vegetation and water body cover due to mining activities (open cast mines), prominently from the Gondwana and Tertiary coalfield areas. The Tinsukia district is one of the primary coal mining areas of the state. The Makum coalfields in the Tinsukia district has witnessed a significant expansion in the coal mine area from 2.44 sq. km to 4.38 sq. km between 1998 to 2017 (Lakhyajit et al., 2020), which has impacted both the forests in the area and the forest-dependent communities (Chakravartty, 2020). As per another study in the same district, the forest area has decreased by 29.76% between 1996 to 2016; the coal mining area witnessed a consistent increase (by 129 %) in the same period (Baruah et al., 2016). Protected areas such as the Kaziranga National Park, Manas Tiger Reserve and Dehing Patkai WLS have also faced the threats of mining and establishment of mineral based industries (Mathur et al., 2005; TCP, 2014; Chakravartty, 2020).

Plantations – monoculture

The proliferation of commercial-scale monoculture plantations, replacing forests, has adversely impacted the forests and biodiversity of the state (Sharma et al., 2012; Purkayastha et al., 2020). A recent study notes that tea plantations, critical to the state's economy, have expanded by 1,280.47 sq. km spanning from 1990-2022 (Parida et al., 2023). The districts of Sonitpur, Dibrugarh have witnessed the maximum expansion, wherein forests, along with other cultivated lands are being converted into tea plantations. In Karbi Anglong district one of the main causes of forest degradation is the extensive clearance of vegetation to create monocultures of a few economically important plants. The surrounding habitats are already broken up by large-scale teak plantations. An increasing amount of woodland and fallow land has been turned into rubber plantations as rubber has been one of the district's major revenue crops in recent years (Teronpi et al., 2015). Similar trends have also been noted in the Patharia Hills Reserved Forest (Talukdar et al., 2018).

In many areas, forest dependent communities have been encouraged to divert their *jhum* lands to cash crops such as tea, rubber, pineapple, beetlenut etc., which is both unsustainable in the long run and reducing the soil fertility (Poffenberger et al., 2006; Sharma and Barua, 2017; Talukdar and Choudhary, 2017). For instance, as per a study conducted in the Biswanath sub-division, the intensive use of pesticides and fertilizers have adverse effects on the medicinal plants in the region; several of them are now on the brink of extinction. The run-off from these activities has also impacted the fish-breeding in paddy fields of the region. Protected areas, such as Kaziranga National Park also face the threat of tea plantations which have been expanding close to its boundary (Mathur et al., 2005).

Forest fires

Forest fires are also widespread in the state of Assam. Approximately 36% of the forest fire events occur in north India out of which 8.45% events occur in Assam (Feroz et. al., 2018). Another study by Wang et al., 2021 notes that forest fires are responsible for destroying a mean area of 6,587.78 sq. km every year, in the Eastern Himalayan Region (Wang et al., 2021). Out of 3,158 mean forest fire incidences, 58% of the total are intentional forest fire incidence. As per the ISFR 2021, a total of 10, 781 forest fires were detected between Nov 2020 to June 2021 by the MODIS and SNPP-VIIRS sensors. In assam, around 3166.11 sq. km, 4871.05 sq. km and 3400.46 sq. km falls under the category of extremely fire prone, very highly fire prone and highly fire prone areas, respectively; this is around 40.39 % of the state's forest cover. Literature suggests that shifting cultivation is also one of the primary reasons for accidental anthropogenic forest fire by tribal communities (Chatterjee et al., 2006). These *jhum* fires are often uncontrollable and spread to the neighboring areas. These communities are suffering from extreme poverty and diminishing livelihood, rendering them to be extremely dependent on the forest lands (Feroz et. al 2018).

Invasive species

The existence of invasive species affects the biodiversity of the region by creating a competition with the native species for the resources. Badiya et al., 2020 has observed that the presence of invasive species has led to low plant diversity in various regions. Invasion of woody species have degraded grasslands. For instance, Sarma et al, 2009 reports a decline in native alluvial grasslands through an increase in woody species from 1977 to 2004 within the Pobitora WLS. Islary & Nautiyal, 2021 has reported invasion of exotic weeds like *Eupatorium sp*., *Melastoma sp*., etc. in Manas National Park and *Mimosa pudica* and *Eichhornia crassipes* inside forest and village peripheries of Laokhowa WLS, Nagaon district.

Activities such as illegal encroachment and cultivation of shallow beds of the wetlands have facilitated the growth of weeds and invasive species which have exacerbated the degradation (Deka et al., 2015; Goswami et al., 2020). Monoculture practices in Singhason landscape have also developed openings for establishment of weeds and exotics (Teronpi et al., 2015).

Natural Hazards

The North-eastern region of India is frequently affected by multiple natural disasters. Assam is one of the most vulnerable and disaster-prone states of India (Barbhuiya, 2015). Assam is prone to various natural disasters like earthquakes, perennial floods, forest fire, landslides, cyclone, and occasional droughts.

The state of Assam is prone to frequent floods, due to its topography and extensive network of rivers and anthropogenic factors that facilitate the same. According to the National Flood Commission, the flood affected area has gone up to 4,98,150 sq. km by 2010 resulting in a loss of more than 1600 lives along with damage to crops and other public utilities. On average, every year, floods affect 409 villages covering an area of about 473.34 sq. km including 123.97 sq. km of cropped area (Talukdar and Kalita, 2005).

The impacts of floods are also felt in National Parks of the State. For instance, a study notes that from 2012 to 2018, the Dibru-Saikhowa National Park marked a total forest cover loss of 8.23%. This is attributed to the riverbank erosion due to the merging of the Siang, Dibang and Lohit rivers and recurrent floods during monsoons. A study conducted in Kaziranga National Park by Sankam et. al, 2023 reveals that anthropogenic factors outweigh the natural factors for flood occurrence in Assam, causing immense loss of life, destroying livelihoods, and affecting wildlife. Recurrent floods affect the entire biodiversity of Pobitora WLS and Kaziranga National Park (Bharali & Boruah, 2023). According to Sarma et al., 2009, the moist alluvial grassland of Pobitora has declined due to the impacts of subsequent floods and silt deposits in 1998 and 2004 leading to loss in habitat of rhinos.

Heavy rainfall supplemented by encroachment aggravates the impacts of floods in the region. Furthermore, flood induced landlessness, leading to further expansion of settlements and encroachment and subsequent decline is also a problem in the state (Madhusudan and Sinha, 2012). The 2022 floods impacted around 24,507 sq. km of vegetation cover and cause flood inundation of around 33,902.49 sq. km (Halder et al, 2023). These impacts were most prominent in the districts of Kamprup, Cachar, Jorhat, Kokrajhar and Dhubri, with significant deforestation.

The state of Assam is one of the most seismically active regions in the world and falls in the seismic V category (Barbhuiya, 2015; Baruah et. al, 2023). Excavation activities for the expansion of highways and the conversion of railway tracks to broad-gauge may have altered the natural slope dynamics, exacerbating the severity of the landslides. According to Gupta, 2003, landslides, deforestation and shifting cultivation along the hills of North Cachar Hills and Karbi Anglong are also partly responsible for increasing the silt load, and consequently the magnitude of floods. In addition to the above, the high rate of population growth has forced people to encroach the riverine areas resulting in constricted waterways, reduced conveyance capacity and increased sediment production due to deforestation (Phukan, n.d.; Ray, 2001; Sankam et. al 2023).

Natural hazards can be caused by both natural and anthropogenic factors. The graph below depicts the percent distribution of the factors causing natural hazards in the reviewed literature.

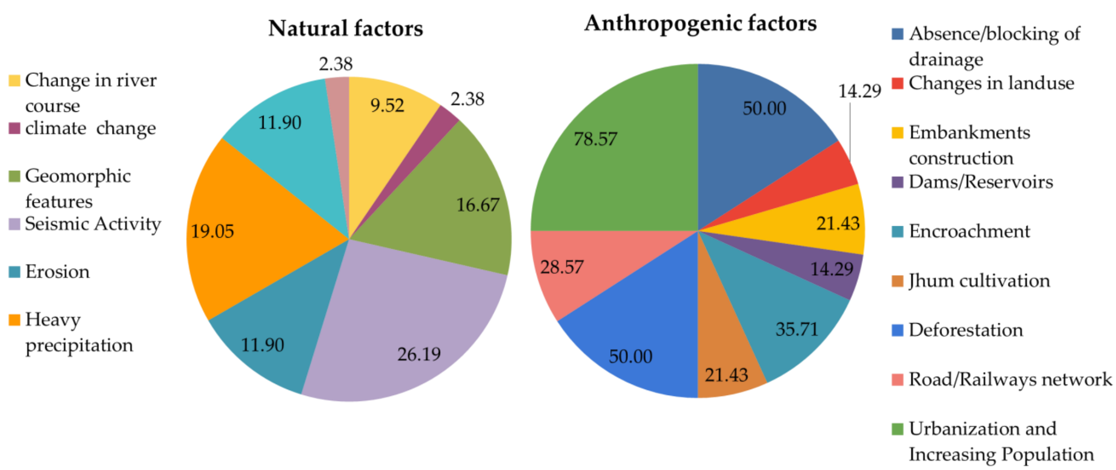


Figure 10: Cumulative percentage mentions of various natural and anthropogenic drivers of forest degradation and deforestation.

3.1.2 Summary

A total of 159 papers were studied in detail (refer to PRISMA flow chart in Section 2.2.1) to identify the different drivers of deforestation and forest degradation present in the state of Assam. The districts in which the mentioned drivers are prevalent are also identified to understand the scale of each driver. The total number of papers mentioning driver and districts is shown below:

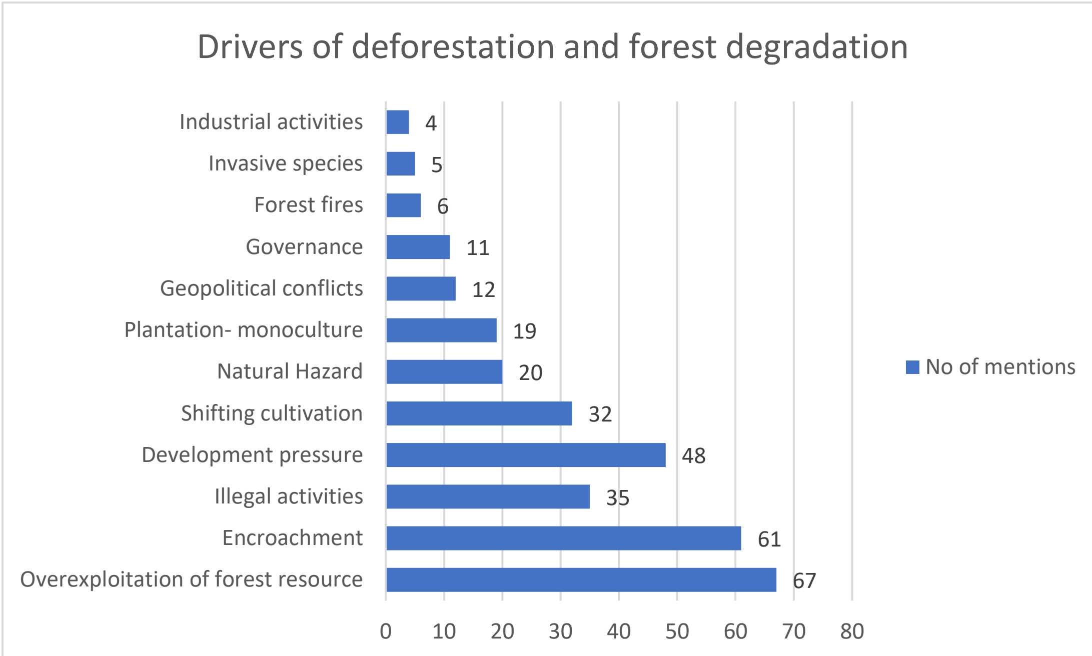


Figure 11: Number of mentions of driver of deforestation and forest degradation in systematic literature review.

The drivers identified from the literature review were also mapped based on their presence in different districts in Assam. The results are shown in the table below.

Table 4: Drivers and their district wise presence in Assam

Drivers	No. of mentions	Districts
Resource Extraction	67	Barpeta, Biswanath, Bongaigaon, Cachar, Darrang, Dhemaji, Dibrugarh, Goalpara, Golaghat, Hailakandi, Karimganj, Karbi Anglong, Kokrajhar, Lakhimpur, Morigaon, Nagaon, Sonitpur, Tinsukia
Encroachment (Agriculture + Settlement)	61	Barpeta, Bongaigaon, Cachar, Darrang, Dhemaji, Dibrugarh, Golaghat, Hailakandi, Jorhat, Kamrup, Kamrup Metro, Karimganj, Karbi Anglong, Kokrajhar, Lakhimpur, Morigaon, Nagaon, Nalbari, Sonitpur, Tinsukia, Udalguri
Illegal activities	35	Baksa, Barpeta, Bongaigaon, Cachar, Chirang, Darrang, Dhemaji, Dhubri, Goalpara, Golaghat, Hailakandi, Jorhat, Kamrup, Karimganj, Karbi Anglong, Kokrajhar, Nagaon, Nalbari, Sivsagar, Sonitpur, Tinsukia, Udalgiri
Development pressure	48	Barpeta, Cachar, Darrang, Dhemaji, Dibrugarh, Kamrup, Kamrup Metro, Karbi Anglong, Kokrajhar, Lakhimpur, Sonitpur, Tinsukia

Shifting Cultivation	32	Barpets, Bongaigaon, Cachar, Darrang, Dibrugarh, Golaghat, Hailakandi, Karbi Anglong, Karimganj, Nagaon, Sonitpur, Tinsukia
Natural Hazard	20	Barpets, Bongaigaon, Cachar, Dima Hasao, Golaghat, Karbi Anglong, Nagaon, Tinsukia
Plantation (monoculture)	19	Cachar, Hailakandi, Karimganj, Lakhimpur
Geopolitical Conflicts	12	Bongaigaon, Cachar, Darrang, Dhemaji, Dhubri, Dibrugarh, Golaghat, Hailakandi, Kamrup, Karbi Anglong, Karbi-Anglong West, Karimganj, Kokrajhar, Lakhimpur, Nagaon, Sivsagar, Sonitpur, Tinsukia,
Governance	11	Barpeta, Bongaigaon, Dhemaji, Kamrup, Kokrajhar, Sonitpur, Tinsukia
Forest Fire	6	Barpeta, Darrang, Cachar, Karbi Anglong, Kokrajhar, Sonitpur, Tinsukia
Invasive species	5	Baksa, Chirang, Golaghat, Nagaon, Sonitpur
Industrial activities	4	Kamrup Metro, Tinsukia

3.2 Findings of the Socio-Economic Assessment

Understanding the dependency of people on forest resources along with their socio-economic conditions is crucial for designing appropriate strategies that will not only contribute to climate change mitigation and adaptation but will also benefit the local communities. The innovative approaches developed for forest management and expansion of forestry initiatives have not been able to completely reverse or halt the trends of forest degradation and deforestation in the state. Forests are vital for the sustenance of millions of people around the world. Forests provide fuelwood for energy demands of households, NTFP for food, economic, and medicinal purposes and maintain ecosystem services and their functions. Unfortunately, overexploitation of these resources to cater to the basic needs of an ever-increasing population and support the economic growth of the country, there has been a considerable degradation of forest resources.

To understand the forest resource dependency of the communities a household survey was conducted in the Forest Fringe Villages (FFV) of Assam. The results obtained from the sampled households are as follows:

General Characteristics of the study

The household survey is designed to cover two strata. Based on the population of the households in the two strata, the percentage of sample distribution in the stratum 1 and stratum 2 is 40% and 60% respectively. On further analysis it was observed that the total size of households in the two strata differs significantly. With stratum 1 having 4,145 members which is very high as compared to stratum 2 having 2,582 members.

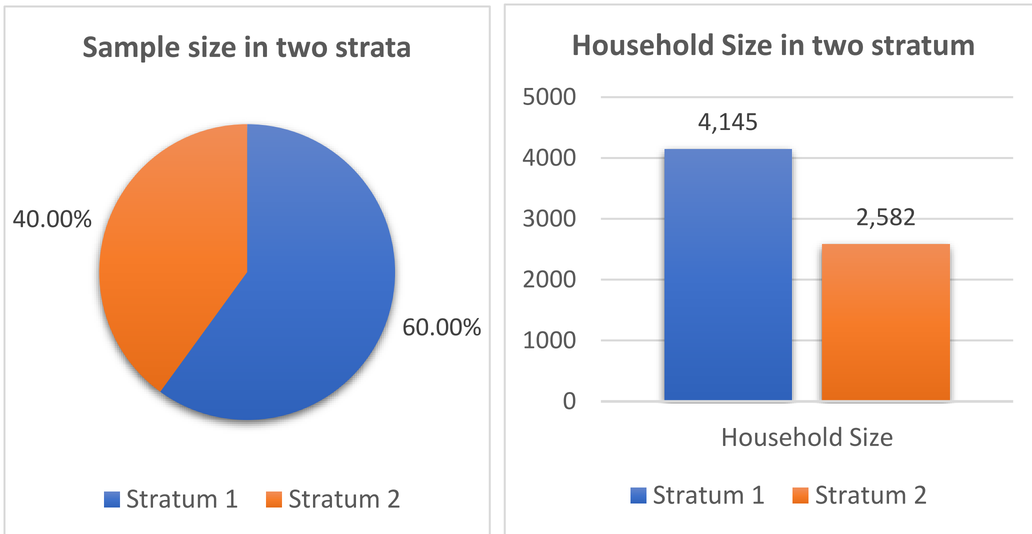


Figure 12: Sample distribution in two strata (on left) and household size (on right)

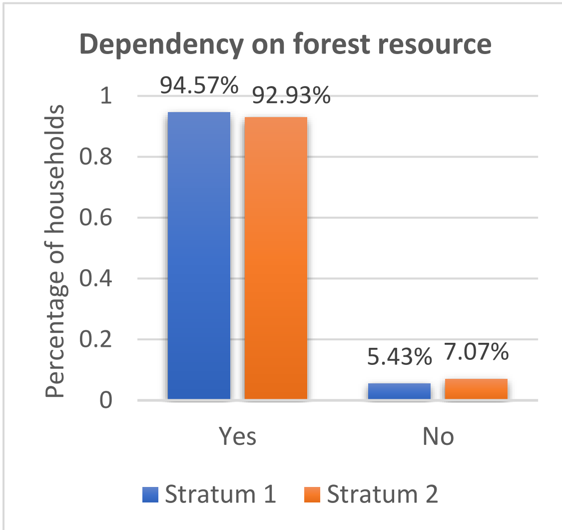
The results obtained from the sample households are as below:

Dependency

It was observed that approximately 94% of the households living in the forest fringe villages are dependent on forest resources. The different types of resources extracted from the forests includes fuelwood, fodder, bamboo, small timber, and NTFPs. Based on the responses provided by the respondents it is observed that fuelwood is the most extracted forest resource with 39% households collecting fuelwood. The second most extracted resource from forest are NTFPs with 28% households involved in NTFP collection. Bamboo, small timber (such as wood for fencing, furniture, agriculture equipment, household equipment, and other purposes) and fodder is collected by 19%, 10%, and 3% of the households, respectively.

The different types of bamboo extracted from the forest includes *bhaluka (Bambusa balcooa), bijuli (Bambusa pallida Munro), hill jati (Oxytenanthera Parvifola), dalu (Teinostachyum Dalloa)), muli (Malocanna Bambusoides), kako (Dendrocalamus Hamiltoni)*, etc.

The different types of NTFP extracted from the forest includes Amla, Arjun, Bael (wood apple), banana, banana flower, bay leaf, cotton, broom, drumstick, honey, cane, fern, *jalphai*, jamun, plum, pineapple, thatch, mushroom etc.



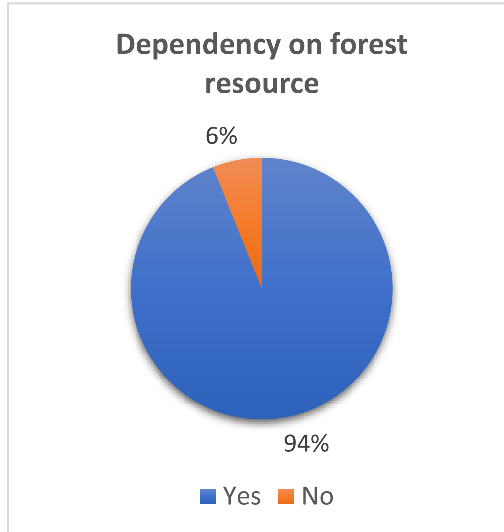


Figure 13: Households dependent on forest resources.

