Educational Administration: Theory and Practice
2024, 30(1), 6265-6300
ISSN: 2148-2403
https://kuey.net/

Research Article

Effects Of Natural Hazards On Upper Teesta River Bank's Ecological Bio- Biodiversity

Dr. Md Hanif[1*], Sareeta Tamang[2], Sulata Mukhia[3]

[1*]Assistant professor, Trinity B. Ed College, Siliguri, W. B.
[2]Assistant Professor, Trinity B. Ed College, Siliguri, W. B.
[3]Assistant Professor, Trinity B. Ed College, Siliguri, W. B.

Citation: Dr. Md Hanif, et.al (2024). Effects Of Natural Hazards On Upper Teesta River Bank's Ecological Bio- Biodiversity, *Educational Administration: Theory and Practice*, 30(1) 6265-6300
Doi: 10.53555/kuey.v30i1.9665

ARTICLE INFO	ABSTRACT

The upper Teesta River, flowing through the Himalayan foothills in the north-eastern Indian region, is increasingly subjected to various natural hazards, including floods, landslides, and seismic events. These hazards significantly influence the ecological biodiversity along the riverbanks, impacting both terrestrial and aquatic ecosystems. This study examines the effects of natural hazards on biodiversity in the upper Teesta River basin, comparing data from three pivotal years—1968, 2017, and 2023—to understand the changing impact over time. In 1968, the region's biodiversity was relatively stable, with minimal human interference and fewer major natural disasters. However, the ecosystem was already beginning to show signs of vulnerability to monsoonal flooding and landslides, which occasionally disrupted local habitats. At that time, the ecological composition along the riverbanks was primarily characterized by dense forest cover, native aquatic species, and a balance between river dynamics and surrounding landscapes.

By 2017, the effects of climate change, deforestation, and increased human settlements had amplified the frequency and intensity of natural hazards. Flooding became more recurrent due to altered rainfall patterns and glacier melt, causing significant erosion and loss of terrestrial habitats. The river's aquatic biodiversity, including endemic fish species, was severely affected by siltation, habitat destruction, and water contamination caused by landslides and unregulated development along the banks. The construction of dams and roads further fragmented ecosystems, limiting wildlife movement and reducing species resilience. In 2023, the situation worsened with increasing human encroachment and ongoing climate variability. Severe floods and landslides, often triggered by extreme weather events and seismic activities, have resulted in the displacement of local communities and the degradation of critical habitats.

The upper Teesta River's ecological zones are increasingly fragmented, with fewer native species able to adapt to the altered environment. Additionally, the river's once-diverse riparian vegetation has been replaced by invasive species, further destabilizing the local ecosystems. The loss of key ecological functions—such as flood regulation, sediment retention, and water purification—has compromised the resilience of biodiversity in the region. This study synthesizes historical data and field observations to evaluate the evolving impact of natural hazards on the upper Teesta River's ecological biodiversity across these three distinct periods. By understanding the trends and cumulative effects over time, the study aims to inform future conservation and disaster risk reduction strategies to protect the fragile ecosystems of the upper Teesta River basin. It underscores the urgent need for integrated management, approaches that address both the natural hazards and human-induced pressures on biodiversity in this ecologically sensitive region.

KEY WORDS: Natural Hazards, Ecological Biodiversity, Upper Teesta River, Flooding, Landslides, Seismic Activity, Climate Change, Terrestrial Ecosystems

,Aquatic Ecosystems, Habitat Destruction, Species Resilience, Environmental Degradation, Ecosystem Fragmentation, Riparian Vegetation, Invasive Species, Human Encroachment, Biodiversity Loss, Sedimentation, Glacial Melt, Conservation, Strategies, Disaster Risk Reduction, Environmental Management.

1.0 INTRODUCTION:

The Teesta River is a prominent river in South Asia, flowing through the Indian states of Sikkim and West Bengal before reaching Bangladesh. Originating from the high-altitude Tso Lhamo Lake in the Himalayas, the river follows a southward course, carving through the mountainous terrain of Sikkim before descending into the fertile plains of West Bengal and eventually joining the Jamuna River in Bangladesh. With a total length of around 315 kilometres, the Teesta River is not only a lifeline for the regions it passes through but also holds significant cultural, ecological, and economic importance.

Throughout its journey, the Teesta nourishes various communities and ecosystems. It supports agriculture, powers hydroelectric projects, and fosters tourism, especially in areas like Kalimpong, Siliguri, and the scenic Dooars region. Towns and cities along its banks, including Jalpaiguri and Gitaldaha, rely heavily on its waters for agriculture, domestic use, and transport. However, the river also faces challenges such as climate change-induced glacial melt, deforestation, soil erosion, and pollution, all of which threaten its ecosystem and the communities that depend on it.

Moreover, the Teesta River holds geopolitical significance, particularly in water-sharing discussions between India and Bangladesh. Balancing ecological preservation, economic benefits, and international cooperation makes the Teesta a complex yet essential river system in South Asia. This assignment will explore the Teesta River’s geography, its influence on the surrounding regions, its environmental challenges, and its role in international relations, highlighting its impact on both human and ecological landscapes.

The Teesta River Flood

The Teesta River, flowing through the Indian states of Sikkim and West Bengal and into Bangladesh, is known for its seasonal flooding, which has had catastrophic impacts over the years. Among the most notable and devastating floods are those of **1968**, **2017**, and most recently **2023**, each event highlighting unique challenges posed by changing environmental conditions, infrastructure limitations, and geopolitical complexities.