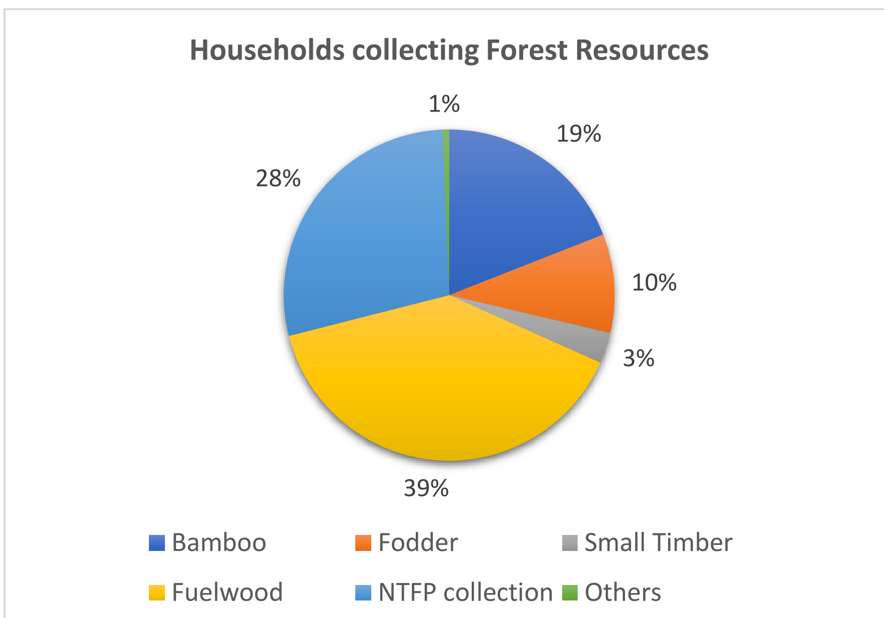


Figure 14: Percentage of different forest resources collected by households.

Extraction of forest resources

The survey provided insights on different forest resources extracted from the forest including fuelwood, small timber, bamboo and fodder. The table below shows the quantity of resources extracted (kg/month) by the sample number of households.

Table 5: Quantity of forest resources extracted by households.

Resources	Qty extracted in stratum 1 (in kg/month)	Qty extracted in stratum 2 (in kg/month)
Fuelwood	45,56,228	33,50,524
Wood for fencing	1,88,910	1,04,363
Wood for furniture	87,019	25,289
Wood for Agricultural Equipment	99,208	34,748
Wood for Household Equipment	64,856	22,968
Other purpose	41,657	9,295
***Total wood-based resources**	**50,37,878**	**35,47,187**
Fodder	**6,43,815**	**1,98,152**
Bamboo	**1,326**	**754**
Total biomass extracted	**56,83,019**	**37,46,094**

*Total wood-based resources include fuelwood, wood for fencing, wood for agricultural equipment, wood for household equipment, and wood for other purpose

From the above table we can see that the dependency of households living near the forest (represented by stratum 1) is more as compared to the households living further away from the forest. The percentage biomass extracted by households in stratum 1 and stratum 2 is 60.27% and 39.73%, respectively.

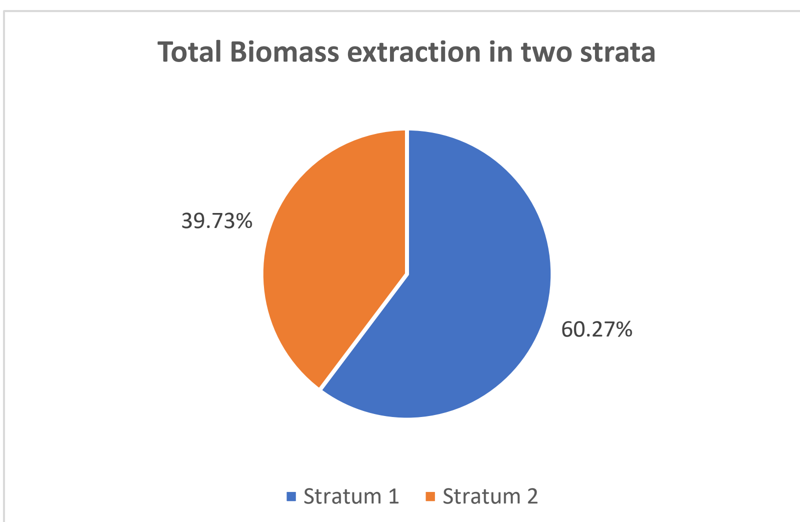


Figure 15: Total biomass extraction by FFV in stratum 1 and stratum 2

It can be observed that in stratum 1, the contribution of biomass extraction for different purposes such as fuelwood, fencing, furniture, agricultural equipment, household equipment, other purpose, fodder, and bamboo are 80.17%, 3.32%, 1.53%, 1.75%, 1.14%, 0.73%, 11.33%, and 0.02% respectively. Furthermore, it can be observed that 88.65% of the biomass extracted is due to the wood-based resources (for fuelwood, fencing, furniture, agricultural equipment, household equipment, and other purposes). Whereas fodder and bamboo contributed to 11.33% and 0.02% extraction of biomass, respectively.

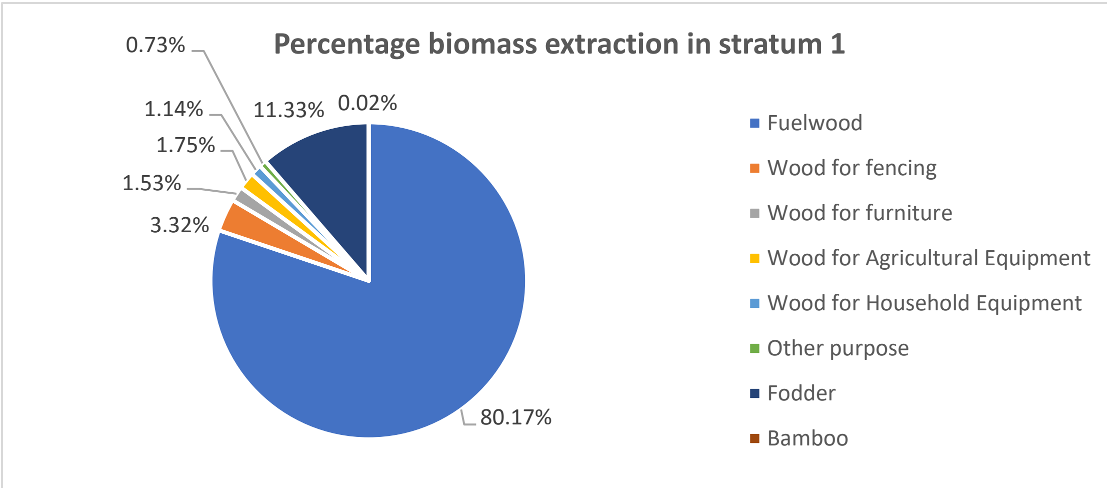


Figure 16: Percentage biomass extraction in stratum 1

In stratum 2, the contribution of biomass extraction for different purposes such as fuelwood, fencing, furniture, agricultural equipment, household equipment, other purpose, fodder, and bamboo are 89.44%, 2.79%, 0.68%, 0.93%, 0.61%, 0.25%, 5.29%, and 0.02% respectively. Furthermore, it can be observed that 94.69% of the biomass extracted is due to the wood-based resources (for fuelwood, fencing, furniture, agricultural equipment, household equipment, and other purposes). Whereas fodder and bamboo contributed to 5.29% and 0.02% extraction of biomass respectively.

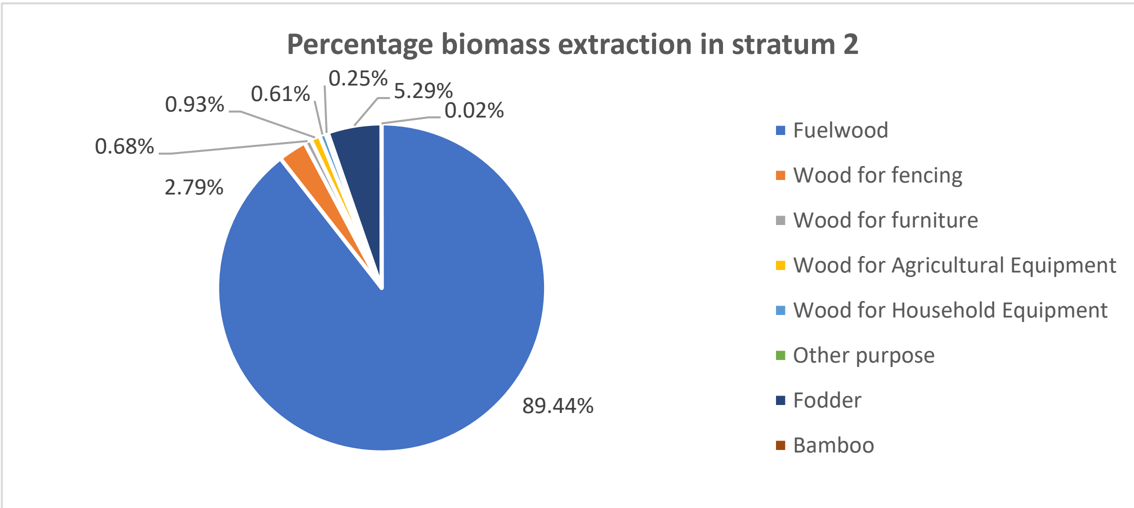


Figure 17: Percentage biomass extraction in stratum 2

Forest resource consumption based on land holding

It was observed that 83.10% households that collect forest resources either don't own any land or own less than 7.5 bigha (1.2 hectare) land. Whereas 14.43 % households collecting forest resources have land holdings between 7.5 to 15 bigha (1.2 to 2.4 hectare).

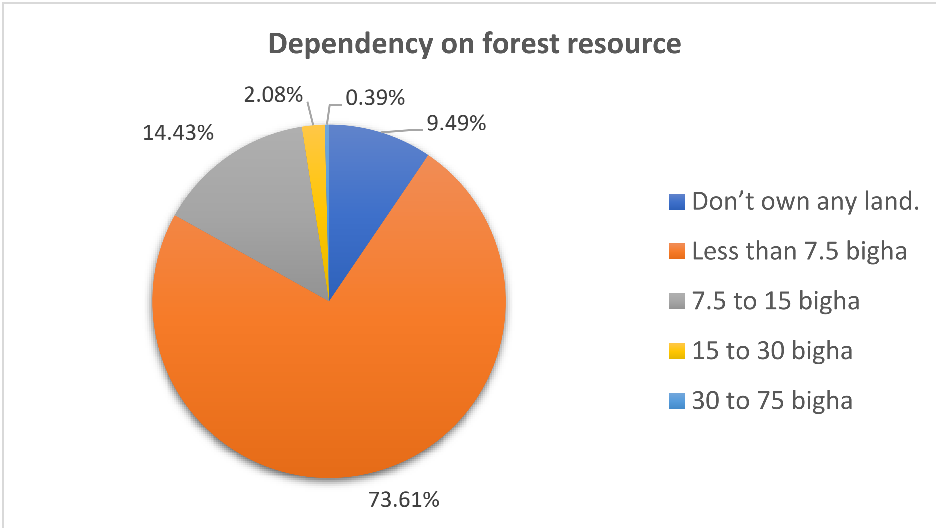


Figure 18: Forest resource consumption based on land available.

Source of income of households

From the figure below we can see that majority of households depend on agriculture as their source of income. On further analysis it was observed that out of total household's dependents on agriculture for income generation, 94% extract forest resources too.

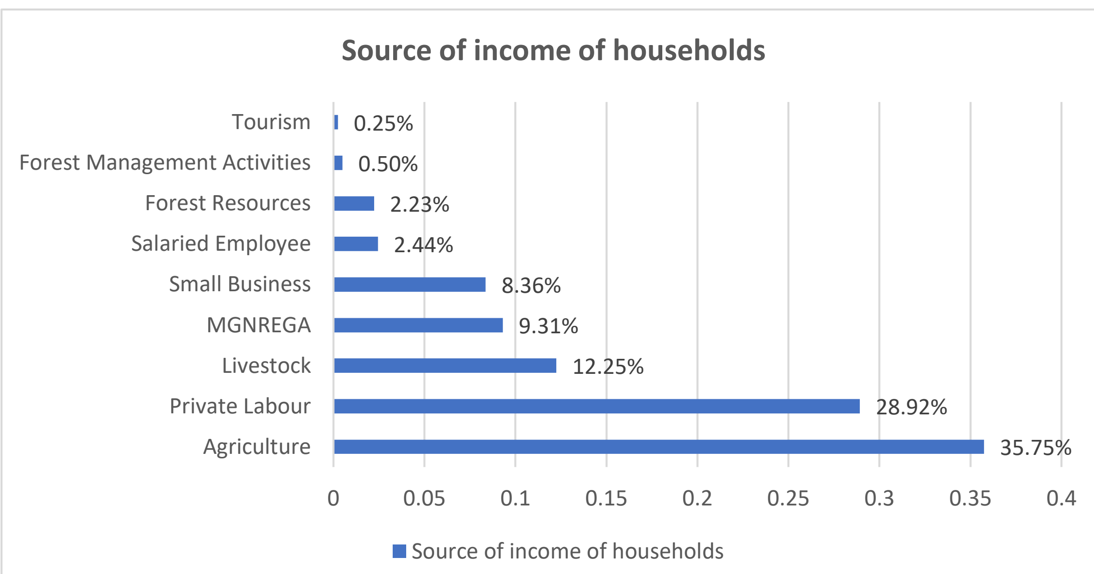


Figure 19: Percentage households and their sources of income

Source of forest resource collection

The resources such as fuelwood, fodder, bamboo collection, and livestock grazing are collected not only from forests lands but are also sourced from agriculture lands or local markets. Following is the data of source-wise forest resource collection:

- In stratum 1, 75.12% of households collect fuelwood from forest and 72.56% households collect fuelwood from forests in stratum 2. Whereas 24.88% and 27.44% households collect fuelwood from other lands in stratum 1 and stratum 2 respectively.
- The source of grazing for livestock is forest for 53.62% and 44.41% households in stratum 1 and stratum 2 respectively. While 46.38% and 55.59% households take their livestock for grazing in other lands.
- The percentage of households collecting fodder for stall feeding from the forest are 34.64% and 22.50% from stratum 1 and stratum 2 respectively. Whereas 63.36% and 77.50% of the households collect fodder for stall feeding from other lands.
- 41.80% households in stratum 1 and 38.95% households in stratum 2 collect bamboo from forest. 58.20% households in stratum 1 and 61.05% households in stratum 2 collect bamboo from other lands.

The below graphs show the source from which the different forest resources are being collected by the households:

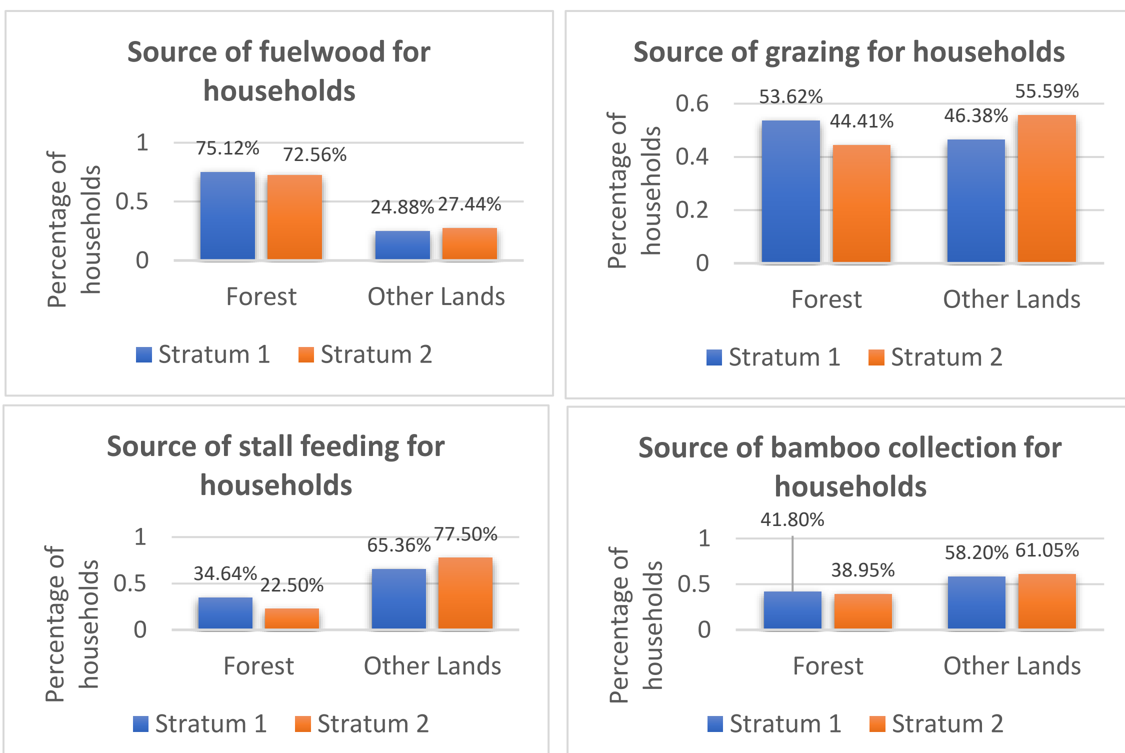


Figure 20: Source of forest resource collection by households

Distance travelled.

The average distance travelled by the households for collecting fuelwood, NTFP, and grazing livestock based on different ranges of distance i.e., Upto 1km, 1 to 2 km, 2 to 3 km, and more than 3 km is provided in the figure below.

Also, the availability of fuelwood over last 5 years and availability of NTFP over the last 10 years is also asked from the households. The results shows that approximately 58% respondents suggested that the distance of collection of fuelwoods has increased over the last 5 years and approximately 35 % respondents suggested that the distance of collection of fuelwoods has remained same. Also, approximately 66% respondent suggested that the availability of NTFP has decreased over the last 10 years and approximately 26 % respondent suggested that the availability of NTFPs has remained the same.

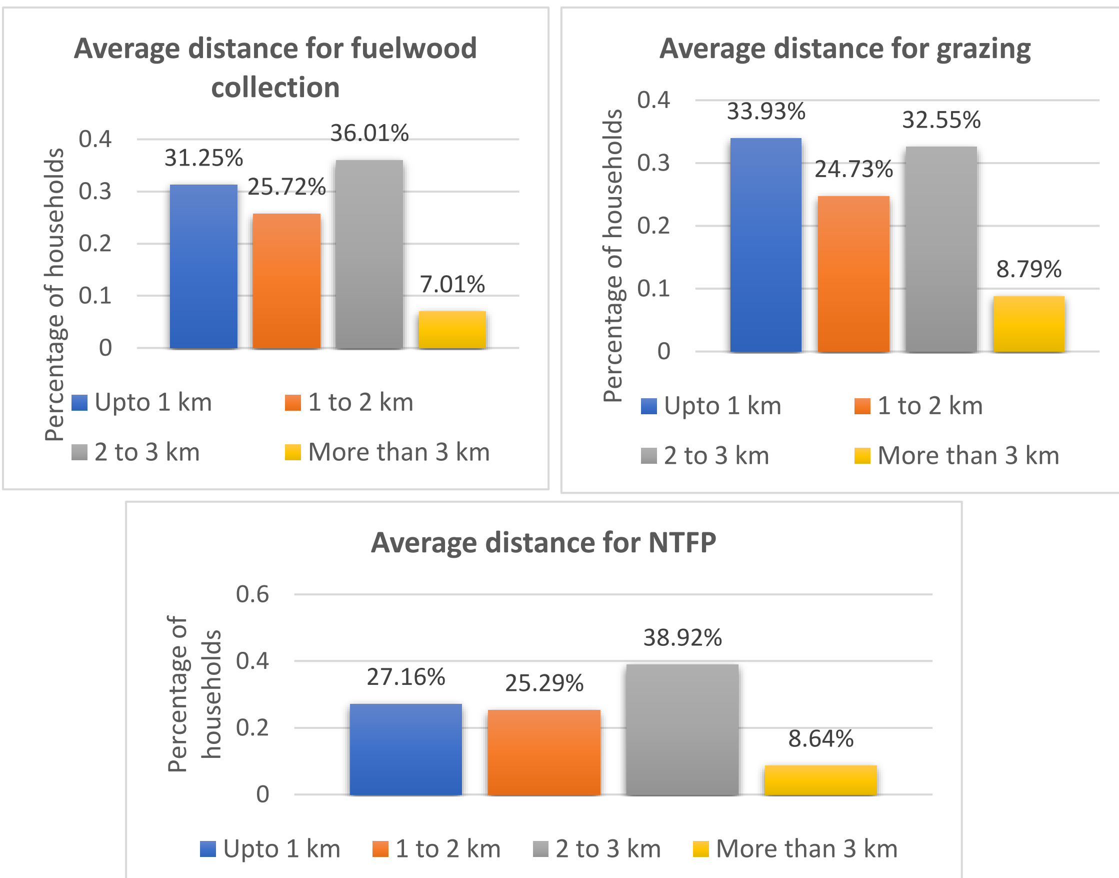


Figure 21: Average distance for collection of fuelwood, livestock grazing and NTFP collection

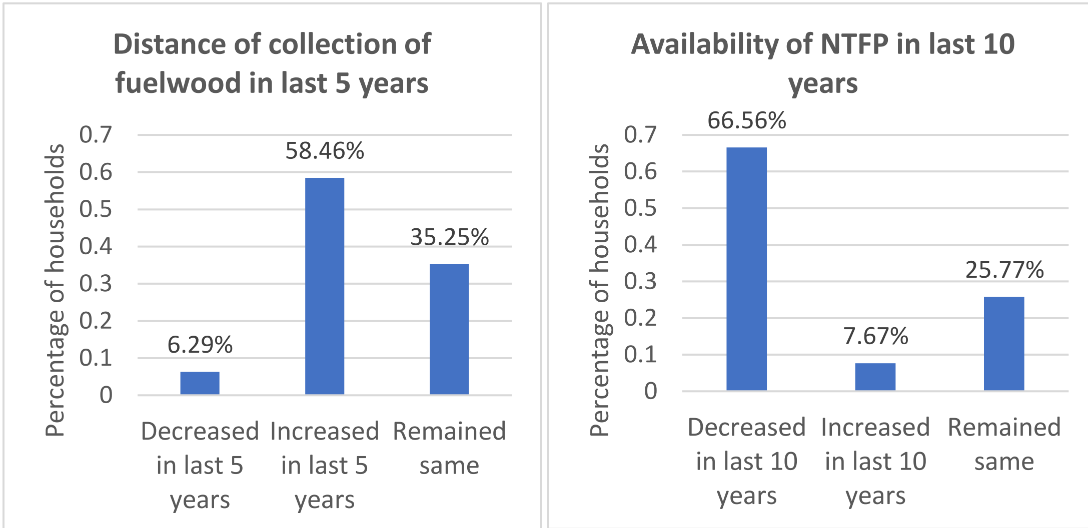


Figure 22: Distance of collection of fuelwood and availability of NTFP

Furthermore, it can be inferred that the extraction of forest resources such as fuelwood, grazing of animals, and collection of NTFP is more for households living nearby the forest i.e. in stratum 1, as the people have to travel less distance to reach the forest. The below graphs show how much households have to travel in the two strata.

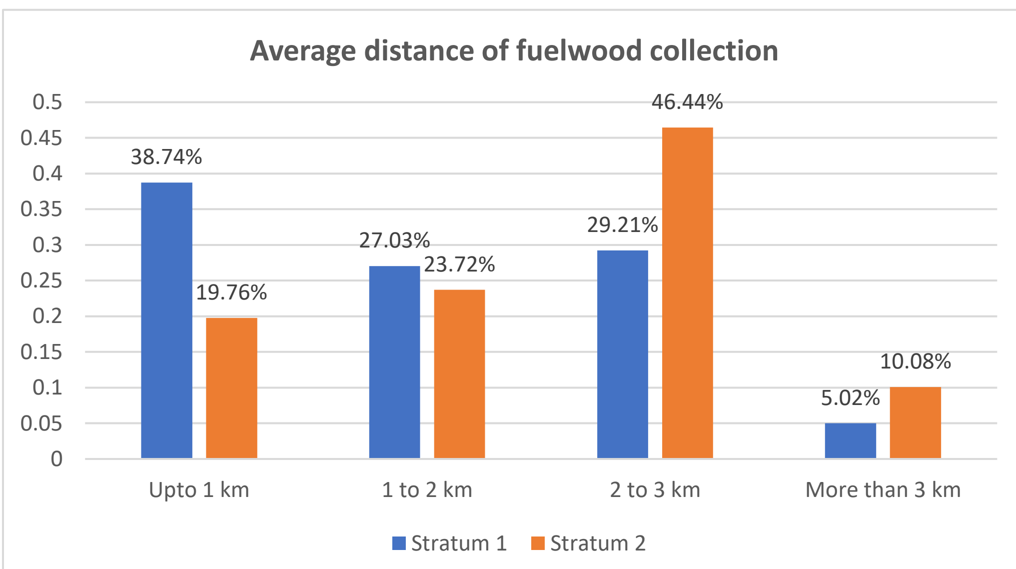


Figure 23: Comparison of average distance travelled by households for fuelwood collection in stratum 1 and stratum 2.

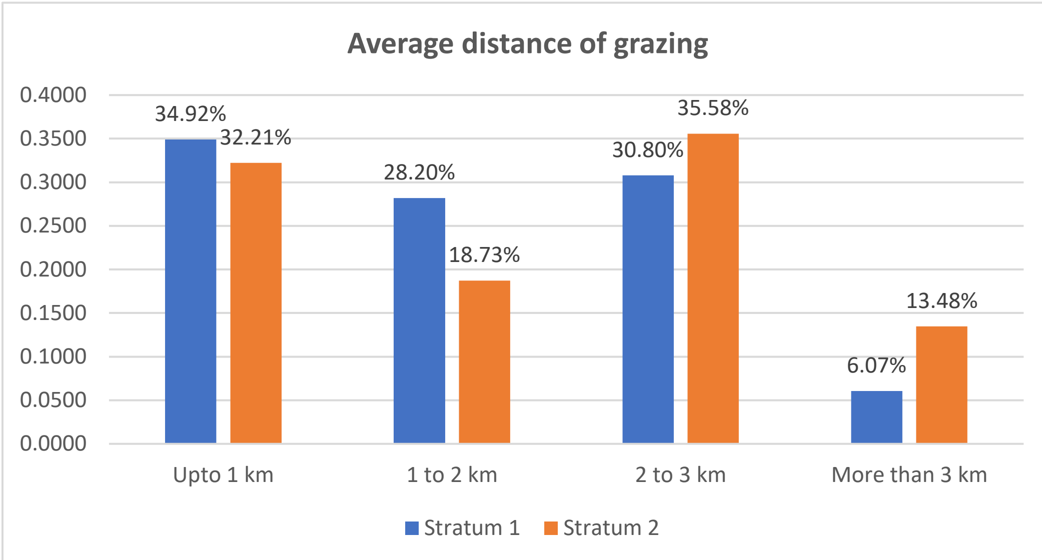


Figure 24: Comparison of average distance travelled by households for grazing in stratum 1 and stratum 2.

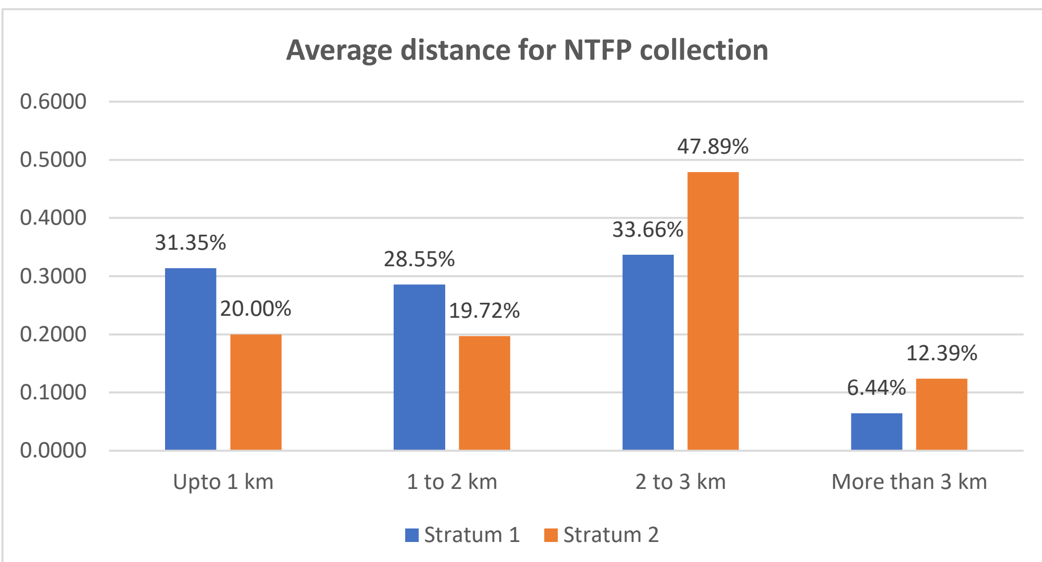


Figure 25: Comparison of average distance travelled by households for NTFP collection in stratum 1 and stratum 2.

Perception of households on forest and causes of degradation

The respondents were asked about their observations of forests degradation, deforestation and their drivers in the last 10-20 years. In the last 10 to 20 years, 74.5% respondents in stratum 1 and 66.19% respondents in stratum 2 observed that forest degradation and deforestation is occurring in Assam. Similarly, 5.37% respondents in stratum 1 and 10.90% respondents in stratum 2 observed enhancement in the forest cover. And 7.06% respondents in stratum 1 and 7.69% respondents in stratum 2 observed no change in the condition of the forest. It should be noted that 13.07% respondents in stratum 1 and 15.22% respondents in stratum 2 have observed human wildlife conflicts in Assam. The results are shown in the figure below.

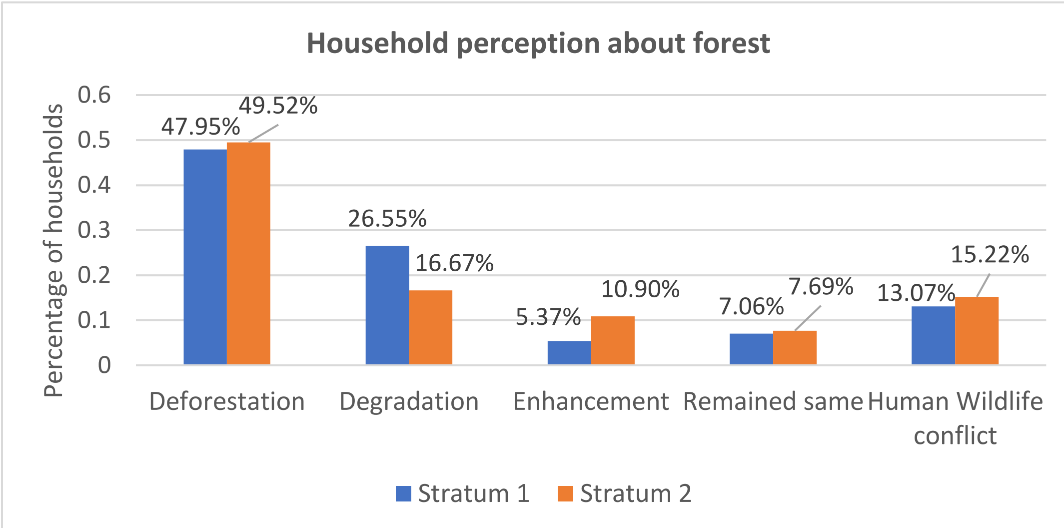


Figure 26: Households perception about forest

The households were also questioned about the drivers of forest degradation and deforestation. It can be seen from the figure below that most households consider anthropogenic factors to be responsible for forest degradation. Considerable households also responded that both natural and anthropogenic factors are responsible for forest degradation. The results are shown in the figure below.

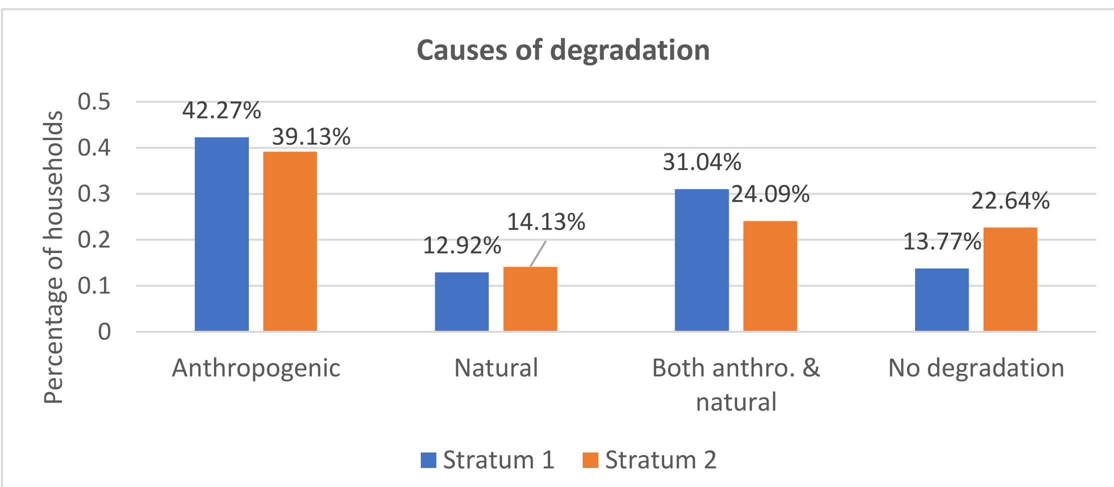


Figure 27: Perception of households on causes of forest degradation

The respondents were also asked to rate the drivers of degradation based on its severity from a scale of 1 to 5 (1 being least severe and 5 being most severe). Based on the ratings provided by the respondent the drivers of degradation are ranked as below:

Table 6: Ranking of drivers based on results from household survey

Drivers	Rank (Cumulative)
Resource Extraction	1
Settlement Encroachment	2
Agriculture Encroachment	3
Extreme Weather	4
Anthropogenic Forest Fires	5
Development Activities	6
Invasive Species	7
Pest and Diseases	8

3.3 Findings of Remote Sensing (RS)-GIS Analysis

The findings of the spatial as well temporal extent of the natural drivers, anthropogenic drivers and their impacts on forest and biodiversity is presented here. Loss in carbon stock due to forest land transition have also been computed. Further, FCD the change matrix has been prepared for the development of forest degradation map for the entire Assam state.

1. **Anthropogenic Drivers**

   a) **Land Transition-** A change matrix and a change map that demonstrates the dynamic transformations in the region have been developed to analyze the variation in Assam's land use and land cover pattern during 2000 and 2022. It indicates the net land transition from forest class to other classes.

   Change detection quantifies the changes that are associated with LULC changes in the landscape using geo-referenced multi-temporal remote sensing images acquired on the same geographical area between the considered acquisition dates (Ramachandra and Kumar 2004). An important aspect of change detection is to determine what is changing to what category of LULC type (i.e., which LULC type is changed to the other type of LULC class). LULC changes matrix depicts the change in area from one class to the LULC type that remains as it is at the end of the period. Thus, to clearly understand the source and destination of major LULC changes, change matrix for each period was analysed. For change analysis, change matrices were generated for the different time periods to analyse changes in the area covered by different LULC classes. This was done by comparing the number of pixels falling into each category of LULC in one time-period with the categorization of the same pixels in same/different class in the previous time-period.

   Change in classes = MATRIX (time 1, time 2)

   The data gathered from the generated matrix was further rearranged to prepare the change matrix. Change map have been prepared over the period of 22 years by overlaying LULC maps of two time periods. Changes in LULC classes between two years have been analysed through the change map generated.

The diagonal cells (in bold) of the matrix in the tables below, represent the area that has remained same in both the time periods. Other cell values represent the area that has changed from one class to another class.

For example, the total area of cropland that has remained unaltered in 22 years is 17431.15 sq. km. (highlighted in bold). A total of 922.75 sq. km. of cropland class has been turned to grassland, while 460.85 sq. km. of cropland class has been transformed into other vegetation class. An area of 1965.9 sq. km. of cropland has been converted to open and barren land, while a total of 392.81 sq.km. of area has been converted into Riverbed class from cropland class.

Likewise, from the year 2000 to 2022, an area of 4685.82 sq. km. of open/barren land class has been transformed into cropland, while 2023.81 sq. km. of grassland class have been converted into cropland. Whereas a total of 823.08 sq.km of area has been converted into cropland from other vegetation, while 777.94 sq.km of area has been converted from riverbed class to cropland class during the period of assessment.

Table 7: LULC change matrix 2000-2022

	2022									
	Classes (Area in sq km)	**Cropland**	**Forest**	**Grassland**	**Open/Bare Earth**	**Other Vegetation**	**River bed**	**Settlement**	**TOF/ Plantation**	**Water Bodies**
2000	Cropland	**17431.15**	283.85	922.75	1965.90	460.85	392.81	860.58	474.63	463.53
	Forest	1505.43	**14718.81**	827.67	915.68	1367.26	20.06	33.30	1946.28	129.72
	Grassland	2023.81	603.75	**740.01**	624.67	622.27	23.43	67.32	827.90	40.65
	Open/Bare Earth	4645.82	815.87	799.29	**1037.18**	570.32	131.09	249.58	844.17	170.26
	Other Vegetation	823.08	2667.78	472.00	335.38	**880.75**	12.15	21.83	1188.17	26.69
	Riverbed	777.94	2.36	13.71	771.79	22.81	**663.76**	317.97	5.29	770.36
	Settlement	784.74	10.32	20.06	192.51	24.29	71.60	**206.71**	17.11	87.67
	TOF/Plantation	2056.58	644.44	315.97	560.50	431.30	39.08	223.32	**612.43**	74.93
	Water Bodies	505.50	9.45	9.92	554.62	15.75	456.70	175.90	7.15	**997.58**

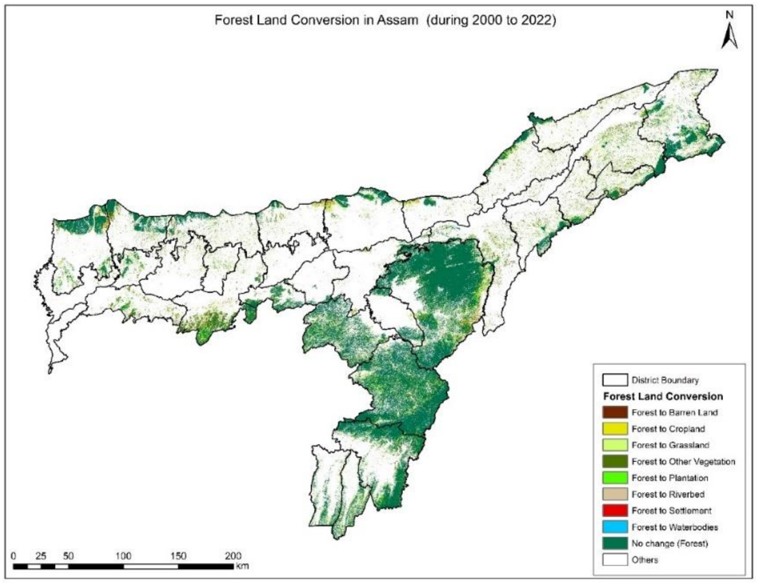


Figure 28: Forest land conversion

An annual rate of land transition analysis has also been developed to better comprehend the net yearly transformation of forested regions into other land cover classifications.

Table 8: Net forest land conversion

Net Forest Land Conversion in Assam (2000 to 2022)			
Forest Conversion	Area (in sq. km).	Conversion Type	Annual Rate of Transition
No change (Forest)	14,718.81	No Conversion	N.A.
Forest to Waterbodies	120.27	Negative	5.47
Forest to Riverbed	17.70	Negative	0.80
Forest to Barren Land	99.81	Negative	4.54
Forest to Grassland	223.92	Negative	10.18
Forest to Other Vegetation	1,300.52	Positive	59.11
Forest to Plantation	1,301.84	Negative	59.17
Forest to Cropland	1,221.58	Negative	55.53
Forest to Settlement	22.98	Negative	1.04

A detailed visual analysis using Google Earth imagery demonstrates the extent to which the recorded forest area has been transformed into cropland. A sizable portion of the Diroi Reserve Forest, Chirang Reserve Forest, and Sonai Rupai Wildlife Sanctuary have been converted into crop fields over the period of 22 years.

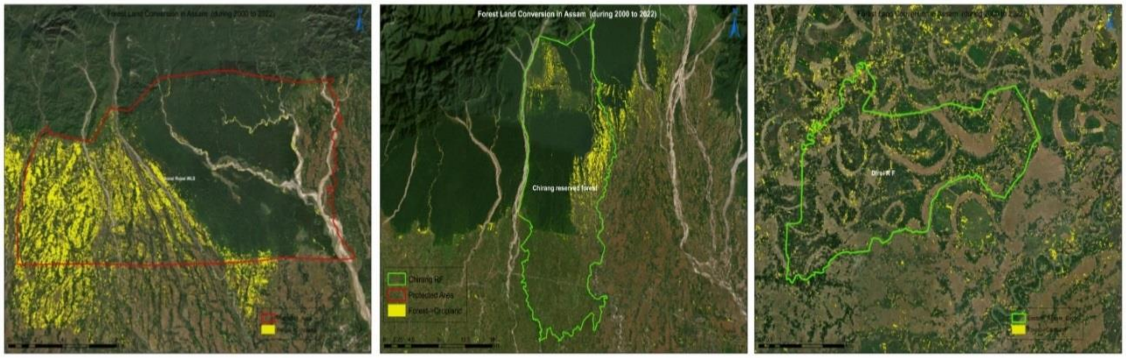


Figure 29: Sonai Rupai Wildlife Sanctuary (left), Chirang Reserved Forest (Center), and Diroi Reserved Forest (Right)

Also, the conversion of forest land into plantation land category over the period of 22 years have been demonstrated using very high-resolution Google Earth imagery for western Assam & central Assam Forest division particularly.

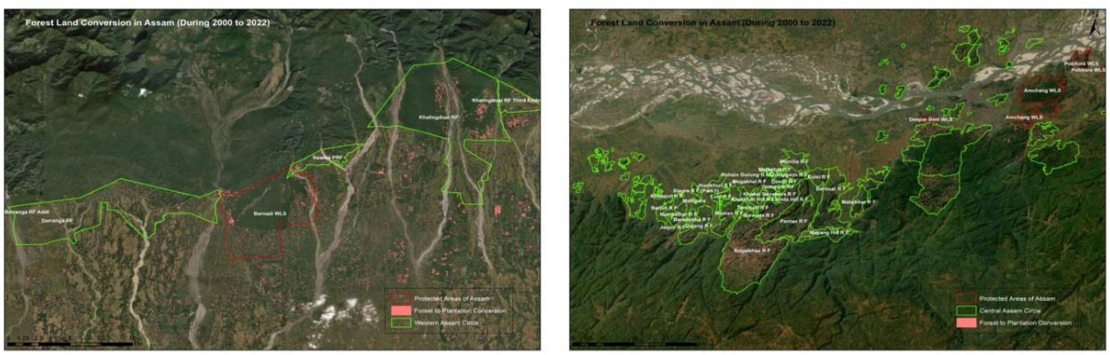


Figure 30: Conversion of Forest area to Plantation

b) **Population-** Spatial distribution of population for the years 1980, 1990, 2000, 2010, 2020, and projection of 2030 have been provided in figure below. This indicates that the population number in the RFA would reach over 2 million (Analysis shown in the population distribution in forest area figure).