The **1968 flood** was among the first major recorded floods, driven by intense monsoon rains and landslides in the Eastern Himalayas. It resulted in extensive loss of life, destruction of villages, and severe agricultural and infrastructural damage, permanently altering the river's floodplain and impacting communities along its banks. In **2017**, the Teesta overflowed once more, inundating large areas of northern West Bengal and Bangladesh due to heavy rains compounded by water releases from dams and barrages. Over 600,000 people were displaced, and the flood led to economic hardship and heightened concerns over the need for cross-border water management strategies.

The latest flood on **October 4, 2023**, emphasized the growing risks associated with climate change. Triggered by a glacial lake outburst flood (GLOF) following heavy rainfall and a cloudburst in Sikkim’s Lhonak Lake, this event resulted in flash floods that ravaged infrastructure, displaced thousands, and caused significant casualties. The 2023 flood particularly underscores the vulnerability of Himalayan river systems to climate-induced glacial melting and extreme weather, posing new challenges for communities and international relations in the region.

Together, these flood events reveal the complexities of managing the Teesta River’s flood risks in an era of climate uncertainty. They underscore the need for resilient infrastructure, improved early warning systems, and cooperative efforts between India and Bangladesh to safeguard lives, livelihoods, and ecosystems along the Teesta’s path. This study examines the causes, impacts, and implications of these historic flood events, providing insights into sustainable flood management and regional cooperation.

1.1 Causes and Impact of Teesta Flood: Effects on Ecological Biodiversity in the Upper Teesta River Basin

Causes of Teesta Floods:

1. **Heavy Monsoon Rainfall**: Intense monsoon rains, especially in the Himalayan foothills, are a significant cause of flooding in the Teesta River basin. The region experiences heavy downpours during the monsoon season, which results in the river's water levels rising rapidly and leading to overflow and flash floods.
2. **Glacial Lake Outburst Floods (GLOFs)**: The Teesta River is fed by glaciers in the Eastern Himalayas. Climate change has accelerated the melting of glaciers, creating unstable glacial lakes. A sudden breach or outburst of these lakes, such as the **2023 GLOF from Lhonak Lake**, can lead to catastrophic flooding downstream, overwhelming the river's capacity to handle the influx of water.
3. **Sedimentation and Siltation**: The steep gradient of the Himalayan landscape causes substantial sediment and silt to be carried by the river, which lowers its water-holding capacity. This results in higher flood risks during heavy rainfall, as the river's natural flow is obstructed by excessive sedimentation.

4. Human Activities and Infrastructure: The construction of dams, barrages, and embankments along the Teesta River has altered the natural flow of the river. While these structures aim to control floods and harness water for irrigation and hydropower, improper management and unplanned releases of water from these reservoirs often exacerbate downstream flooding, especially during periods of heavy rain.
5. Climate Change: Rising global temperatures have increased the frequency and intensity of extreme weather events. The **2023 flood** and the melting of glaciers are a direct result of climate change, which has disrupted the natural balance of the Teesta River and heightened the risk of extreme floods.

1.2 Impacts of Teesta Floods on Ecological Biodiversity in the Upper Teesta River Basin:

1. Destruction of Riparian Forests: The flooding causes erosion of riverbanks, leading to the destruction of **riparian forests** that line the Teesta River. These forests are crucial habitats for a variety of plant and animal species. The removal of vegetation disrupts the ecosystems and diminishes biodiversity, affecting species that depend on these habitats for food and shelter.
2. Loss of Aquatic Biodiversity: The Teesta River is home to several species of **fish** and other aquatic organisms. Flooding causes the river to overflow, carrying silt, debris, and pollutants. This drastically reduces water quality and leads to the destruction of **aquatic habitats**, particularly in the upper reaches of the river where species like **masher** and other endemic fish are found. These species face habitat loss, disruption in their breeding grounds, and pollution-related stress.
3. Soil Erosion and Habitat Loss: Floodwaters in the upper Teesta River basin lead to severe **soil erosion**, particularly in hilly and mountainous areas. This erosion results in the loss of fertile soil, which affects plant growth and disrupts food sources for wildlife. The destruction of vegetation further diminishes wildlife habitats and reduces the food chain for herbivores and predators alike.

Fig: Effected Area by the Teesta river Flash Flood.

4. Disruption of Migration Patterns: Certain species in the Teesta basin, such as migratory fish and amphibians, rely on specific river conditions for breeding and migration. Flooding can destroy critical spawning grounds and block migration routes, leading to declines in species populations and altering local ecosystems.
5. Alteration of Watercourse and Riverbed: Flooding leads to **changes in the riverbed** and watercourse, disrupting the natural flow and dynamics of the river. This can affect the habitats of species that are adapted to particular water conditions, including flow speed, sediment load, and temperature. The alterations in the river's flow may also cause the river to change course, affecting entire ecosystems along its banks.
6. Pollution and Chemical Contamination: Floodwaters often carry chemicals from agricultural runoff, waste, and pollutants from industrial sources. These pollutants, along with sediment from the riverbed, further degrade water quality in the upper reaches of the Teesta. Toxic substances can have a long-term negative impact on both **terrestrial and aquatic species**, poisoning plants, fish, and wildlife.
7. Invasive Species Proliferation: After flooding, the destruction of native habitats often provides space for invasive species to take over. Invasive plants and animals can outcompete native species for resources, further threatening the ecological balance of the region and reducing overall biodiversity.

Teesta Bazar

Teesta Bazar, located in the Kalimpong District of West Bengal, India, is a crucial commercial hub situated along the Teesta River. Serving as a key transit and trading center for the region, it plays a significant role in connecting local communities in both **West Bengal** and **Sikkim**. Known for its proximity to the Teesta River and its scenic beauty, Teesta Bazar has also been a focal point for economic activities, including trade in agricultural products, textiles, and local goods. Its strategic location along major transport routes makes it an essential stopover for travelers and a vital link between the plains and the mountains.