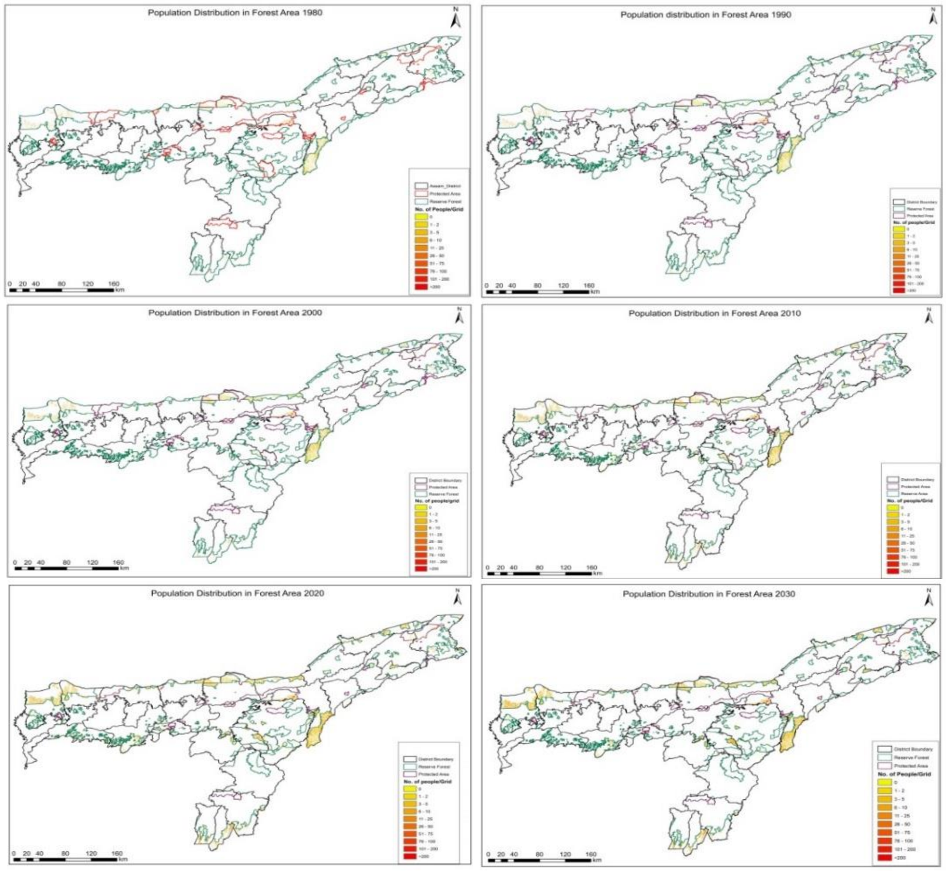


Figure 31: Population Distribution of 1980, 1990, 2000, 2010, 2020, and projection of 2030

The population in the Recorded Forest Area (RFA) in Assam and its decadal growth rate is shown in the table below:

Table 9: Population in forest areas

Year	Population in Recorded Forest Area	Decadal Growth Rate (in %)
2030	20,25,289	13.36
2020	17,86,546	24.25
2010	14,37,902	20.46
2000	11,93,701	27.69
1990	9,34,829	17.37
1980	7,96,479	-

The decadal variation in population pressure in the recorded forested area of Assam state has been presented in figure below since the year 1980 for each corresponding epoch.

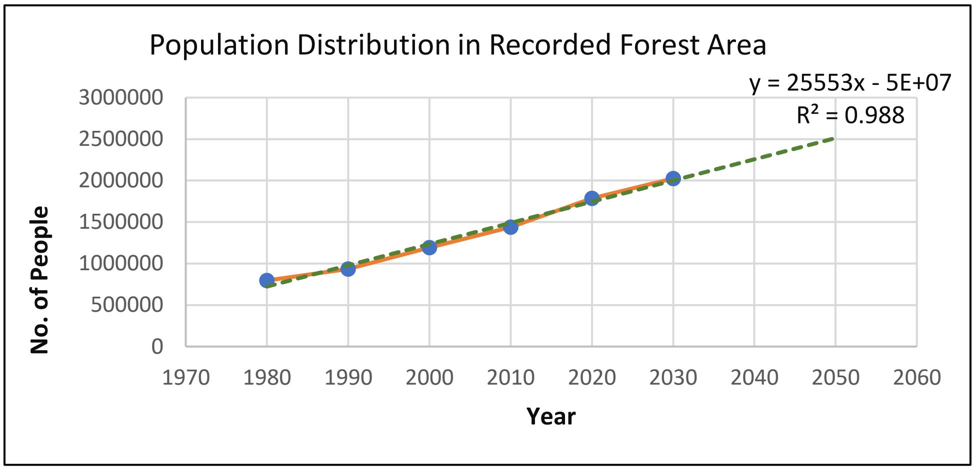


Figure 32: Population distribution in forest area

2. **Natural Drivers**

a) **Landslides-** As per the spatial distribution of the rain triggered landslides, out of the 90 occurrences that have happened since 2007, 38 have resulted in some number of casualties being reported. There have been 4 cases of large intensity landslides in the past 16 years. A spatial distribution map below has been developed to highlight the areas where the landslides events more frequently take place.

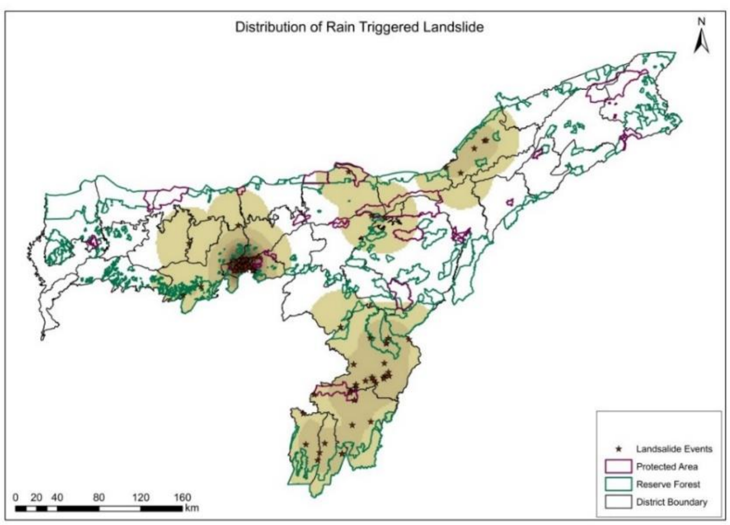


Figure 33: Distribution of rain triggered landslides

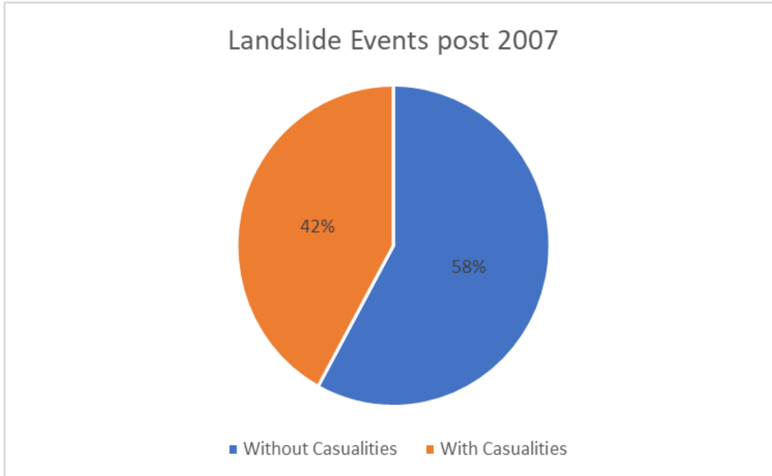


Figure 34: Landslide events (Casualties)

Number of landslide events, size of landslides, fatalities, and their location is provided in Annexure 3.

b) **Earthquakes-** According to the spatial distribution of earthquakes, there have been roughly 100 earthquake incidents since 1950. There have been 45 cases where the magnitude of earthquake was larger than 5.

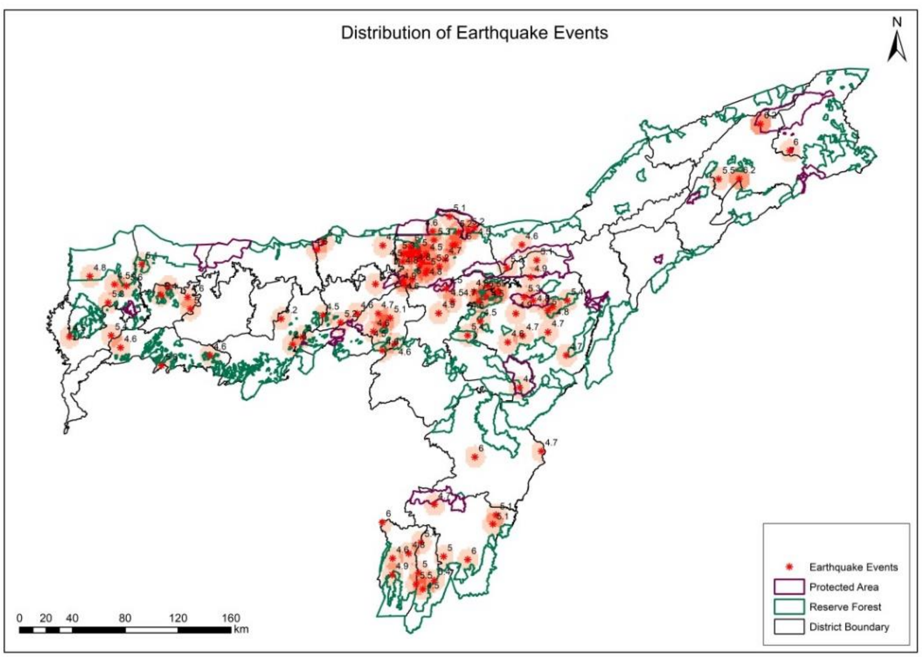


Figure 35: Distribution of earthquake events

The state has experienced earthquakes 45 times since 2000, as compared to 55 times in 50 years since 1950.

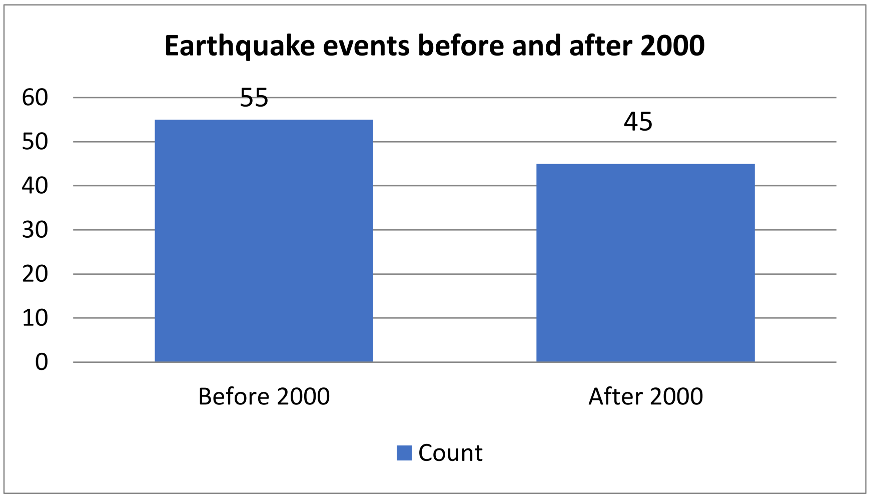


Figure 36: Number of earthquake events (pre and post 2000)

Number of earthquake events in Assam, their magnitude and depth s provided in Annexure 4.

c) **Fire point intensity (FPI)-** To illustrate the total number of fire occurrences and the average FRP score for each district throughout the course of the 22-year period, a layout has been developed.

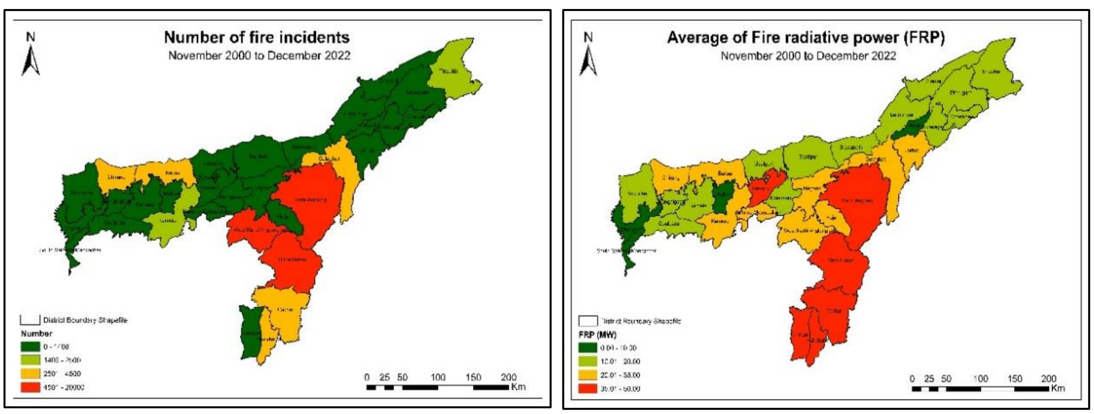


Figure 37: Number of Fire Incidents (Left), Average fire radiative power (Right)

It has been observed that Karbi Anglong and Dima Hasao have exhibited a notably high frequency of fire incidents (>14,000 incidents) over the 22-year time period.

d) **Drought Assessment-** A layout has been developed to show the average SPI value over a 22-year period for each district. Drought-prone districts with SPI values more than -0.5 includes west and east Karbi Anglong, Hojai, Dima Hasao, Kamrup Metropolitian, Darrang, and Morigaon.

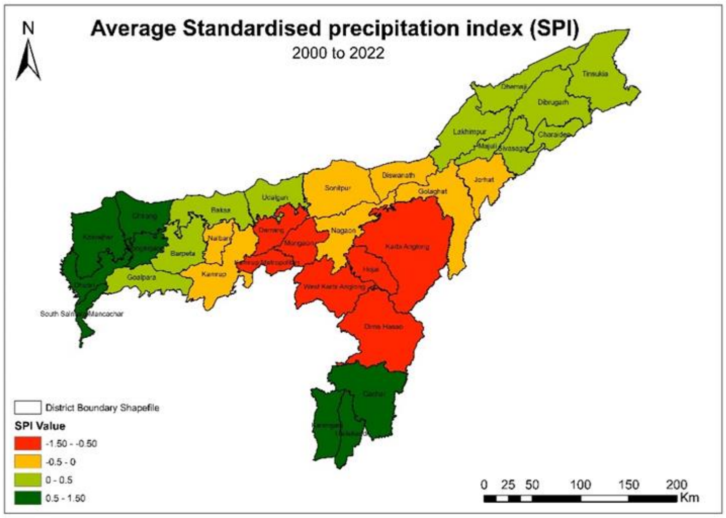


Figure 38: SPI Average

e) **Flood Analysis-** In Assam, floods are a widespread phenomenon. Millions of people as well as thousands of hectares of land are being affected each year due to the annual flood events in Assam. Here, four pre and post flood events have been monitored using Sentinel-1 SAR data to demonstrate the devastating impact of flood events on the entire state as well as recorded forest area.

- **Flood Event of 2017**

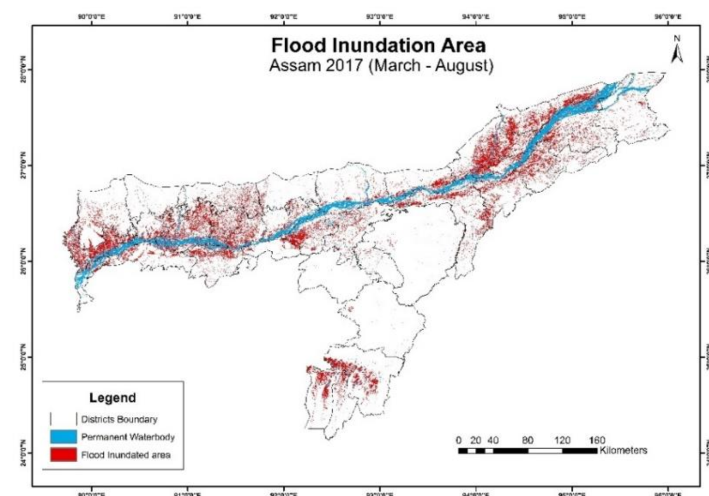


Figure 39: Flood inundation area 2017

During the 2017 floods, more than 14 lakh people were affected, more than 40 thousand people were homeless, and there were at least 85 casualties. **Flood inundated area have been monitored through SAR data (Sentinel-1) which indicates that**, over 20 percent of the land was submerged in the districts like as Barpeta, Dhemaji, Dibrugarh, Goalpara, Jorhat, Karimganj, Kokrajhar, Lakhimpur, Nalbari, Sivasagar, and South Salmara Mancachar. More than 45% of the area was inundated in the districts like Dhubri and Majuli.

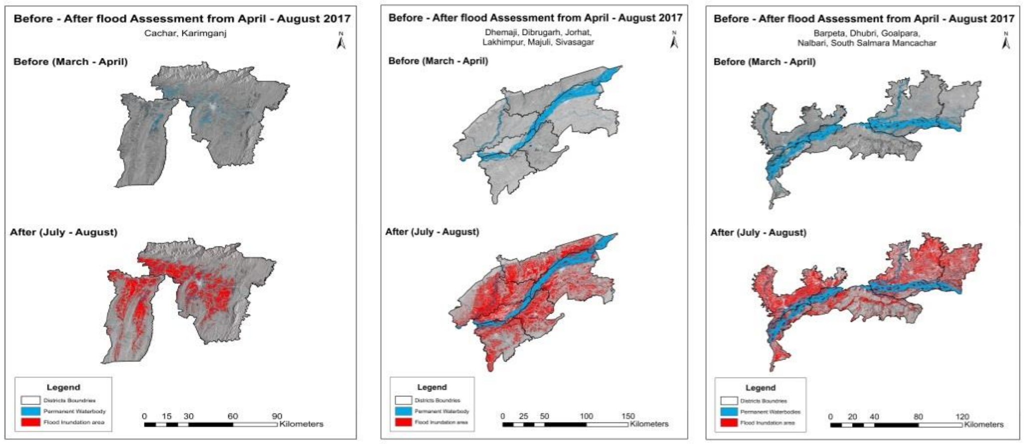


Figure 40: Flood inundation in South Zone (Left), East Zone (Center), and West Zone (Right)

- **Flood Event of 2020**

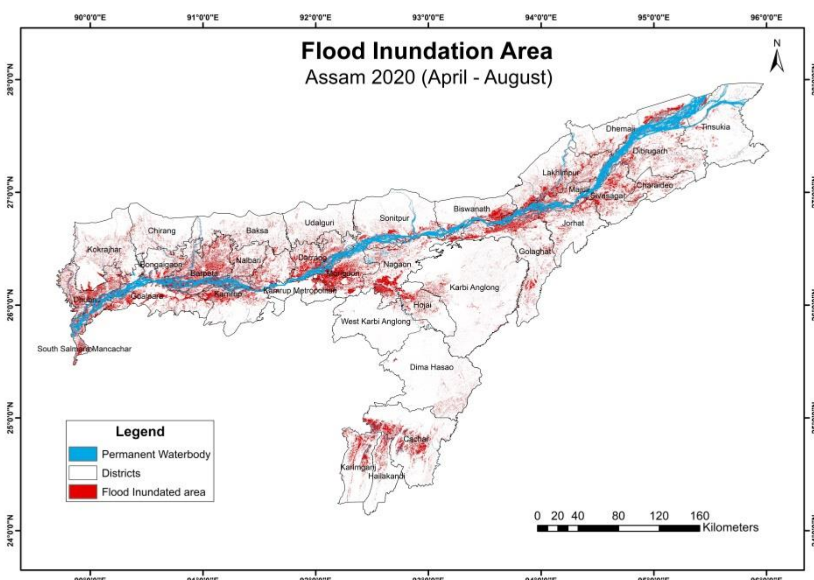


Figure 41: Flood inundation area of 2020

Over 70 lakh people were affected and more than 120 **people were reported dead** in the 2020 Assam floods. Nearly, 30% of the Morigaon and Majuli was inundated in water.

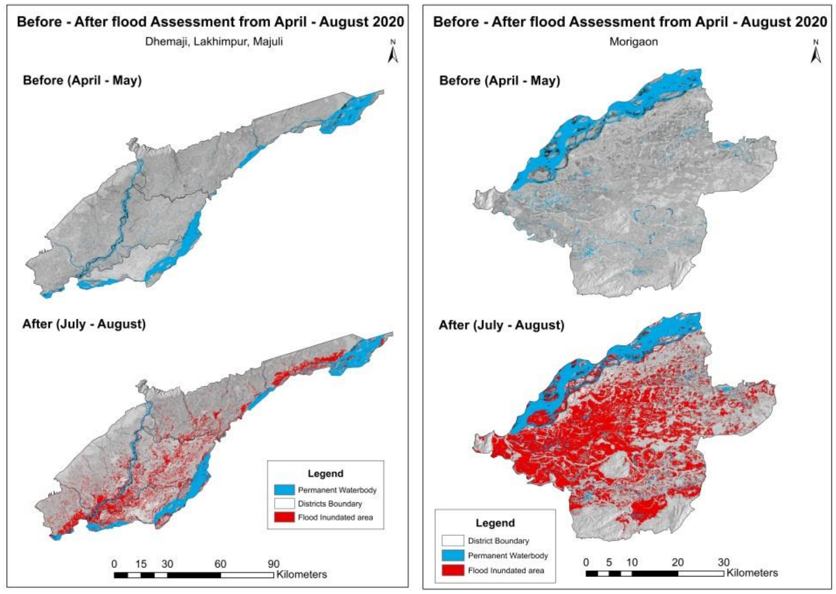


Figure 42: Flood Assessment Dhemaji, Lakhimpur& Majuli (Left), and Morigaon (Right)

- **Flood Event of 2022**

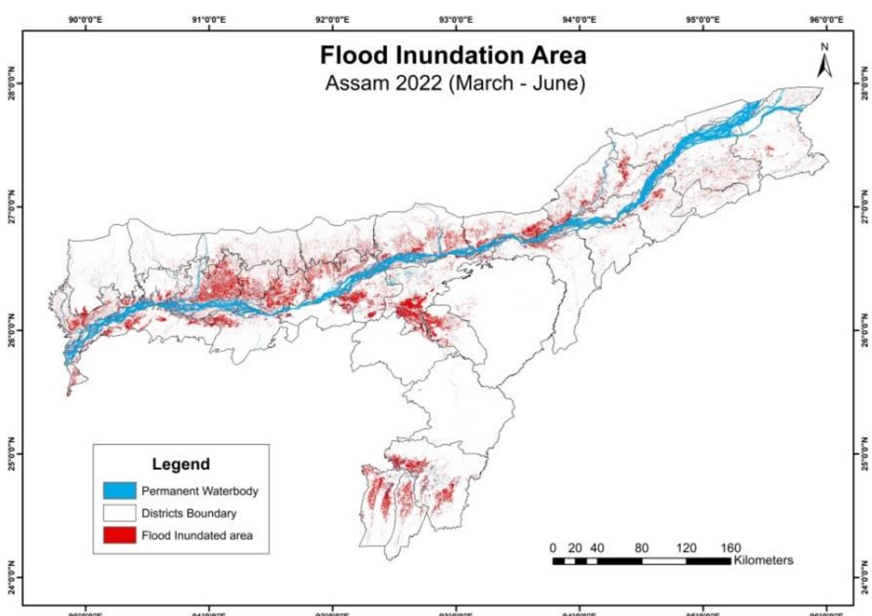


Figure 43: Flood inundation area of 2022

The floods of 2022 were reported as the worst flood in the state in the decade, affecting well over 88 lakhs people and causing the lives of at least 181 people. All the 35 districts were crippled under the flood. Atleast 20% of the area was submerged in the districts of Barpeta, Darrang, Karimganj, Majuli, Lakhimpur, Nagaon, Morigaon, and Nalbari.

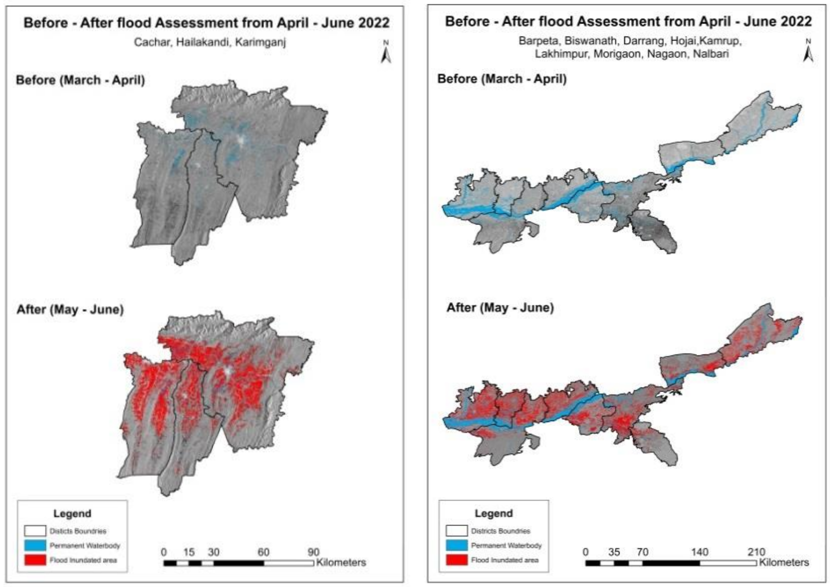


Figure 44: Flood Assessment South Zone (Left), and West Zone (Right)

- **Flood Event of 2023**

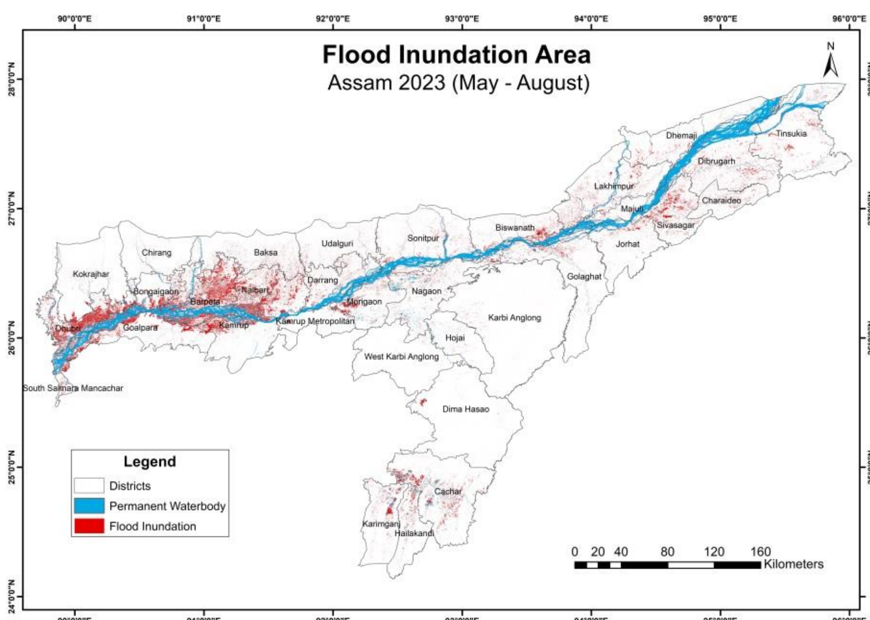


Figure 45: Flood inundation area of 2023

More than 2 lakhs people were affected during the floods of 2023. Over 20% of the land area of Dhubri and Barpeta had been submerged in water as highlighted from the flood inundation analysis using the SAR data.

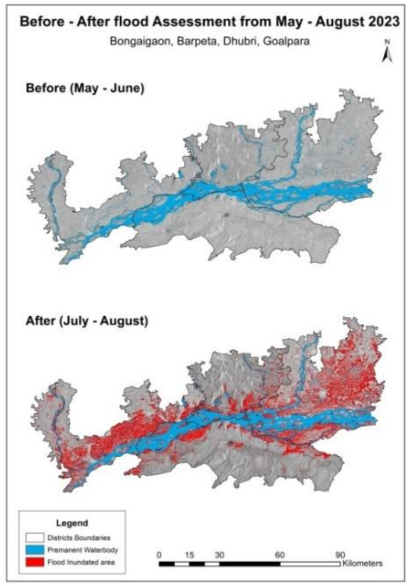


Figure 46: Flood assessment west zone

f) **Climate Variability-** Spatial distribution maps of annual precipitation have been developed for each decade since 1951 using CRU dataset which has been further validated using the high resolution IMD gridded dataset (0.25 x 0.25 degree) (https://www.imdpune.gov.in/cmpg/Griddata/Rainfall_25_NetCDF.html) which shows high positive correlation. Also, the dataset has been validated with very high resolution Terra Climate dataset having a spatial resolution of 0.04 x 0.04 degree (https://www.climatologylab.org/terraclimate.html).

The spatial distribution maps (as shown in figure below) and the decadal variation of annual average precipitation indicates a decreasing trend in precipitation for the state of Assam. There is a decrease of 171.81 mm in average precipitation over the period of 60 years.

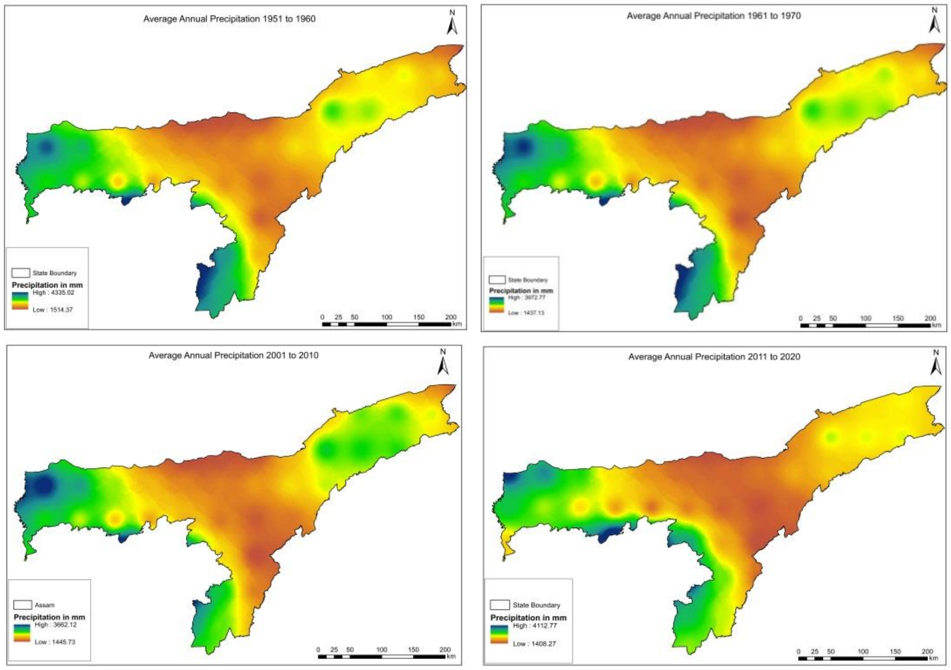


Figure 47: Average Annual Precipitation 1951-60 (top left), 1961-70 (top right), 2001-10 (bottom left), and 2011-20 (bottom right)

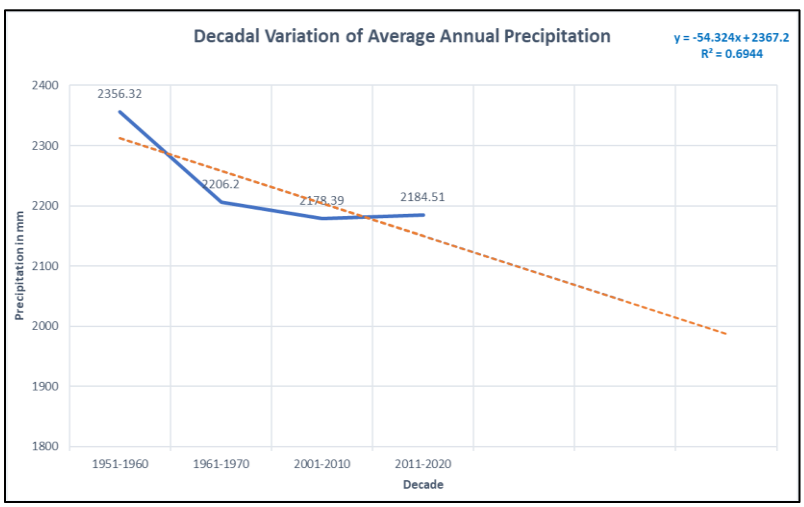


Figure 48: Variation in average annual precipitation

Spatial distribution maps of average air temperature have been developed for each decade since 1951 using CRU dataset which has been further validated using the high resolution IMD gridded dataset and TerraClimate dataset.

Spatial distribution maps and the decadal variation of average air temperature indicate a gradually increasing trend. There is an increase of 0.3 ° in average air temperature over the period of 60 years. It further accelerating the 'increasing trend' during the present three years (2020-2022) which highlights an increase of 0.57 ° in average air temperature than that of during 1951-1960.

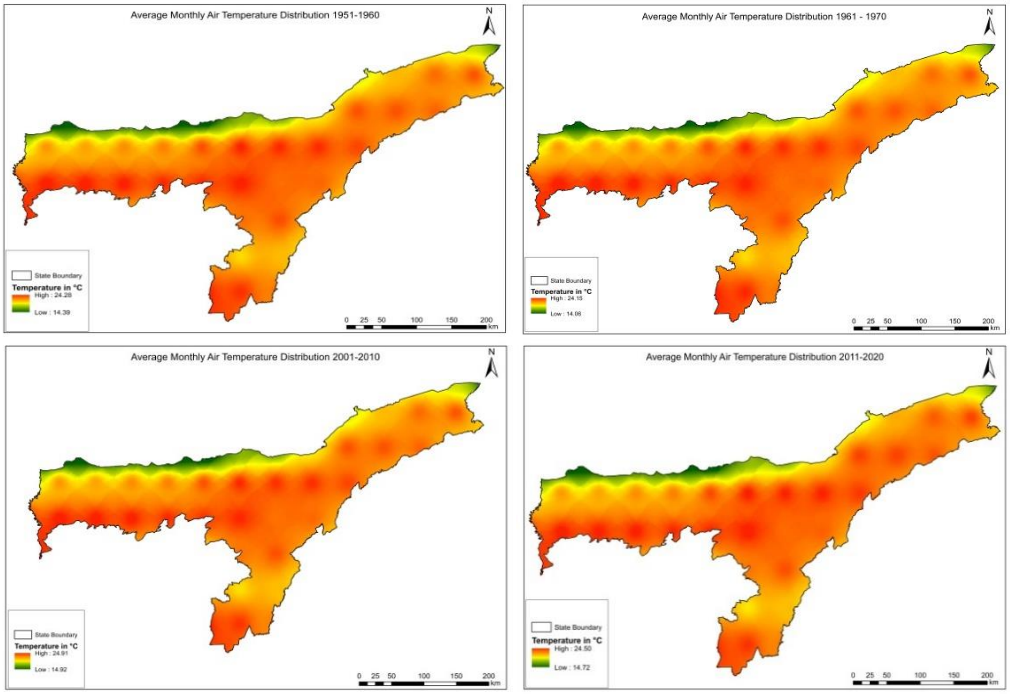


Figure 49: Average monthly air temprature1951-60 (top left), 1961-70 (top right), 2001-10 (bottom left), and 2011-20 (bottom right)

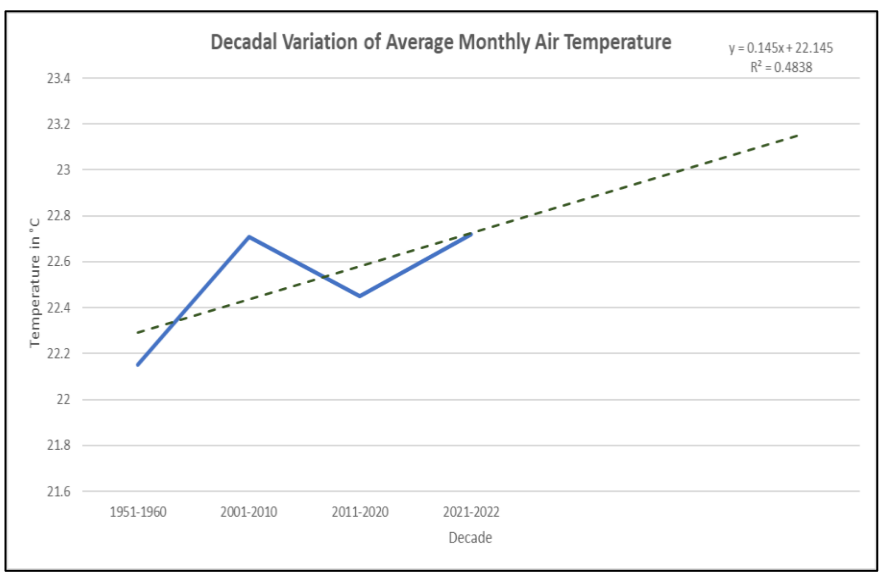


Figure 50: Variation of Average Monthly Air Temperature

3. **Impact Assessment**

a) **Carbon stock change-** The Spatio-temporal conversion of forest land into other land use classes (such as Cropland & Settlement) due to increasing anthropogenic activities have drastic impact on forest carbon stocks as shown in table below:

Table 10: Loss in carbon stock

Change in land use classes	**Change in Forest Area (in sq. km./year)**	**Change in Forest Area (in ha/year)**	***Average Carbon Stock (in t/h)**	**Loss in Carbon Stock (in tonne/ year)**	**tCO2eq/year**
Forest to Waterbodies	5.47	546.70	95.85	52,400.89	1,92,311.27
Forest to Riverbed	0.80	80.45		7,711.31	28,300.50
Forest to Barren Land	4.54	453.67		43,484.62	1,59,588.55
Forest to Grassland	10.18	1,017.83		97,559.05	3,58,041.71
Forest to Cropland	55.53	5,552.64		5,32,220.94	19,53,250.84
Forest to Settlement	1.04	104.44		10,010.27	36,737.69
Total Annual Loss in Carbon Stock				**7,43,387.07**	**27,28,230.54**

*The average carbon stock (in t/ha) is taken from ISFR 2021

As per the ISFR, 2021, the total forest cover area in Assam state is 28,312 sq. km. (i.e., 28,31,200 hectare). Henceforth, the total loss in carbon stock in tons of carbon dioxide equivalent per hectare per year is 0.96 tCO2eq/hectare/year due to the conversion of forest land class into other land use classes specifically cropland and built-up over the period of analysis.

b) **Forest Canopy Density (FCD)-** A change matrix and a change map that demonstrates the dynamic transformations in the region have been developed to analyze the changes in Forest quality between 2000 and 2022. It's clear that during the course of 22 years, a significant portion of forest cover have witnessed degradation in quality. Further, the spatio-temporal extent of FCD suggest that a large area of Very Dense Forest (VDF) has been converted to other forest density classes over the span of 22 years.

Change detection quantifies the changes that are associated with FCD changes in the landscape using geo-referenced multi-temporal remote sensing images acquired on the same geographical area between the considered acquisition dates (Ramachandra and Kumar 2004). An important aspect of change detection is to determine what is changing to what category of FCD type (i.e., which FCD type is changed to the other type of FCD class). FCD change matrix depicts the change in area from one class to another FCD type that remains as it is at the end of the period. Thus, to clearly understand the source and destination of major FCD changes, change matrix for each period would have to analyse. For change analysis, change matrices would have to be generated for the different time periods to analyse changes in the area covered by different FCD classes. This would be done by comparing the number of pixels falling into each category of FCD in one time-period with the categorization of the same pixels in same/different class in the previous time-period.

Change in classes = MATRIX (time 1, time 2)

The data gathered from the generated matrix would further rearrange to prepare the FCD change matrix. Forest density change maps would be prepared for each of the two consecutive time periods by intersecting FCD maps of two successive time periods. Changes in FCD classes between two years would be analysed through the change maps generated.

The diagonal cells of the matrix in the change matrix tables, represent the area that has remained same in both the time periods. Other cell values represent the area that has changed from one class to another class.

Table 11: FCD change matrix

		2022			
	FCD Classes (Area in sq. km.)	**Moderately Dense Forest**	**Non-Forest and Scrub**	**Open Forest**	**Very Dense Forest**
2000	**Moderately Dense Forest**	**3829.7799**	1267.2522	4282.9173	1814.9526
	Non-Forest and Scrub	714.2283	**42819.6627**	3951.2745	275.2155
	Open Forest	2317.7646	4233.1599	**4537.1079**	1185.6096
	Very Dense Forest	4149.6075	674.4843	1643.9094	**740.7018**

For the spatial distribution mapping of change in forest canopy density, four major categories, namely, forest degradation, deforestation, enhancement & afforestation have been defined as per the IPCC & FAO:

Forest Degradation: As per the FAO definition, changes within the forest class that negatively affect the stand or site and, in particular, lower the production capacity have defined as forest degradation. Forest degradation denotes the reductions in the productive capacity of the forest.

Enhancement: Enhancement defined as the increases in the density or average size of trees in a stand. Consequently, enhancement indicates the increase in the carbon stock in forest strata.

Deforestation: Deforestation is defined as the conversion of forest land to non-forest land. Deforestation is also marked as the drastic decrease in carbon forest carbon stock in forest strata.

Afforestation: Afforestation is defined as the conversion of non-forested lands to forests. Afforestation is usually marked as the establishment of forest on land that has been without forest for a period of 20-50 years or more and was previously under a different land use.

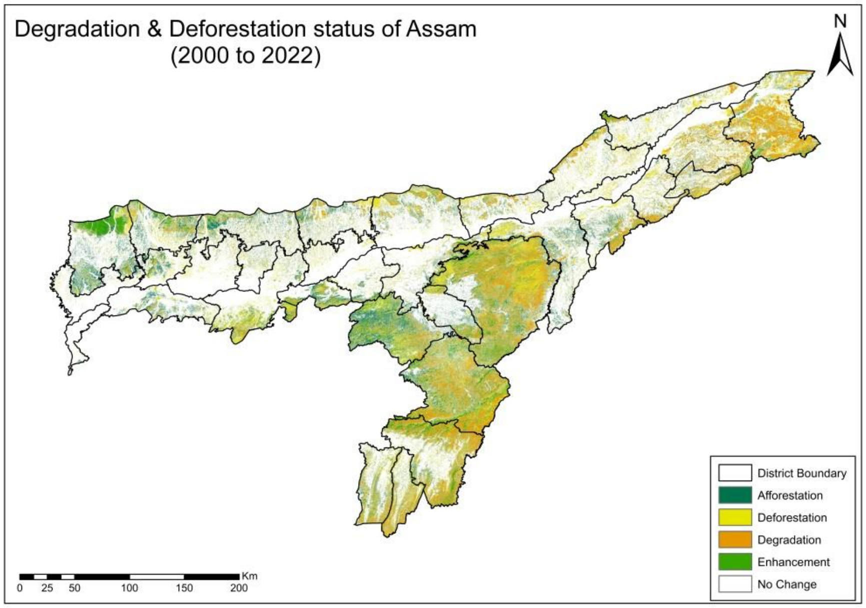


Figure 51: Deforestation and forest degradation status in Assam

The degradation/enhancement area stat has been developed using the FCD change matrix and demonstrates forest dynamics over the 22-year period.