In the wake of the **October 2023 Teesta flood**, Teesta Bazar has been significantly impacted with widespread damage to infrastructure, loss of agricultural produce, and displacement of people. As part of our research, we collected data from Teesta Bazar to better understand the localized effects of this devastating event. The flood, triggered by a glacial lake outburst flood (GLOF) from Lhonak Lake in Sikkim, caused flash floods that swept through the region, impacting both the economy and the environment. The findings from Teesta Bazar provide valuable insights into the human and economic toll of the 2023 flood, highlighting the region's vulnerability to extreme weather events exacerbated by climate change.

The 2023 flood also led to significant **ecological destruction** in the region. The Teesta River, which flows through biodiversity-rich areas, saw its natural habitats devastated as flash floods carried away sediments, debris, and pollutants. This disruption has caused serious damage to **aquatic ecosystems**, affecting the flora and fauna dependent on the river and surrounding wetlands. **Fish populations** and **aquatic vegetation** have been heavily impacted, while the **riparian forests** along the riverbanks were eroded, leading to loss of biodiversity and the destruction of habitats for many species. Additionally, the sedimentation and debris carried by the floodwaters have altered the river's course and landscape, further destabilizing the environment. This study delves into the causes, impacts, and responses to the 2023 Teesta flood in Teesta Bazar, shedding light on the urgent need for improved flood management, infrastructure resilience, and climate adaptation strategies for communities along the river. The ecological damage caused by the flood calls for greater attention to conservation efforts and sustainable management of the Teesta River's ecosystem to prevent further degradation of its biodiversity.

2.0 LITERATURE REVIEW

Floods are a frequent hazard in the Teesta basin, especially during the monsoon season, often leading to severe habitat destruction. According to studies by Gurung et al. (2014) and Singh & Jain (2019), flooding erodes soil and vegetation, leading to the loss of plant diversity along riverbanks, which in turn affects animal species that depend on stable habitats. Das and De (2017) support this finding, noting that high-velocity floodwaters uproot tree species and cause a decline in vegetation that provides shelter and food for small mammals and insects. The increased sediment load in the river during flood events is also detrimental to aquatic species. A study by Shrestha & Bhandari (2017) indicates that high sedimentation reduces water clarity and oxygenation, which negatively impacts fish and other aquatic organisms, especially those with low tolerance for turbidity. Similarly, Sinha and Singh (2018) describes how sediment-covered aquatic habitats experience reduced primary productivity, which impacts the food chain dynamics across various tropic levels. The overall effect is a reduction in the diversity and abundance of fish, invertebrates, and plant life in these riverside ecosystems.

Bhattacharyya et al. (2016) argue that landslides dramatically disrupt terrestrial ecosystems by uprooting vegetation, altering soil composition, and impacting plant diversity. They highlight how landslides also fragment habitats, which can lead to a decrease in species diversity and create barriers for animal migration and dispersal. Lama et al. (2018) further illustrate that landslides often trigger an increase in pioneer plant species that dominate disturbed areas, altering the natural plant composition along the riverbanks.

Additionally, the impact of landslides on sedimentation affects aquatic ecosystems. Sarkar & Sen (2020) demonstrate that landslide-induced sedimentation significantly reduces water quality and alters the microhabitats of aquatic species. The sediment load from landslides can cover spawning grounds of fish, disrupting reproductive cycles, as shown by Mishra & Bhatt (2019), who describe how sedimentation impacts the Teesta River's native fish species, which are sensitive to water quality changes.

The Teesta region is in a seismically active zone, with earthquakes that can trigger secondary natural hazards such as landslides and flash floods, further disrupting biodiversity. Pal & Gupta (2020) suggest that seismic activity in this region results in habitat fragmentation and sudden vegetation loss along riverbanks. They report that earthquakes increase soil instability, which causes landslides that impact riparian habitats by uprooting trees and eroding riverbanks, making it difficult for native plant species to re-establish. Moreover, Roy and Mishra (2018) argue that the habitat disturbances following an earthquake can lead to an invasion of non-native plant species that thrive in disturbed soils, which can outcompete native species and alter the composition of the ecosystem.

Studies by Sharma et al. (2020) and Basnet & Thapa (2019) discuss how earthquakes can alter river channels and create barriers within river systems, impacting the migratory routes of fish species. Tiwari & Chhetri (2021) report that rising temperatures and changes in precipitation patterns intensify floods and landslides in the region, placing additional stress on already vulnerable ecosystems. Studies by Pandit et al. (2019) and Joshi & Lama (2020) indicate that warmer temperatures also accelerate glacial melt, raising water levels and increasing flood risk, which compounds the impact of natural hazards on riverbank biodiversity. The result is an increase in habitat loss, species displacement, and altered seasonal patterns for plant and animal species.

Similarly, Kaul & Sharma (2018) suggest that temperature shifts are causing some species to migrate to higher elevations, leading to a decline in biodiversity in lower elevation riverbanks.

The literature reveals that natural hazards such as floods, landslides, and earthquakes have severe impacts on the biodiversity of the Upper Teesta River's banks.

3.0 STUDY AREA:

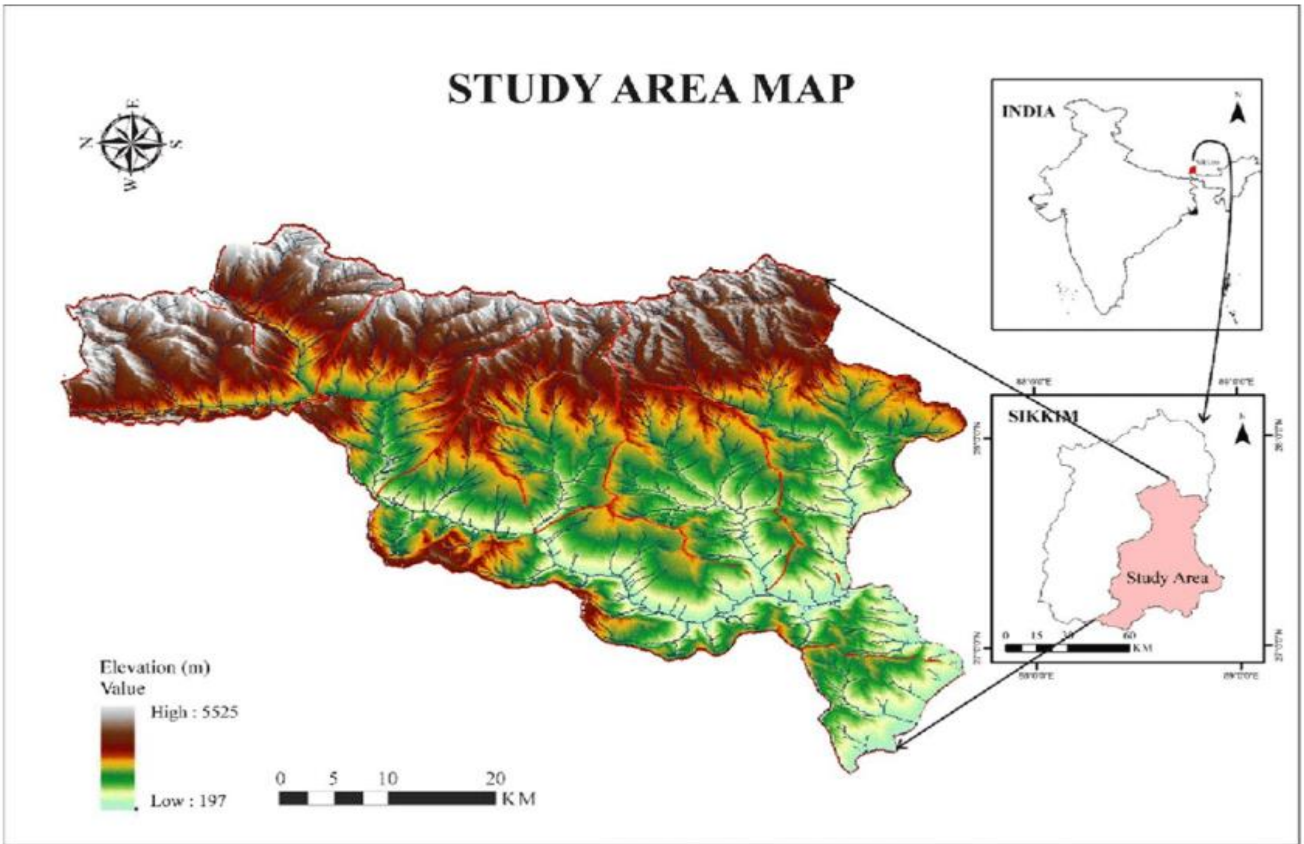


Fig: Study area map of Teesta basin Sikkim Himalaya, India

The present study focused on Upper River bank of ecological biodiversity that integrates with land cover categories for identification of erosion hotspot areas. The general character of the sub-watersheds was derived from the linear, areal and relief aspects, while land cover types derived from maximum likelihood. Upper Teesta River basin of Sikkim Himalaya falls in between 88°17′5" E to 88°55′54" E longitude and 27°4′34" N to 27°4′36" N latitude and covers an area of 2524.59 sq. km. Teesta River is a perennial river that is also the trunk river in Sikkim Himalaya. It originates from Tso Lamo Lake of Trans Himalayan region; Northern part of Sikkim state flows from north to south and divides the state into two parts. It flows down to the parts of North Bengal and Bangladesh, and it finally joins the Bay of Bengal. Topo-graphically, the area lies at the Higher Himalaya, which consists of steep-sided hills and deep valleys. The area is prone to erosion due to the presence

of semi soft nature type of rocks. The Daling Group of rock was exposed in the Teesta valley, the second largest abundant rock group. The un-fossiliferous low-grade meta-sediments divided into dominantly greenish argillaceous assemblage comprising the Daling "Series" and dolostone, quartzite and variegated slate assemblage making up the Buxa "Series" by Mallet (1875). The major type of soil found in Sikkim is the loamy type of soil.
According to the strategic and extension plan of East Sikkim, the soils found between 15 and 30% slopes are deep excessively drained, coarse loamy to the fine loamy surface with slight stoniness and moderate erosion. Soils are moderately acidic and rich in humus contain. These areas are also predominantly under forest & cultivation. The soils on ridges of steeply sloppy hill-sides (30–50%) slopes are moderately shallow to deep, well drained, silty to fine loamy soils with slight stoniness and moderate erosion. The soil is acidic and stony surface. They are largely under temperate forest. Alpine forests and some are under cultivation crops. Soils on ridges of more than 50% slope are moderately deep developed on steep sloppy hills, excessively drained, coarse loamy to fine loamy soil with slight stoniness and moderate erosion. Soils are moderately acidic, dark brown to dark yellows and rich in humus. Un-terraced lands are susceptible to severe erosions. These are largely under temperate forest covers.