Table 12: Degradation/Enhancement Status (from year 2000 to 2022)

Based on FCD change from 2000 to 2022	
Type of Forest Density Change	Area Change (sqkm)
No Change	51,927.25
Degradation	10,076.43
Deforestation	6,174.90
Enhancement	5,318.33
Afforestation	4,940.72

3.3.1 Limitation of RS-GIS analysis

The accuracy of forest canopy density as well as forest degradation & forest land conversion mapping have been affected due to the inherent limitations of remote sensing data. In this assessment, satellite sensors like Landsat-5 TM & Landsat-8 OLI/TIRS have been used, with spatial resolutions of 30 meters. Hence, heterogeneous information with a geometric dimension on the ground less than the respective resolutions mentioned is not discernible.

Similarly, the presence of agricultural crops near forest regions and the heterogeneity of tree species often influences spectral signatures. As a result, it becomes difficult to precisely define forest cover and types.

Due to their limited growth, young plants and tree species characterized by a low leaf index and transmittance often remain indiscernible in satellite imagery. The occurrence of weeds like lantana in forest areas and agricultural crops like sugarcane, cotton, etc. specifically which are adjacent to forest area cause mixing of the spectral signatures and often make precise forest cover delineation comparatively difficult.

Additionally, other limitations, including atmospheric conditions, terrain cast shadows, and the unavailability of seasonal data, lead to the minor misinterpretation of features in image classification methods.

3.4 Findings of Stakeholder Consultation

The stakeholder consultation was conducted with the objective to:

a) Identify drivers of deforestation and forest degradation acting in the Assam and their categorization as direct or indirect driver.

b) Mapping prominent drivers in the districts of Assam to understand their geographical spread.

This was done via an individual activity (conducted in Task 1) and a group activity (conducted in Task 2). All the stakeholders provided their perception on different drivers of degradation (Refer to Annexure 5 for reference sheet with list of drivers), categorized them as either a direct or indirect driver, provided the severity of the each identified driver on a Likert scale ranging from 1 to 5 (1 being least severe and 5 being most severe), and finally mapped the drivers in a political map of Assam.

Findings of Task 1

The top 5 drivers based on percentage of number of responses from different stakeholders are development pressure (9.36%), natural hazards (9.14%), encroachment (8.36%), increasing population pressure & urbanization (7.58%), and illegal activities (6.8%). The detailed percentage contribution of each driver based on the number of mentions by all stakeholders is provided in Annexure 6.

The ranking of top five drivers based on number of mentions by different stakeholder groups are as follows:

1. NGO- Development pressure (10.15%), increasing population pressure and urbanization (9.14%), illegal activities (8.12%), encroachment (7.61%), and governance (7.61%).
2. Forest & allied- Development pressure (10.2%), encroachment (8.67%), resource extraction (8.16%), shifting cultivation (8.16%), and invasive species (7.14%).
3. Rural development & livelihood- Natural Hazards (13.20%), development pressure (8.58%), encroachment (8.58%), increasing population pressure and urbanization (8.25%), and climate change (7.26%).
4. Other research institutions- Development pressure (8.96%), natural hazards (8.46%), encroachment (8.46%), resource extraction (7.96%), and illegal activities (7.46%).

The list of all drivers and their percent contribution (based on number of mentions) by stakeholder's category is provided in Annexure 7.

The session-1 exercise also included questions on the category of driver i.e., direct or indirect driver and the severity of individual driver based on their impacts.

The categorization of drivers (direct and indirect) based on different impacts is provided below:

Table 13: Direct and indirect drivers as per different stakeholders

Impacts	Direct	Indirect
Impact on livelihood	Resource Extraction, Forest Fire, Natural Hazards, Development pressure, Encroachment, Shifting Cultivation, Plantation: monoculture, Invasive species, Illegal activities, Geopolitical Conflicts, Governance, Increasing population pressure and urbanization, Privatization of communal lands, Subsistence for livelihood, Landlessness, Riverbank erosion and Sedimentation, Anthropogenic hazards, Climate Change, Human Wildlife Conflict	Invasive species, Geopolitical Conflicts, Lack of awareness
Impact on Ecosystem Services	Resource Extraction, Forest Fire, Natural Hazards, Development pressure, Encroachment, Shifting Cultivation, Plantation: monoculture, Illegal activities, Governance, Increasing population pressure and urbanization, Subsistence for livelihood, Landlessness, Riverbank erosion and Sedimentation,	Invasive species, Geopolitical Conflicts, Privatization of communal lands, Subsistence for livelihood

	Anthropogenic hazards, Lack of awareness, Climate Change, Human Wildlife Conflict	
Impact on biodiversity	Resource Extraction, Forest Fire, Natural Hazards, Development pressure, Encroachment, Plantation: monoculture, Invasive species, Illegal activities, Increasing population pressure and urbanization, Riverbank erosion and Sedimentation, Climate Change	Shifting Cultivation, Geopolitical Conflicts, Governance, Privatization of communal lands, Subsistence for livelihood, Landlessness, Anthropogenic hazards, Lack of awareness
Impact on forest cover	Resource Extraction, Forest Fire, Natural Hazards, Development pressure, Encroachment, Shifting Cultivation, Plantation: monoculture, Illegal activities, Geopolitical conflicts, Increasing population pressure and urbanization, Privatization of communal lands, Landlessness, Anthropogenic hazards, Riverbank erosion and Sedimentation, Climate Change, Human Wildlife Conflict	Governance, Subsistence for livelihood, Lack of awareness

Based on the severity of the individual drivers the responses are as follows. (*Severity: 1 – least severe; 5 – most severe)*:

Table 14: Classification of drivers based on impact on livelihood and level of severity.

Severity	Drivers
1	Resource Extraction
3	Forest Fire, Development pressure, Shifting Cultivation, Invasive species, Illegal activities, Geopolitical Conflicts, Landlessness, Anthropogenic hazards, Lack of awareness
4	Natural Hazards, Plantation: monoculture, Governance, Increasing population pressure and urbanization, Privatization of communal lands, Subsistence for livelihood, Riverbank erosion and Sedimentation
5	Encroachment (Agriculture + Settlement), Climate Change, Human Wildlife Conflict

Table 15: Classification of drivers based on impact on ecosystem services and level of severity.

Severity	Drivers
2	Forest Fire
3	Shifting Cultivation, Plantation: monoculture, Landlessness, Anthropogenic hazards, Lack of awareness, Climate Change, Human Wildlife Conflict
4	Natural Hazards, Development pressure, Encroachment (Agriculture + Settlement), Invasive species, Illegal activities, Geopolitical Conflicts, Governance, Increasing population pressure and urbanization, Privatization of communal lands, Subsistence for livelihood, Riverbank erosion and sedimentation
5	Resource Extraction

Table 16: Classification of drivers based on impact on biodiversity and level of severity.

Severity	Drivers
3	Forest Fire, Shifting Cultivation, Plantation: monoculture, Invasive species, Landlessness, lack of awareness
4	Resource Extraction, natural hazards, development pressure, Encroachment (Agriculture + Settlement), illegal activities, geopolitical conflicts, governance, privatization of communal lands, subsistence for livelihood, anthropogenic hazards, climate change
5	Riverbank erosion and Sedimentation

Table 17: Classification of drivers based on impact on forest cover and level of severity.

Severity	Drivers
2	Geopolitical Conflicts, Anthropogenic hazards
3	Forest fires, natural hazards, shifting cultivation, invasive species, illegal activities, Subsistence for livelihood, Lack of awareness
4	Resource Extraction, Development pressure, Plantation: monoculture, Privatization of communal lands, Landlessness, Riverbank erosion and Sedimentation, Climate Change
5	Encroachment (Agriculture + Settlement), Governance, Increasing population pressure and urbanization, Human Wildlife Conflict

The responses of all the stakeholders with respect to all the drivers, their impact on forest cover, biodiversity, ecosystem services and livelihood of forest dependent communities are analyzed based on their severity. To get the cumulative score of drivers the severity level of individual driver is multiplied with the number of responses received from the stakeholders. The highest score signifies the cumulative impacts of all the drivers and based on this score all the drivers are ranked (Annexure 8). The top 10 drivers are as follows:

Table 18: Ranking top 10 drivers based on stakeholder consultation.

Drivers	Rank
Development pressure	1
Natural Hazards	2
Increasing population pressure and urbanization	3
Encroachment (Agriculture + Settlement)	4
Illegal activities	5
Resource Extraction	6
Climate Change	7
Governance	8
Lack of awareness	9
Invasive species	10

Findings of Task 2

In Task-2 of the group activity, all groups marked the drivers based on their code in a political map of Assam to understand the drivers and the region in which the drivers of deforestation and forest degradation are prominent. Based on the perception of different stakeholders in the group the identified drivers were mapped and the results where more than 1 group marked the same driver in the same district is selected as the inclusion criteria for the prominence of driver in a district.

The top five drivers of degradation identified by the stakeholders based on the number of mentions are: encroachment (agriculture, and settlement), resource extraction (fuelwood, timber, bamboo, Non-Timber Forest Produce (NTFP) etc.), natural hazards (majorly floods, and landslides), Illegal activities (felling, hunting, teasing, poaching etc), development pressure (mining, hydro, road development, infrastructure, oil exploration, poor waste management), and increasing population pressure and urbanization.

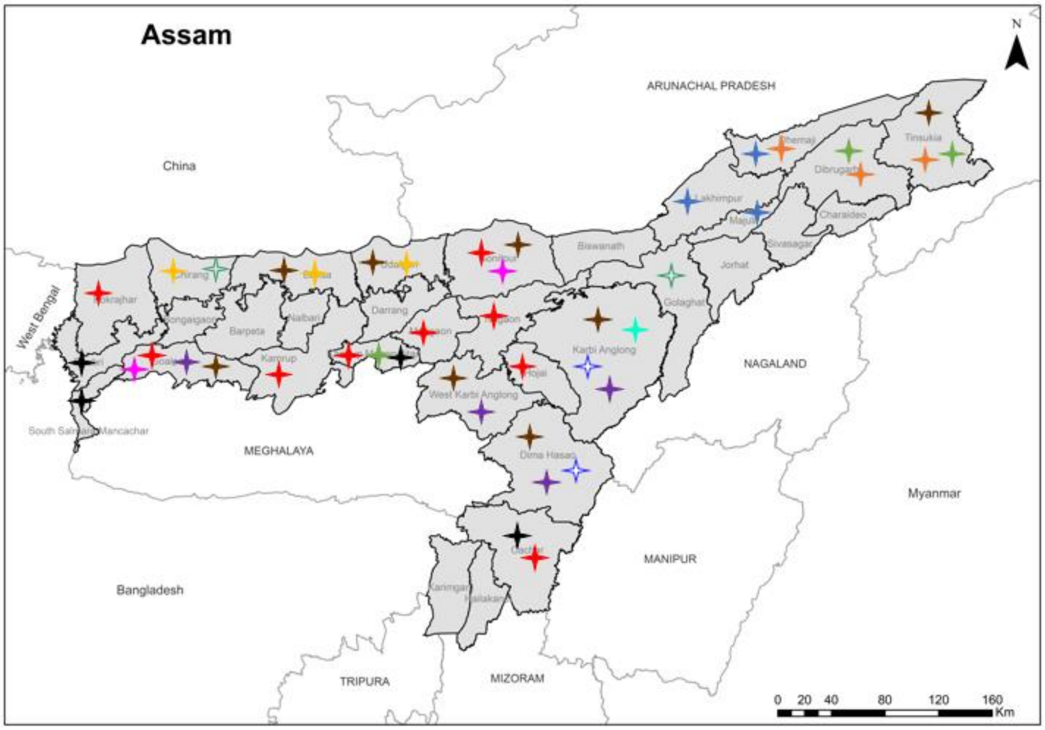
The code of driver, number of times its mentioned, description of driver, and the districts in which it is marked by different stakeholder groups are mentioned in the table below:

Table 19: Stakeholder perception on drivers and their presence in the districts of Assam.

Driver Code	Driver	Districts
D05	Encroachment	Cachar (2), Goalpara (3), Hojai (2), Kamrup (rural) (2), Kamrup metro (3), Morigaon (2), Nagaon (2), and Sonitpur (2)
D01	Resource Extraction	Baksa (2), Dima Hasao (3), Goalpara (2), Karbi Anglong (2), Karbi Anglong (West) (2), Sonitpur (2), Tinsukia (2), and Udalguri (2)
D03	Natural Hazards	Dhemaji (2), Lakhimpur (2), Majuli (3)
D09	Illegal activities	Baksa (2), Chirang (2), Udalguri (2)
D04	Development pressure	Dibrugarh 2), Kamrup metro (2), Tinsukia (3)
D12	Increasing population pressure and urbanization	Cachar (2), Dhubri (2), Kamrup metro (3), South Salmara Mancachar (2)
D18	Riverbank erosion & Sedimentation	Dhemaji (2), Dibrugarh (2), Tinsukia (2)
D14	Subsistence for livelihood	Dima Hasao (2), Goalpara (2), Karbi Anglong (2), Karbi Anglong (West) (2)
D07	Plantation- monoculture	Goalpara (2), Sonitpur (2)
D10	Geopolitical conflicts	Karbi Anglong (2)
D06	Shifting Cultivation	Dima Hasao (2), Karbi Anglong (4)
D08	Invasive species	Golaghat (2)

Note: The numbers in the bracket represent the number of times the driver is mentioned in the same district by multiple stakeholders.

The above responses from the stakeholders are marked in the political map of Assam as shown in the figure below:



Driver	Symbol
Encroachment	
Resource Extraction	
Natural Hazards	
Illegal activities	
Development pressure	
Increasing population pressure & urbanization	
Riverbank erosion & sedimentation	
Subsistence for livelihood	
Plantation- monoculture	
Geopolitical conflicts	
Shifting cultivation	
Invasive species	

Figure 52: Mapping presence of drivers in Assam.

The responses of all the groups for task 2 is provided below:

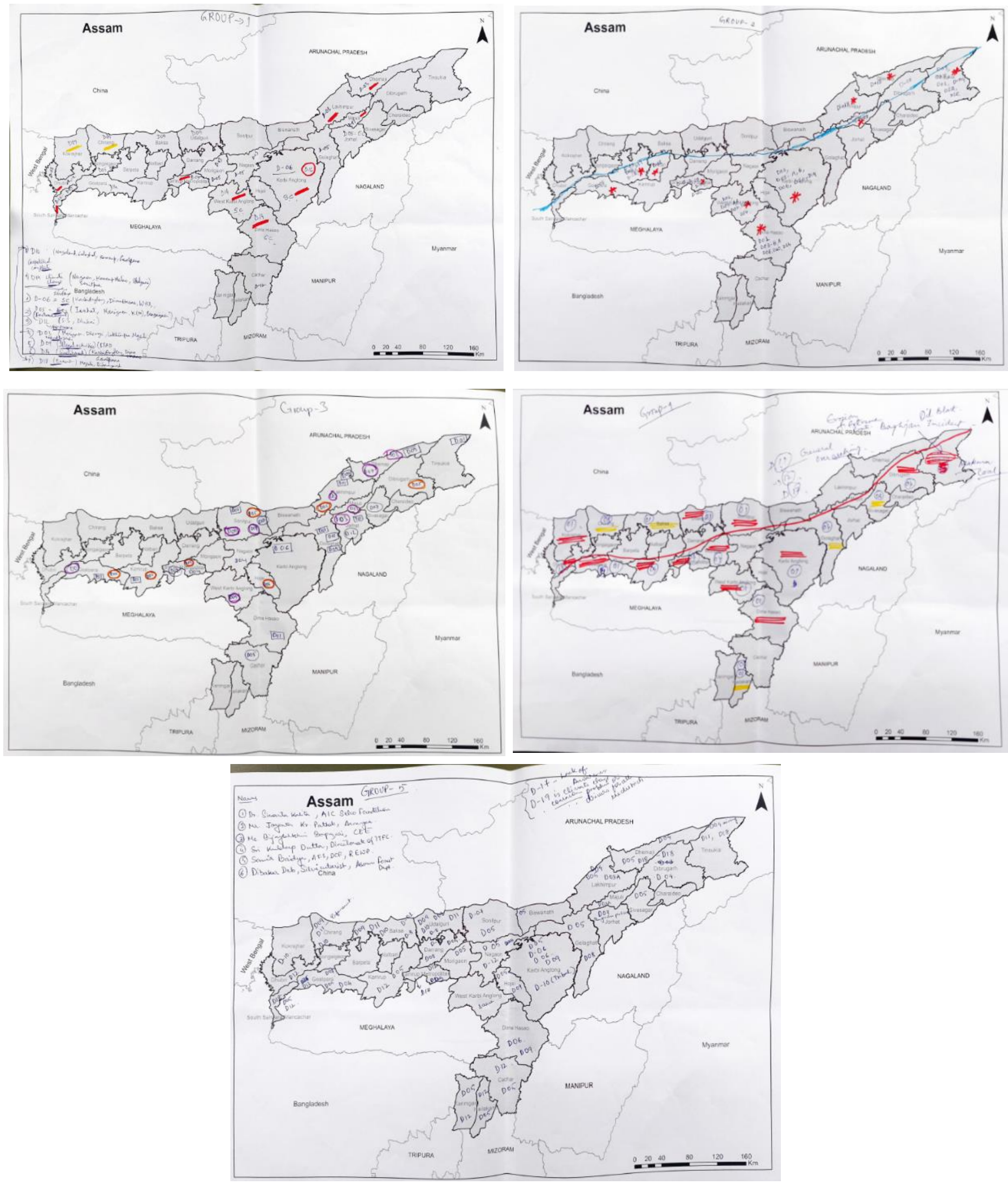


Figure 53: Mapping of drivers of deforestation and forest degradation by Groups in task 2.

3.5 Summary of Findings

Highlights of the systematic review of literature

- The systematic review of literature suggests that resource extraction, encroachment (agriculture and settlement), illegal activities (timber extraction, poaching, hunting etc), development pressure and shifting cultivation are the prominent drivers of degradation and deforestation.

- Several underlying causes for forest degradation and deforestation haven been discerned in literature. Each of the drivers mentioned in the review can be attributed or linked to other direct or indirect contributing factors. For instance, some common factors cited in most of the literature are population growth, burgeoning industrialisation/urbanization and the subsequent demand and dependency on various resources- from land for expansion to extraction of numerous forest resources. In addition to dependency on the resources, literacy, or lack thereof, combined with poverty and lack of livelihood opportunities also drives unsustainable extraction of resources and increased cultivation of cash crops. Drivers such as encroachment, a major issue in the state, have been attributed to political unrests, insurgencies and immigration and sometimes inefficient forest management.
- Furthermore, as inferred from the literature review, these drivers can be both natural and anthropogenic in nature, with the latter being the most common. The occurrence and impacts of various natural drivers, such as floods or increased precipitation, increased sedimentation and erosion, are often aggravated by many anthropogenic drivers such as encroachment, timber felling etc.; various anthropogenic activities are directly responsible for increased GHG emissions, leading to climate change and increased frequency of natural hazards.

The various interlinkages between each driver of deforestation and forest degradation are depicted in the figure below:

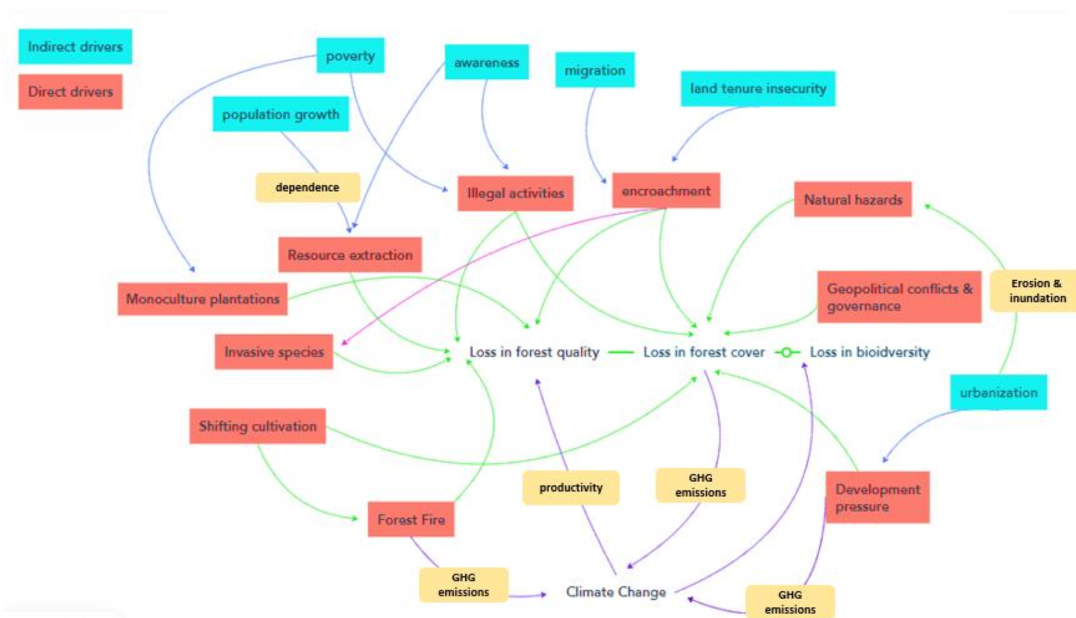


Figure 54: Mind map showing interlinkages between various drivers.