4.0 OBJECTIVES:

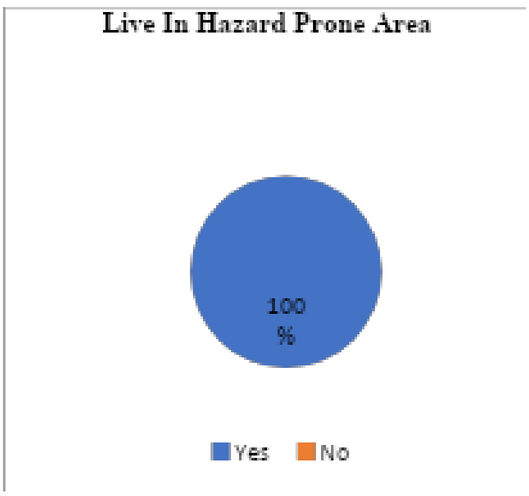
For a study focused on the effects of natural hazards on the upper Teesta River bank's ecological biodiversity, here are the following objectives-

- To evaluate the current state of biodiversity along the upper Teesta River banks to identify species, habitats, and ecosystems most vulnerable to natural hazards (e.g. floods, landslides etc).
- To investigate how specific natural hazards impact the riverbank ecosystems, including habitat degradation and species displacement.
- To study the patterns of biodiversity loss related to recurring natural hazards.
- To examine the role of human activities, like construction an agriculture in complicating the impacts of natural hazards on riverbank biodiversity.
- To engage with local communities to raise awareness about the importance of ecological biodiversity.
- To establish a framework for long-term data collection and monitoring to track ecological changes and assess the effectiveness of conservation strategies in response to natural hazards.

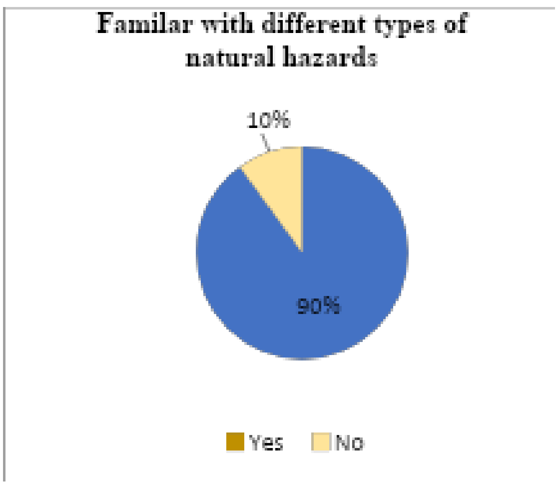
5.0 RESEARCH METHODOLOGY

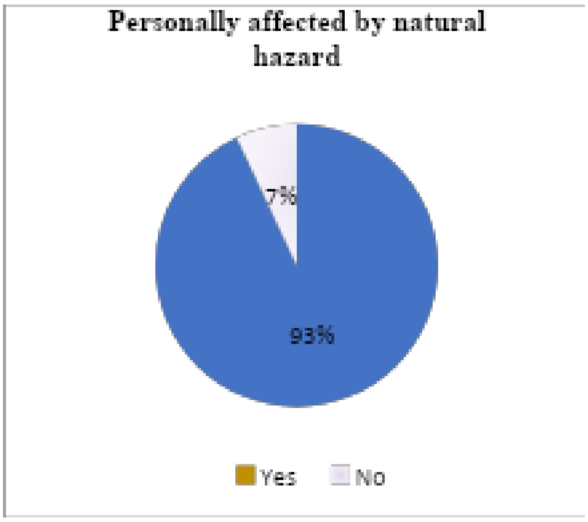
A number of literature reviews are included to develop this article and also some field work in some selected affected areas of upper Teesta River bank. Both Primary and Secondary data sources were used for the research. A survey method with sets of 60 questionnaire were used to collect statistical data. Simple random sampling method is used for survey purpose for collecting primary data.
Secondary data sources such as government publications, international publications as well as other secondary data sources were used.

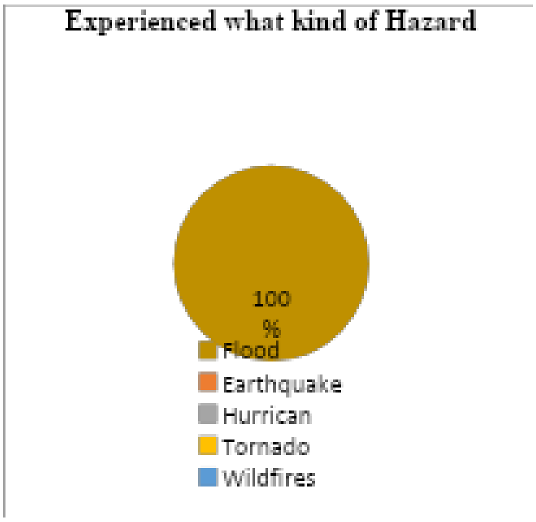
6.0.DATA PRESENTATION AND ANALYSIS

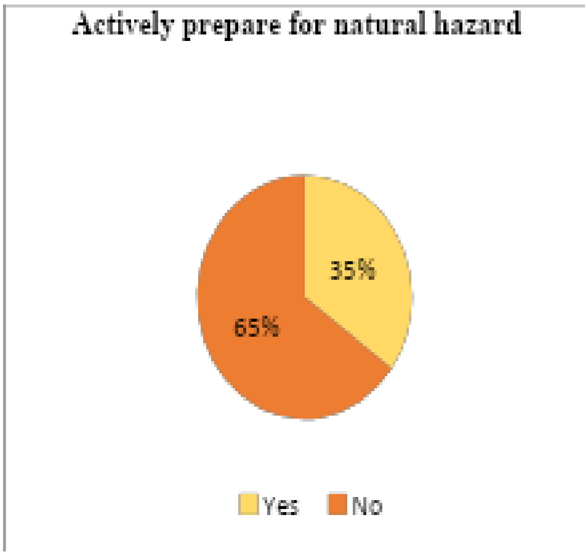


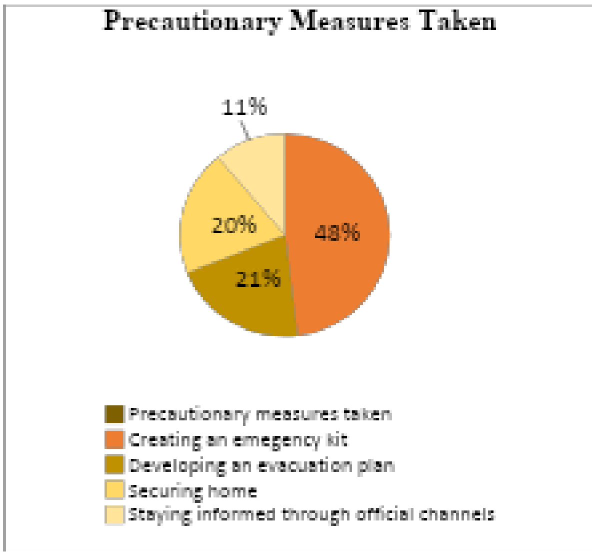
d

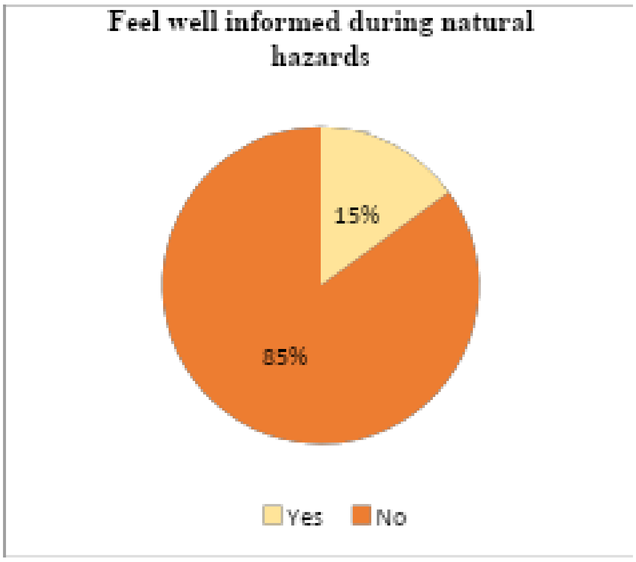


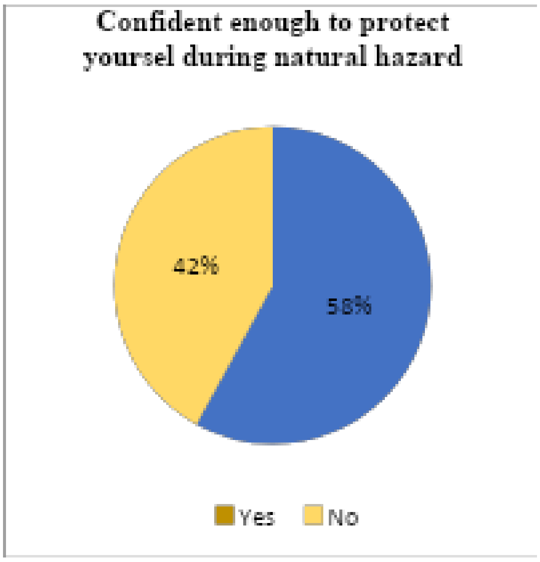

Personally affected by natural hazard
7%
93%
Yes
No

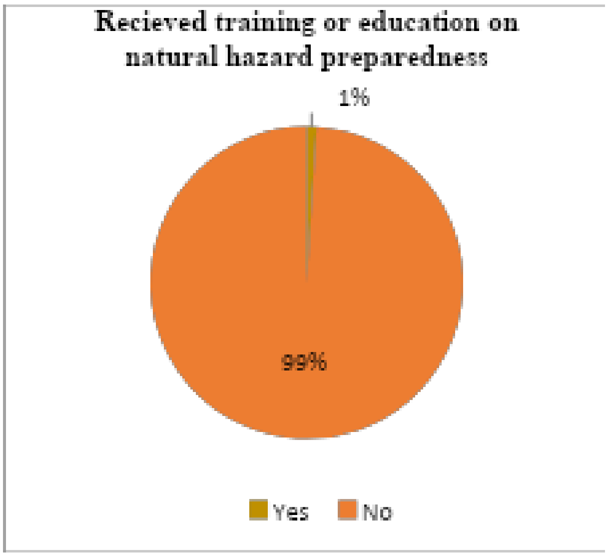

Experienced what kind of Hazard
100 %
Flood
Earthquake
Hurrican
Tornado
Wildfires