Highlights of the Socio-economic Assessment (SEA)

- The FFV lying closest to the forest area (up to 1 km) extract the maximum quantum of resources. This suggests that accessibility and proximity to a forest influences the quantity of resources extracted.
- Fuelwood is the major forest resource collected by the FFV.
- Household with no or small landholdings extract the maximum resources from the forest. This suggests that the size of landholding influences the forest resource dependency.
- Agriculture is the primary source of income for the sampled households. The number of households depending on forest resources as a source of income is small as compared to other sources of income. This suggests that a subsistence-based dependency on forest resources.
- The majority of the landless households or those with small landholdings (83%) are most dependent on forest resources despite driving their income from agricultural activities.
- Forests are the major source of resource extraction for fuelwood, grazing fodder and stall fodder.
- Availability of certain forest resources have decreased over the last few decades. The average distance to collect a forest resource has been noted to have increased. This, supplemented by the respondents' observations of their forest quality suggests that the forests are getting degraded.
- **Biomass Extraction Intensity (BEI)-** Biomass Extraction Intensity (BEI) of Forest Fringe Villages measures the collection intensity of forest products by forest-resource-dependent communities. Communities depend on forests for a variety of products such as fuelwood, fodder, housing etc. Unsustainable use of forest products has resulted in large-scale forest degradation, depletion, and biodiversity loss, thereby adding to vulnerability. BEI captures the extraction pressure on forests and their vulnerability to deforestation, degradation, and biodiversity loss. It is quantified in terms of tonnes of forest produce per hectare per year (t/ha/yr).

  The fringe villages of the recorded forests falling in the vicinity of the villages have maximum extraction pressure. The image below shows the spatial distribution of BEI categorised into 4 zones based on intensity of extraction quantified at district level: low (6–50), moderate (50–100), high (100–200), and very high (>200). The extraction intensity is directly proportional to the vulnerability of forest & biodiversity; therefore, a higher BEI denotes higher contribution towards vulnerability, while a low BEI depicts low vulnerability. In Assam, spatial extent of BEI indicates that total 9 districts fall on very high BEI zone (>200 t/ha/yr) whereas 7 districts experienced low extraction pressure (< 50 t/ha/yr). The result indicates that Nalbari and Kamrup Metro shows very high extraction intensity, Tinsukia & Kokrajhar shows high extraction intensity, Karimganj and Morigaon shows moderate extraction intensity and Barpeta shows low extraction intensity.

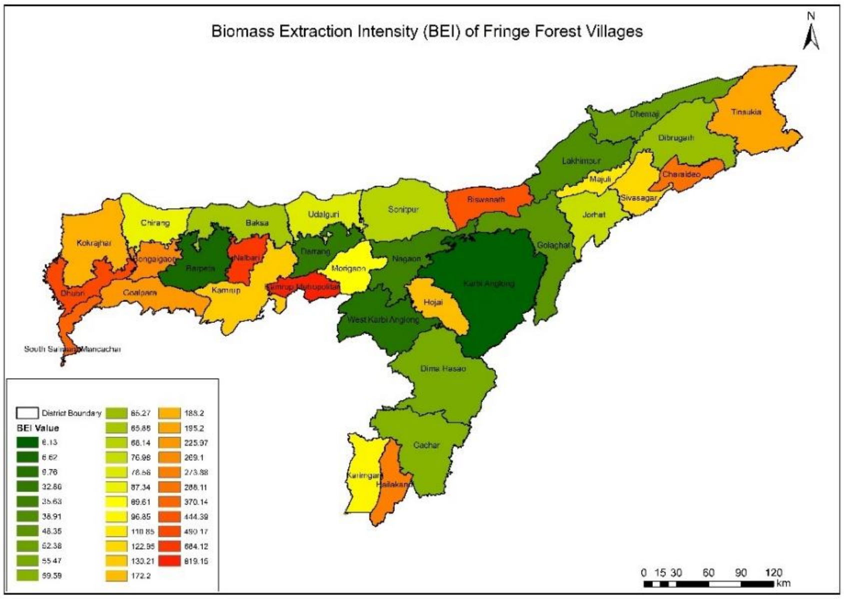


Figure 55: Biomass Extraction Intensity (BEI)

Highlights of the RS-GIS Analysis

- Between 2000 to 2022, 2,546 sq. km of forests have been converted into plantations, croplands and settlement areas. The annual rate of land transition of forests to settlements, croplands and plantations are 1.04 sq. km/yr, 55.53 sq. km/yr, 59.17 sq. km/yr, respectively.
- A sizable portion of the Diroi Reserve Forest, Chirang Reserve Forest, and Sonai Rupai Wildlife Sanctuary have been converted into crop fields over the period of 22 years.
- The annual loss in forest carbon stock from 2000 to 2023 is 2.7 million tonnes of CO_2 eq/yr.
- The total loss in carbon stock in tons of carbon dioxide equivalent per hectare per year is 0.96 tCO_2 eq/hectare/year due to the conversion of forest land class into other land use classes specifically cropland and built-up over the period of analysis.
- FCD analysis suggests that a large area of Very Dense Forest has been degraded over the span of 22 years. A total of 3,188 sq. km of VDF has been degraded, and 170 sq. km of the MDF has been changed to other forest classes. Non-forest and Open Forest (OF) class has seen a growth of 2,152 sq. km and 1,263 sq. km respectively over 22 years.
- Fire Point Intensity (FPI) analysis over 22 years indicates that 6 districts in Assam are very highly prone towards fire incidents.
- Standard Precipitation Index trends analysis over 22 years indicates that 7 districts fall within very high drought prone zones.
- The state has experienced earthquakes 45 times since 2000, as compared to 55 times in 50 years since 1950.
- Decadal variation of annual average precipitation indicates a decreasing trend in precipitation for the state of Assam. There is a decrease of 171.81 mm in average precipitation over the period of 60 years.

- Decadal variation of average air temperature indicates a gradually increasing trend. There is an increase of 0.3 ° in average air temperature over the period of 60 years. The trend is in further increasing trend during the present three years (2020-2022) which highlights an increase of 0.57 ° in average air temperature than that of during 1951-1960.
- The projection of the population for the year 2030 indicates that the population number in the RFA would reach over 2 million.
- Floods, being a recurrent hazard, inundate/submerges a substantial portion of several districts each time. It plays a pivotal role as a driver of forest degradation and biodiversity loss.

Highlights of the Stakeholder Consultation

- The top 5 drivers based on percentage of number of responses from different stakeholders are development pressure, natural hazards, encroachment, increasing population pressure & urbanization, and illegal activities.
- There is a consensus among four different stakeholder groups- NGOs, Forest and allied department, Rural and livelihood development, other research institutes. Development pressure and encroachment were cited as drivers in all stakeholder groups.

Consolidating analysis from SEA, stakeholder consultation, and systematic literature review

1. Top 5 drivers based on systematic literature review, stakeholder consultation, and Socio-Economic Assessment are:

Systematic Literature Review	Stakeholder Consultation	Socio-Economic Assessment
• Resource Extraction	• Development pressure	• Resource extraction
• Encroachment	• Natural hazards	• Encroachment
• Illegal activities	• Increasing population pressure & urbanization	• Natural hazards
• Development pressure	• Encroachment	• Anthropogenic forest fires
• Shifting cultivation	• Illegal activities	• Development pressure

Figure 56: Top 5 drivers.

2. The results of systematic literature review and stakeholder consultation indicates that below mentioned districts were found common in both the analysis:

Table 20: Driver-wise prevalent districts

Driver	Common Districts
Encroachment	Cachar, Kamrup, Kamrup Metro, Kokrajhar, Morigaon, Nagaon, and Sonitpur
Resource Extraction	Goalpara, Karbi Anglong, Sonitpur, Tinsukia
Illegal activities	Baksa, Chirang, Udalguri
Development pressure	Dibrugarh, Kamrup metro, Tinsukia
Geopolitical conflicts	Karbi Anglong
Shifting Cultivation	Karbi Anglong
Invasive species	Golaghat

The description of major drivers from SEA, stakeholder consultation, and systematic literature review is provided in Annexure 9.

4. CONCULSION

Due to variability of available data, existing literature and the limitations of the methods used for assessment, it is difficult to accurately quantify different identified drivers and thereafter rank them based on their impact. However, our effort for this report is to identify the most likely drivers, geographically spread in Assam for suggesting the most suitable mitigation strategies. There is synergy in the findings of the literature review, Socio-Economic Assessment (SEA), and stakeholder consultation.

While land diversion due to development pressure, encroachment, and natural hazards was found to be the major drivers for deforestation, resource extraction and illegal activities is causing the degradation of the forest. This is also supplemented by RS-GIS findings, which shows that sizeable portions of reserved forest and protected area have been encroached upon and converted into croplands.

Population pressure, landlessness, privatization of community lands, subsistence needs, and a lack of awareness are some of the common indirect or underlying drivers in both the literature review and stakeholder consultation.

Perceptions, driven by experiences, regarding all the drivers (direct or indirect/ natural or anthropogenic) vary between different stakeholders and in literature, with several interlinkages. Furthermore, the scale, severity and impact of these drivers would vary from place to place. Therefore, owing to the subjective nature of these drivers, it would not be appropriate to accurately rank these drivers for the entire state of Assam.

The present report provides us important insights on various drivers of deforestation and forest degradation acting in the state of Assam. Addressing these drivers would require devising appropriate strategies and gap analysis of the current management practices. The results obtained from the study will be used to devise a comprehensive, region-specific adaptation and mitigation strategies for forests and biodiversity of Assam.

5. ANNEXURE

Annexure 1

Questionnaire

Devising Climate Change Mitigation and Adaptation Strategies for Forests and Biodiversity of Assam

HOUSEHOLD SURVEY QUESTIONNAIRES

This survey is taken up as a part of project "Devising Climate Change Mitigation and Adaptation Strategies for Forests and Biodiversity of Assam" for Assam Project on Forest and Biodiversity Conservation Society (APFBCS). The survey will be conducted by TERI in collaboration with Assam Forest Department to evaluate the socio-economic status, drivers of deforestation & forest degradation and awareness regarding forest management practices of forest dependent communities in Assam. Based on the finding's suggestions will be provided to Assam Forest Department to develop climate smart mitigation and adaptation strategies.

Surveyor Code Date
Surveyor Name Time

1. BASIC INFORMATION

Name of the village________________________ VDC (Village Development Council or Committee)/ Gram Panchayat____________________________ Range____________________
Block____________________________ District______________________
Village Type (Tick one) ☐ Forest Village ☐ Revenue Village
GPS Coordinates of Village: Latitude______________ Longitude______________
Name of the Respondent______________________ Age______ Sex ___________
Household size ___________ Phone No. of Respondent ___________________________
Level of Education (tick one) ☐ 5th to 8th Class ☐ 8th to 10th Class ☐ 10th to 12th Class
☐ Diploma ☐ Graduate & above ☐ Illiterate
Aadhaar No./ Voter ID No. of Respondent (optional) ___________________________

2. SOCIO ECONOMIC STATUS OF THE RESPONDENT

2.1. What is the total land size under your ownership?
- a) Don't own any land.
- b) Less than 7.5 bigha
- c) 7.5 to 15 bigha
- d) 15 to 30 bigha
- e) 30 to 75 bigha
- f) More than 75 bigha

2.2. What is the source of income for your household? (Can select multiple options)
- a) Salaried Employee
- b) Agriculture
- c) Livestock
- d) Small business
- e) Sale of forest resources (NTFP, fuelwood etc)
- f) Tourism
- g) Private Labour
- h) Forest Management Activities
- i) MGNREGA
- j) Others, please specify.

2.3. Does any member from your household need to migrate for livelihood?
- a) Migrate within Assam
- b) Migrate outside Assam
- c) Does not migrate.

2.4. What is your Economic Status?
- a) APL
- b) BPL

2.5. Which social group do you belong to?
- a) General
- b) SC
- c) ST
- d) OBC

2.6. What is your annually average income?
- a) Upto Rs 36000
- b) From Rs 36000 to Rs 50000
- c) From Rs 50000 to 1 Lakhs
- d) More than 1 Lakhs

2.7. Facilities available:

Facilities	Availability (Yes/No)	If available under a Scheme? (Name the scheme)	Is it a Personal or community resource? (N/A if does not apply)
House Electrified			
Solar Powered Electrification			
Tap Water			
Toilets			
LPG			
LPG Refilling			
Solar Powered Equipment			
Biogas Plant			
Pucca House			
Bank Account			
Health Insurance			

2.8. Which of the following facilities are available nearby your village? (Can select multiple options)

a) Health Centres
b) Medical Stores
c) Police Station
d) School
e) College
f) Market
g) Post Office
h) Bank
i) Community Hall

2.9. Are women in the household involved in income generation activities?

a) Yes
b) No

2.10. If yes, how much are women contributing to income generation annually? (In Rupees)_______________

2.11. What is the highest level of education in your household?

a) 5th to 8th Class
b) 8th to 10th Class
c) 10th to 12th Class
d) Diploma
e) Graduate and above
f) Illiterate

3. DEPENDENCY ON FOREST

3.1 What benefits do you derive from the forests? (Can select multiple options)

a) Fuelwood
b) NTFP collection
c) Bamboo
d) Fodder
e) Small Timber
f) Others

3.2. Do you have any forest rights?

Name of Right	Area Recognized under the right (If applicable)	Year when recognized (If applicable)
Individual Forest Right		
Community Rights		
Community Forest Resource Rights		
Development Rights		
Others, please specify__________		
Not aware		

3.3. What is the source of wood and its uses?

Uses of Wood	Amount required in a month (in Kg)	Source of wood (Tick where applicable)		
		Forest	Agriculture fields	Purchased (Forest Depot, market etc.)

Wood as a fuel		☐	☐	☐
Fencing		☐	☐	☐
Furniture		☐	☐	☐
Agriculture Equipment		☐	☐	☐
Household Equipment		☐	☐	☐
Other uses		☐	☐	☐

3.4. What is the source of energy and amount used per household?

Source of energy	Quantity collected monthly.	Breakdown of quantity collected (Tick where applicable)			
		Cooking	Heating	Lighting	Selling
Fuelwood (in kg)		☐	☐	☐	☐
Cow dung (in kg)		☐	☐	☐	☐
Kerosene (in ltrs)		☐	☐	☐	☐
LPG (number of cylinders)		☐	☐	☐	☐
Coal/lignite/Charcoal (in kg)		☐	☐	☐	☐
Briquettes (in Kg)		☐	☐	☐	☐
Others		☐	☐	☐	☐

3.5. What is the source and quantity of fuelwood collected per household?

Source of fuelwood	Frequency of collection in a month	Quantity collected per visit (in Kg)
Forest		
Other lands		
Purchased (Forest Depot, market etc.)		

3.6. What is the average distance travelled for collecting fuelwood from forest in one trip?

a) Upto 1km
b) 1 to 2 km
c) 2 to 3 km
d) More than 3 km

3.7. How has the distance changed for the collection of fuelwoods over the last 5 years?

a) Increased b) Decreased c) Remained Same

3.8. Livestock details:

S.No.	Livestock Type	Number	Monthly Requirement of Fodder/Feed (in Kg)
1	Cow		
2	Buffalo		
3	Sheep		
4	Goats		
5	Pigs		
6	Duck		
7	Chicken		

3.9. What is the source of grazing and frequency?

Source of grazing	Grazing hours in a day	Frequency of grazing in a month	Total months in a year for grazing
Forest			
Other lands			

Source of Stall feeding	Frequency of collection in a month	Quantity collected per visit (in Kg)	Number of months stall feeding is done.

Forest			
Other lands			
Market			

3.10. How far do you travel from village to forest for grazing livestock? (In Kilometer)

a) 0 to 1 kms
b) 1 to 2 kms
c) 2 to 3 kms
d) More than 3 kms

3.11. NTFPs collected:

S.No	MFP/NTFP	Number of Months of Collection	Availability of NTFP: Increased, decreased, remained same in last 10 years.	Quantity collected per year (In Kg)

3.12. How far do you travel from village to forest for collecting NTFP?

a) 0 to 1 kms
b) 1 to 2 kms
c) 2 to 3 Kms
d) More than 3 kms

3.13. Bamboo collection:

Source of Bamboo collection	Frequency of collection in a month	Type of bamboo	Quantity collected per visit	
			In No. of poles	In kg
Forest				
Homestead				
Other land				
Purchased (Market, individual etc.)				

4. DRIVERS OF DEFORESTATION AND FOREST DEGRADATION

4.1. Have you observed any of the following in the forest in last 10 to 20 years?

a) Deforestation -Reduction in forest area
b) Forest Degradation – Reduction in forest quality
c) Forest Enhancement – Increase in forest area and quality.
d) Remained same
e) Human Wildlife conflict

4.2. Which of the following leads to reduction in forest area or reduction in quality of forest?

a) Natural drivers (flood, draught, earthquake etc.)
b) Anthropogenic drivers (forest fires, encroachment, development etc.)
c) Both
d) No loss in forest area and quality

4.3. If there is reduction in area or quality of forest then, what are the major reasons according to you? Please rate it on the following scale of severity (1 being least and 5 being most)

Sources of drivers	1	2	3	4	5
Anthropogenic forest fire	☐	☐	☐	☐	☐
Extraction of forest resources	☐	☐	☐	☐	☐
Invasive species	☐	☐	☐	☐	☐
Pest Infestation and diseases	☐	☐	☐	☐	☐
Extreme weather events like flood, drought, earthquake etc.	☐	☐	☐	☐	☐
Agricultural encroachment in forest (subsistence/commercial)	☐	☐	☐	☐	☐
Forest encroachment for settlement, occupancy etc.	☐	☐	☐	☐	☐

Development activities like Mining, road infrastructure etc.	☐	☐	☐	☐	☐
Others, please specify____________	☐	☐	☐	☐	☐

4.4. What is the frequency of extreme weather events in your locality? Please rate it on the following scale of severity (1 being least and 5 being most)

Type of extreme weather events	**1**	**2**	**3**	**4**	**5**
Flood	☐	☐	☐	☐	☐
Drought	☐	☐	☐	☐	☐
Cloud bursts/flash flood	☐	☐	☐	☐	☐
Landslide	☐	☐	☐	☐	☐
Earthquake	☐	☐	☐	☐	☐
Others such as Lightening, natural forest fire etc.	☐	☐	☐	☐	☐

4.5. Do you think the frequency of these extreme events is?
- a) Increasing
- b) Decreasing
- c) No change in last 10 to 20 years

5. AWARENESS GENERATION

5.1. Which of the following are available in your village?
- a) Eco-Development Committee (EDC)
- b) Joint Forest Management Committee (JFMC)
- c) Biodiversity Management Committee (BMC)
- d) Self Help Group (SHG)
- e) Community Forest Resource Management Committee (CFRMC)
- f) Others, please specify___________
- g) Don't Know

5.2. Are you aware about the following points related to usage and management of forest resources by forest management committees?

Usage and Management of Forest Resources	**Yes**	**No**
Limit on Extraction of Forest Resources		
Penalties for Illegal Activities		
Control of Forest Fires		
Value Addition of Forest Resources		
Livelihood Opportunities		

5.3. Are you aware of the following:
- a) Roles and Responsibilities of EDC/JFMC/BMC/CFRMC/Others
- b) Forest Department Rules for Protection and Conservation
- c) Both

5.4. What steps are being undertaken by the local people when they witness any kind of illegal activity in and around the forest area?
- a) Raise Alarm and Communicate to Forest Department
- b) No Action
- c) Others. Please specify.