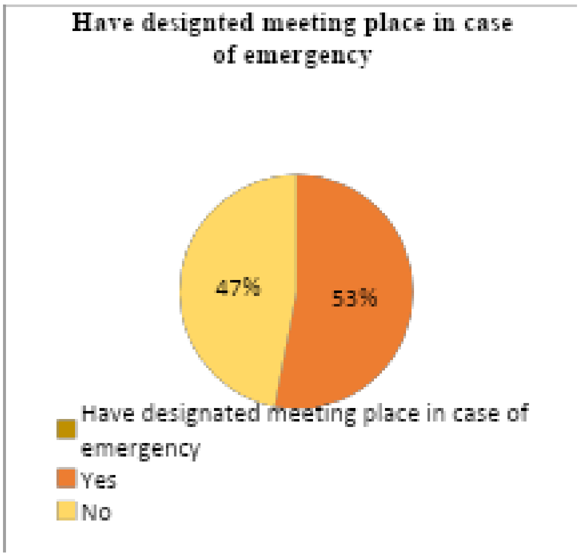

Actively prepare for natural hazard
35%
65%
Yes
No

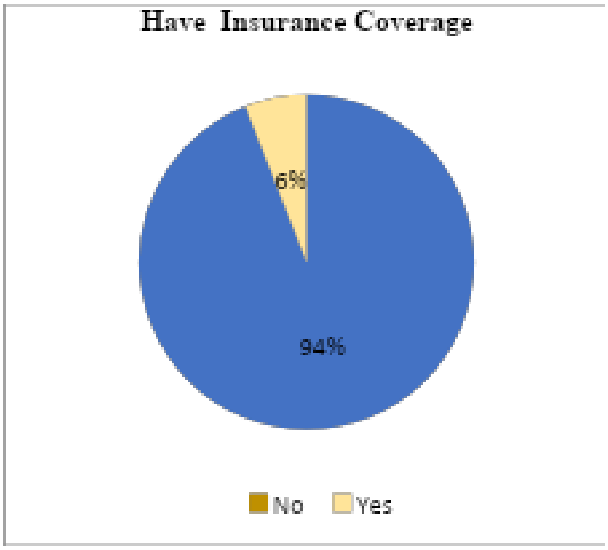

Precautionary Measures Taken
11%
20%
48%
21%
Precautionary measures taken
Creating an emegency kit
Developing an evacuation plan
Securing home
Staying informed through official channels

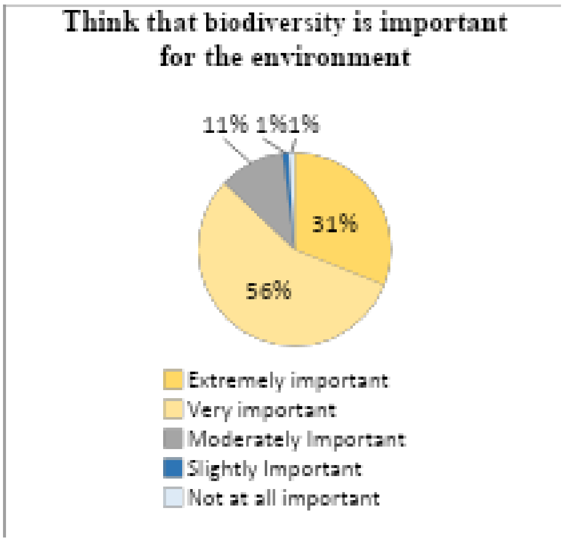

Feel well informed during natural hazards
15%
85%
Yes
No

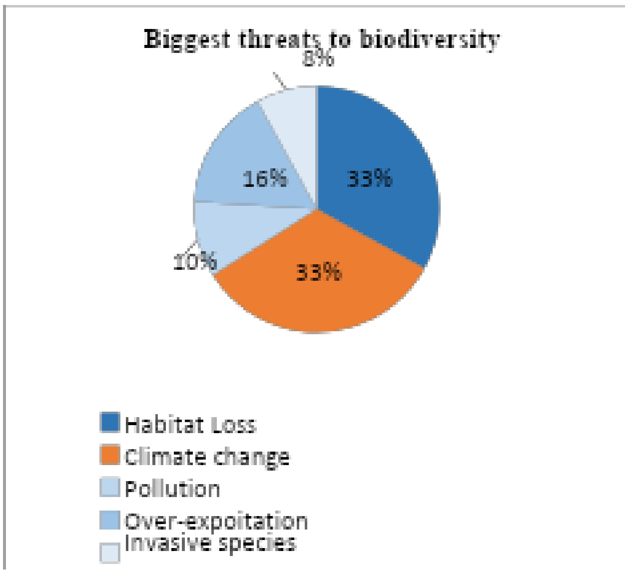

Confident enough to protect yoursel during natural hazard
42%
58%
Yes
No

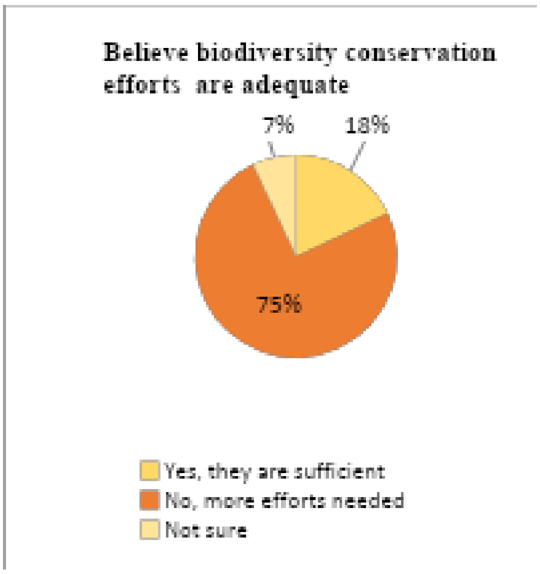

Recieved training or education on natural hazard preparedness
1%
99%
Yes
No

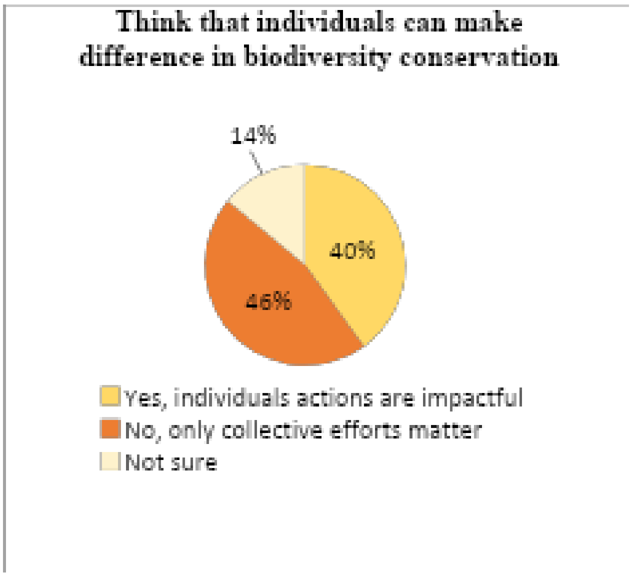

Have designted meeting place in case of emergency
47%
53%
Have designated meeting place in case of emergency
Yes
No