5.5. Did the forest department/NGO organize any skill development/ capacity building/ awareness creation workshops/ programs?
- a) Yes
- b) No

5.6. Did you participate in skill development/ capacity building/ awareness creation workshops/ programs?
- a) Yes
- b) No

5.7. If yes, how many members of the household participated in the skill development/ capacity building/ awareness creation workshops/ programs? ____

5.8. Did such programs/workshops were able to help/ assist people in enhancing their livelihood/ changing mindset about importance of wildlife & forest protection/ mitigating impacts of human wildlife conflicts?

a) Yes b) No

5.9. Did the activities taken up by the Forest Department, EDCs, JFMC, BMC, CFRMC, SHGs, and others have any positive impacts on the living conditions/ enhancement of livelihood/ mindset of local communities?

a) Yes b) No

5.10. Do you partake in any forest management activities?

a) Yes a) No

5.11. If yes, what activities are you engaged in? ____

Annexure 2

Agenda of Stakeholder consultation

Agenda

Friday- 17th November 2023	
0930-1000 hrs.	**Registration**
1000-1010 hrs.	**Welcome Address and Introduction to the Theme of the Project** **Dr. J. V. Sharma** IFS Rtd, Senior Director, Land Resources Division,
1010-1020 hrs.	**Special Remarks** **Dr. Dipankar Saharia**, Senior Director, Administrative Services, TERI
1020-1135 hrs.	**Inaugural Address** **Mr Sandeep Kumar**, IFS, Project Director, Assam Project on Forest and Biodiversity Conservation Society
1135-1145 hrs.	**Tea Break**
1145-1215 hrs.	**Introduction to the Project and Purpose of the Workshop, Vulnerability Assessment Findings** **Mr. Aniruddh Soni**, Area Convenor and Associate Fellow, Centre for Biodiversity and Ecosystem Services, Land Resources Division, TERI **Mr. Sayanta Ghosh**, Research Associate, TERI
1215-1330 hrs.	**Drivers of Deforestation and Forest Degradation in Assam** *Group Activity – Identification and review of the findings* *Group Presentation and discussion by participants* *Review of the findings by TERI* - **Ms Aabha Ballal**, and **Mr Sayanta Ghosh** Research Associate, TERI
1330-1415 hrs.	**Lunch Break**
1415-1510 hrs.	**Ongoing Climate Change Mitigation and Adaptation Interventions in Assam** *Review of ongoing schemes* – **Mr Pranjul Chauhan**, Research Associate, TERI *Group Activity – Discussion and Gap Analysis*
1510-1520 hrs.	***Open Discussion and Suggestions***
1520-1530 hrs.	**Concluding Remarks** **Dr. J. V. Sharma** IFS Retd, Senior Director, Land Resources Division, TERI **Mr Sandeep Kumar**, IFS, Project Director, Assam Project on Forest and Biodiversity Conservation Society

Pictures from stakeholder consultations

Annexure 3- Landslide events

Table 21: Landslide events details

S.no	Date	Landslide Size	fatalities	Event Description
1	7/19/2007	medium	6	Guwahati
2	8/26/2007	medium	0	Shillong Road at Kuliang in the Jaintia Hills
3	9/13/2007	medium	0	Guwahati
4	5/20/2008	medium	5	A Cachar District village, near village of Srinager, Assam
5	6/15/2008	medium	17	Lakhimpur district, Bihpuria, Assam
6	8/14/2008	medium	0	Kimin-Ziro road in Papum Pare district, road between Doimukh and Sagalee, Doimukh-Hoj road; Arunachal Pradesh
7	10/29/2008	medium	0	North Lakhimpur
8	10/29/2008	medium	7	Kamrup, and Sonitpur, Assam
9	8/20/2009	medium	0	Lumding-Badarpur section in North Cachar Hills district
10	8/27/2009	medium	0	between Mahur and Phaiding railway stations on Barail hills (Mahur and Barail hills located)
11	4/1/2010	medium	3	Paglanala village, Dholai Block, near Dwarbandh locality of the district, Cachar district (could only find district) 45 km from Silchar, Assam
12	4/20/2010	medium	0	Kharghuli, Guwahati, Assam
13	4/20/2010	medium	0	Raj Bhavan Guwahati, Assam
14	6/3/2010	medium	2	Rongpur village under Bhairabhnagar panchayat in Karimganj district
15	6/9/2010	medium	0	Ishok Chingphu(?), Bishnupur, Assam
16	6/15/2010	medium	0	rails between Mahur and Wadringdisa(?), Assam
17	6/16/2010	medium	0	rails between Jatinga and Longrangjao(?), Assam
18	7/25/2010	medium	0	road between Halfong and Redzol(?) or Silchar, Assam
19	9/10/2010	medium	0	districts Lakhimpur, Dhemaji, Golaghat, and Sonitpur, Assam province
20	10/9/2010	medium	0	between Mahur and Maigrandisa(?) or Lumding, Assam
21	10/9/2010	medium	0	road between Haflong and Lanka, Assam
22	10/9/2010	medium	1	Haflong, Assam
23	5/24/2011	medium	0	Silchar-Haflong rd., at Reko(Rekha)(?), near Harangajao, Barail Hills, Assam

24	6/29/2011	medium	0	Portions of NH 39, Connectin Manipur with Assam via Nagaland
25	7/24/2011	medium	0	NH 37
26	9/23/2011	large	4	Maighuli, Guwahati, Meghalaya
27	6/2/2012	large	0	Guwahati, Assam
28	6/3/2012	medium	0	between Maibang and Daotohaja, Assam
29	6/3/2012	medium	0	between Haflong and Bagetar, Assam
30	6/3/2012	medium	0	between Harangajao and Mailongdisa, Assa,
31	6/20/2012	medium	0	Lalunggaon, Guwahati, Assam
32	6/22/2012	medium	3	Lalunggaon near Gorchuk area
33	6/25/2012	large	1	Sonaighuli area near Kahilipara, Guwahati City, Assam
34	5/11/2013	medium	0	Boragaon, North Guwahati, Guwahati, Assam,
35	5/11/2013	medium	0	Nursery, North Guwahati, Guwahati, Assam,
36	5/11/2013	medium	0	Sarania Hills, North Guwahati, Guwahati, Assam,
37	10/6/2013	medium	0	Nilachal Hill, Guwahati, Assam
38	10/6/2013	medium	1	Batahguli, Guwahati, Assam
39	5/9/2014	small	7	Satgarakul Village, Karimganj, Assam State
40	6/26/2014	small	1	Bamunimaidam
41	6/26/2014	small	3	Narakasur
42	6/27/2014	small	3	Bhangagarh, Assam
43	6/28/2014	medium	0	Kharghuli Hills, Assam
44	9/22/2014	small	0	Pamohi
45	9/22/2014	small	0	Garchuk
46	9/22/2014	small	0	VIP Road
47	9/22/2014	small	0	Dhirenpara
48	9/22/2014	small	0	Batahghuli
49	9/22/2014	small	0	Noonmati
50	9/22/2014	small	0	Dakhingaon
51	9/22/2014	small	1	Lalmati
52	2/14/2015	small	1	Kailashpur hill
53	2/19/2015	medium	2	Hailākāndi : Two labourers died while another was injured in a landslide in Assam's Hailakandi district, the police said today.
54	3/19/2015	small	0	Ratacherra
55	7/22/2015	medium	5	Lakhipur
56	7/25/2015	medium	2	Dispur : According to report, a huge hillock slipped into the house after heavy rain where Dinesh Bodo along with his wife and daughter lived in. Thi*
57	8/22/2015	medium	0	Natonal Highway in Jorabat area
58	9/1/2015	medium	2	Amingaon
59	9/1/2015	medium	2	Maligaon

60	9/23/2015	medium	0	Kamakhya Temple
61	5/18/2016	small	1	Ramchandi , Hailakandi District, Assam, India
62	5/18/2016	medium	5	Sonachirra, Karimganj district, Assam, India
63	5/18/2016	unknown	2	Bilaipur, Hailakandi district, Assam, India
64	5/18/2016	unknown	2	Bilaipur, Hailakandi district, Assam, India
65	6/22/2016	medium	1	Piyali Phukan Nagar, Guwahati, India
66	7/7/2016	medium	2	Kamrup district, Assam, India
67	7/14/2016	small	1	Pub Sarania hill, South Sarania, Guwahati, Assam, India
68	7/14/2016	small	1	Noonmati Nijarapar area of the city, Guwahati, Assam, India
69	7/20/2016	medium	0	Noonmati, Guwahati, Assam, India
70	9/1/2016	large	4	Landslide in Silchar
71	12/15/2016	small	1	Landslide at Pub Sarania Hill
72	12/15/2016	small	1	Landslide at Noonmati Nijarapar
73	4/4/2017	small	0	Landslide in Harangajao
74	4/4/2017	small	0	Landslide in Phaiding
75	4/4/2017	small	0	Landslide in N. Leikul
76	4/4/2017	small	0	Landslides along National Highway 54
77	4/4/2017	small	0	Landslide in Mahur
78	4/5/2017	medium	2	Fatal landslide in Bonda
79	4/29/2017	medium	3	Fatal landslide in Makhim village
80	6/4/2017	medium	0	Flood, Landslide in Assam
81	6/18/2017	medium	0	Landslide traps commuters
82	7/3/2017	small	0	Landslide hits Jorabat
83	7/3/2017	medium	1	Fatal landslide in Chandrapur
84	7/3/2017	medium	1	Landslide in Panikhaiti kills girl
85	7/6/2017	medium	0	Landslide crushes house
86	7/9/2017	small	0	Landslide blocks NH-37
87	7/10/2017	small	0	Landslide in Chandmari
88	7/10/2017	small	0	Landslide damages house
89	7/10/2017	medium	2	Fatal landslide in Narayanpur
90	12/18/2018	small	0	Rock fall on Railroad tracks between Phiding and Mahur Stations

Annexure 4- List of earthquake events in Assam.

Table 22: Earthquake events

S.no	Date	Magnitude	Depth
1	6/20/1982	4.5	12 km
2	1/13/1992	4.5	14 km
3	11/24/1996	4.5	9 km
4	1/20/1999	4.5	17 km
5	10/26/2001	4.5	32 km
6	3/27/2002	4.5	27 km
7	5/29/2008	4.5	14 km
8	2/10/2012	4.5	28 km
9	3/13/2016	4.5	9 km
10	1/20/2018	4.5	6 km
11	5/4/2020	4.5	25 km
12	6/17/2021	4.5	8 km
13	6/18/2021	4.5	4 km
14	7/29/1979	4.6	23 km
15	2/26/1982	4.6	18 km
16	12/30/1982	4.6	13 km
17	11/12/1987	4.6	33 km
18	9/19/1989	4.6	13 km
19	11/6/1989	4.6	10 km
20	5/28/1993	4.6	32 km
21	5/14/1996	4.6	11 km
22	8/4/2003	4.6	36 km
23	4/17/2008	4.6	22 km
24	10/30/2012	4.6	14 km
25	4/12/2014	4.6	7 km
26	10/23/2016	4.6	5 km
27	11/15/2016	4.6	23 km
28	4/27/2019	4.6	31 km
29	2/17/2021	4.6	9 km
30	2/28/1981	4.7	14 km
31	3/10/1984	4.7	32 km
32	11/15/1984	4.7	10 km
33	9/19/1991	4.7	15 km
34	7/24/1994	4.7	17 km
35	2/23/2010	4.7	Assam
36	11/25/2015	4.7	30 km

37	2/16/2016	4.7	34 km
38	11/13/2019	4.7	38 km
39	11/18/1982	4.8	2 km
40	12/31/1986	4.8	22 km
41	5/8/1994	4.8	7 km
42	7/17/2005	4.8	32 km
43	3/25/2006	4.8	14 km
44	10/29/2009	4.8	13 km
45	8/19/2012	4.8	14 km
46	6/11/2013	4.8	30 km
47	4/16/2015	4.8	11 km
48	10/29/2015	4.8	11 km
49	4/28/2021	4.8	4 km
50	3/21/1984	4.9	24 km
51	1/12/1987	4.9	49 km
52	10/29/1990	4.9	9 km
53	2/27/2001	4.9	5 km
54	10/11/2006	4.9	24 km
55	11/6/2018	4.9	18 km
56	11/13/1977	5	36 km
57	12/30/1982	5	7 km
58	12/29/1990	5	13 km
59	7/18/1997	5	28 km
60	2/12/1998	5	34 km
61	2/15/2005	5	9 km
62	12/8/2006	5	15 km
63	8/19/2009	5	9 km
64	8/2/2020	5	10 km
65	4/28/2021	5	6 km
66	2/5/1968	5.1	6 km
67	6/9/1987	5.1	19 km
68	8/3/1989	5.1	18 km
69	2/22/1990	5.1	19 km
70	6/28/2015	5.1	18 km
71	1/23/2023	5.1	12 km
72	2/24/1966	5.2	6 km
73	2/2/1983	5.2	23 km
74	9/22/1984	5.2	4 km
75	2/9/1990	5.2	12 km
76	5/10/1999	5.2	18 km
77	2/10/2012	5.2	15 km

78	11/4/1965	5.3	8 km
79	6/30/1969	5.3	3 km
80	4/30/1990	5.3	36 km
81	6/23/1991	5.3	Assam
82	12/9/2018	5.3	5 km
83	5/24/1959	5.4	10 km
84	8/18/1968	5.4	5 km
85	11/19/1996	5.4	India
86	9/12/2004	5.4	8 km
87	11/5/2012	5.4	19 km
88	6/11/2013	5.4	24 km
89	12/11/1950	5.5	11 km
90	7/17/1971	5.5	37 km
91	4/13/1989	5.5	14 km
92	7/29/1960	5.6	Assam
93	7/4/1951	5.8	25 km
94	8/15/1950	6	20 km
95	10/29/1950	6	6 km
96	12/30/1984	6	20 km
97	8/5/1997	6	11 km
98	4/28/2021	6	8 km
99	8/26/1950	6.2	7 km
100	9/13/1950	6.2	14 km

Annexure 5

Reference sheet for list of possible drivers

REFERENCE SHEET FOR QUESTIONNAIRE/ GROUP ACTIVITY

ASSAM PROJECT ON FOREST & BIODIVERSITY CONSERVATION (APFBC)

Stakeholder Consultation on Devising Climate Change Mitigation and Adaptation Strategies for Forest and Biodiversity of Assam

Section 1: List of drivers of deforestation and forest degradation

To be used for group activity 1

Driver Code	List of drivers
D01	Resource Extraction (fuelwood, timber, bamboo, NTFP etc.)
D02	Forest Fire
*D03	Natural Hazards- **D03A**- *Floods* **D03B**- *Landslides* **D03C**- *Drought* **D03D**- *Earthquake* **D03E**- *Others please specify*___________________________
D04	Development pressure (mining, hydro, road development, infrastructure, oil exploration, poor waste management)
D05	Encroachment (Agriculture + Settlement)
D06	Shifting Cultivation
D07	Plantation: monoculture (tea, rubber, pineapple, oil palms, bamboo, teak, Sal)
D08	Invasive species
D09	Illegal activities (felling, hunting, teasing, poaching etc)
D10	Geopolitical Conflicts (insurgency, migration, tribal dominance, land tenure uncertainty, historical issues etc.)
D11	Governance (Policy issues, implementation issues, institution issues, regulation, corruption, enforcement, capacity/ capability, land tenure uncertainty, inefficient management etc)
D12	Increasing population pressure and urbanization
D13	Privatization of communal lands
D14	Subsistence for livelihood (lack of alternative options, poverty etc)
D15	Landlessness
D16	Anthropogenic hazards (mishandling, accidental fires, etc)
D17	Lack of awareness (importance of forest, policy, rules etc.)
D18	Riverbank erosion and Sedimentation
D19	Climate Change
D20	Please Specify____
D21	Please Specify____

Annexure 6- List of drivers based on maximum numbers of responses from all the stakeholders.

Table 23: Drivers as pe stakeholder consultations

Code	Driver	Total no. of mentions	Percentage of mentions
D04	Development pressure (mining, hydro, road development, infrastructure, oil exploration, poor waste management)	84	9.36
D03	Natural Hazards	82	9.14
D05	Encroachment (Agriculture + Settlement)	75	8.36
D12	Increasing population pressure and urbanization	68	7.58
D09	Illegal activities (felling, hunting, teasing, poaching etc)	61	6.80
D01	Resource Extraction (fuelwood, timber, bamboo, NTFP etc.)	59	6.58
D11	Governance (Policy issues, implementation issues, institution issues, regulation, corruption, enforcement, capacity/ capability, land tenure uncertainty, inefficient management etc)	51	5.69
D19	Climate Change	51	5.69
D17	Lack of awareness (importance of forest, policy, rules etc.)	50	5.57
D08	Invasive species	42	4.68
D10	Geopolitical Conflicts (insurgency, migration, tribal dominance, land tenure uncertainty, historical issues etc.)	41	4.57
D06	Shifting Cultivation	38	4.24
D07	Plantation: monoculture (tea, rubber, pineapple, oil palms, bamboo, teak, Sal)	38	4.24
D02	Forest Fire	35	3.90
D14	Subsistence for livelihood (lack of alternative options, poverty etc)	33	3.68
D18	Riverbank erosion and Sedimentation	33	3.68
D13	Privatization of communal lands	21	2.34
D15	Landlessness	16	1.78
D16	Anthropogenic hazards (mishandling, accidental fires, etc)	15	1.67
D20	Human Wildlife Conflict	4	0.45

Annexure 7- List of drivers based on responses from the different groups of stakeholders

Table 24: Drivers as per different groups in stakeholder consultation

Code	Drivers	Total Mentions				Percentage mentions			
		NGO	F&A	RDL	ORI	**NGO**	F&A	RDL	ORI
D04	Development pressure	20	20	26	18	10.15	10.20	8.58	8.96
D03	Natural Hazards	11	14	40	17	5.58	7.14	13.20	8.46
D05	Encroachment (Agriculture + Settlement)	15	17	26	17	7.61	8.67	8.58	8.46
D01	Resource Extraction	9	16	18	16	4.57	8.16	5.94	7.96
D09	Illegal activities	16	10	20	15	8.12	5.10	6.60	7.46
D12	Increasing population pressure and urbanization	18	11	25	14	9.14	5.61	8.25	6.97
D19	Climate Change	9	6	22	14	4.57	3.06	7.26	6.97
D17	Lack of awareness	14	5	19	12	7.11	2.55	6.27	5.97
D18	Riverbank erosion and Sedimentation	7	3	11	12	3.55	1.53	3.63	5.97
D07	Plantation: monoculture	8	9	9	12	4.06	4.59	2.97	5.97
D14	Subsistence for livelihood	9	6	6	12	4.57	3.06	1.98	5.97
D11	Governance	15	11	17	8	7.61	5.61	5.61	3.98
D10	Geopolitical Conflicts	12	11	12	6	6.09	5.61	3.96	2.99
D06	Shifting Cultivation	4	16	13	5	2.03	8.16	4.29	2.49
D02	Forest Fire	8	10	12	5	4.06	5.10	3.96	2.49
D08	Invasive species	12	14	11	5	6.09	7.14	3.63	2.49
D13	Privatization of communal lands	4	8	4	5	2.03	4.08	1.32	2.49
D16	Anthropogenic hazards	1	5	6	3	0.51	2.55	1.98	1.49
D15	Landlessness	4	3	6	3	2.03	1.53	1.98	1.49
D20	Human Wildlife Conflict	1	1	0	2	0.51	0.51	0.00	1.00

NGO- Non-Government Organization, F&A- Forest and allied, RDL- Rural development & livelihood, ORI- Other research institutions

Annexure 8 - Ranking of drivers based on their level of severity and number of mentions by different stakeholders.

Table 25: Driver ranking

Code	Drivers	No. of mentions				Cumulative score	Rank
		FC	**B**	**ES**	**L**		
D04	Development pressure	84	76	77	74	311	1
D03	Natural Hazards	76	61	65	92	294	2
D12	Increasing population pressure and urbanization	85	53	77	53	268	3
D05	Encroachment (Agriculture + Settlement)	102	83	44	33	262	4
D09	Illegal activities	56	62	55	44	217	5
D01	Resource Extraction	69	51	53	23	196	6
D19	Climate Change	40	63	49	41	193	7
D11	Governance	45	40	49	47	181	8
D17	Lack of awareness	60	42	28	37	167	9
D08	Invasive species	21	60	28	21	130	10
D10	Geopolitical Conflicts	11	22	33	64	130	11
D18	Riverbank erosion and Sedimentation	35	23	44	25	127	12
D07	Plantation: monoculture	17	57	29	16	119	13
D14	Subsistence for livelihood	32	30	19	35	116	14
D06	Shifting Cultivation	30	34	24	15	103	15
D02	Forest Fire	17	36	15	28	96	16
D13	Privatization of communal lands	7	13	31	40	91	17
D15	Landlessness	16	3	3	33	55	18
D16	Anthropogenic hazards	4	13	6	24	47	19
D20	Human Wildlife Conflict	5	0	3	9	17	20

Annexure 9 - Description of major identified drivers

Table 26: Description of drivers

S.No.	Driver	Description
1	Development pressure	Development pressure includes infrastructure extension activities such as transport (road, railway etc.), mining, renewable energy development (hydropower etc) that lead to change in land use/land transition (from forest to non-forest)
2	Natural Hazards	This included hazards such as floods, earthquakes, landslides and drought that leads to forest degradation and deforestation
3	Increasing population pressure and urbanization	This includes demographic factors (migration, population pressure) and economic factors (urbanization) that leads to overextraction of forest resources thereby causing forest degradation and deforestation
4	Encroachment (Agriculture + Settlement)	This includes unlawful occupation of forest land for habitation and cultivation purposes. This can be triggered due to geopolitical conflicts, economic crisis, migration and increasing population pressure.
5	Illegal activities	This includes illegal extraction of forest resources such as timber logging, poaching hunting activities and illegal trade of wildlife.
6	Resource Extraction	This includes extraction of forest resources such as timber, minor forest produces etc., due to high dependency on forest resources. The dependency is exacerbated due to high levels of poverty, lack of alternate livelihood options etc.
7	Climate Change/variabilities	Various anthropogenic activities lead to climate change which further magnifies the impacts of forest degradation and deforestation (IPBES, 2018). This generates various positive feedback loops between climate change, loss of biodiversity, loss of forest cover and quality.
8	Governance	This includes factors such as weak law implementation and enforcement, weak regulatory mechanisms, ineffective management etc.
9	Lack of awareness	This includes public awareness with regards to forest management, various drivers of degradation and deforestation, their impacts and the community's capacity to understand the same.
10	Invasive species	Invasive alien species (IAS) – species which may be introduced into new ecosystems via intentional or unintentional introductions – are a major threat to biological diversity (FAO, 2016). They compete with native species for essential resource and gradually destroy the ecology of the area.

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