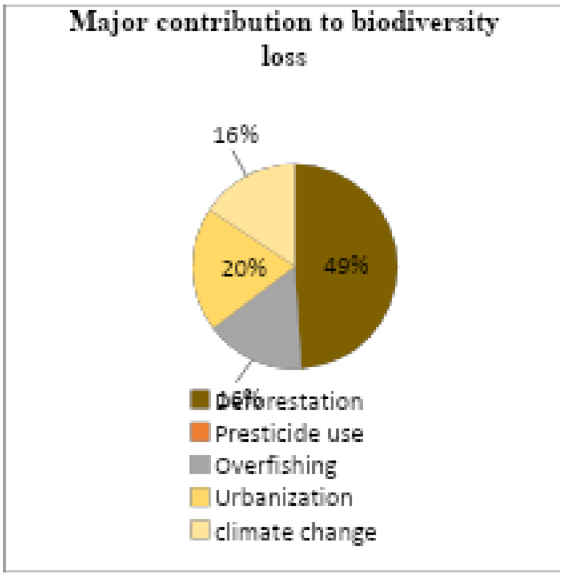

Have Insurance Coverage
6%
94%
No
Yes

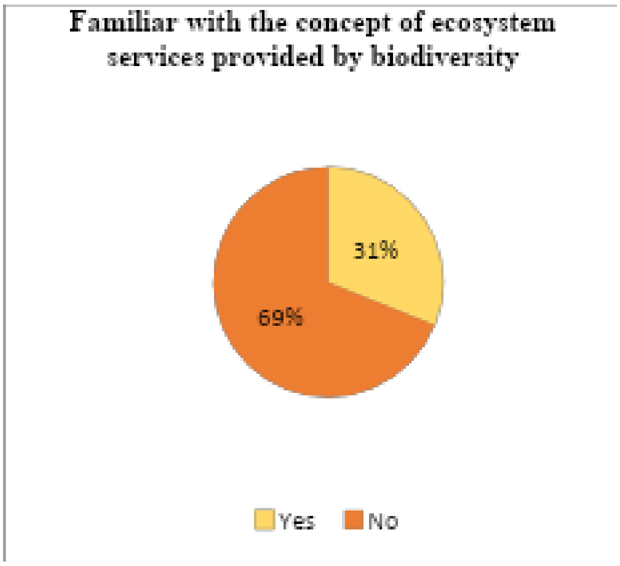

Think that biodiversity is important for the environment
11%
1%
1%
31%
56%
Extremely important
Very important
Moderately Important
Slightly Important
Not at all important

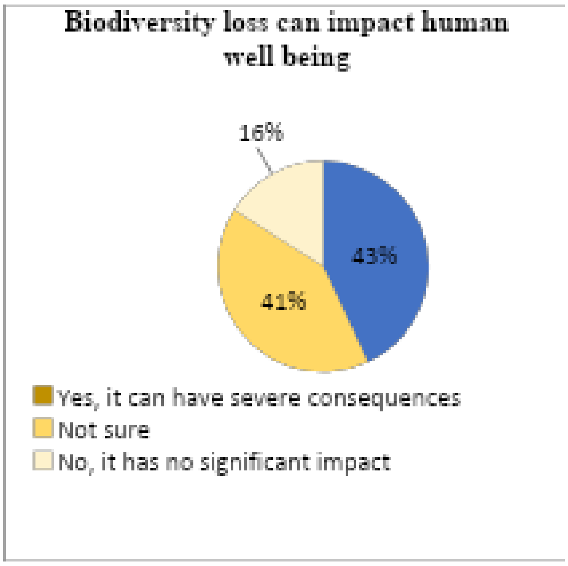

Biggest threats to biodiversity
8%
16%
33%
10%
33%
Habitat Loss
Climate change
Pollution
Over-expoitation
Invasive species

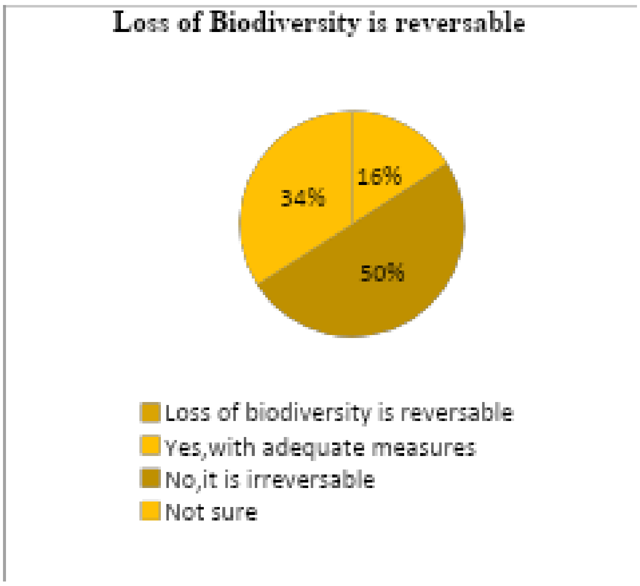

Believe biodiversity conservation efforts are adequate
7%
18%
75%
Yes, they are sufficient
No, more efforts needed
Not sure

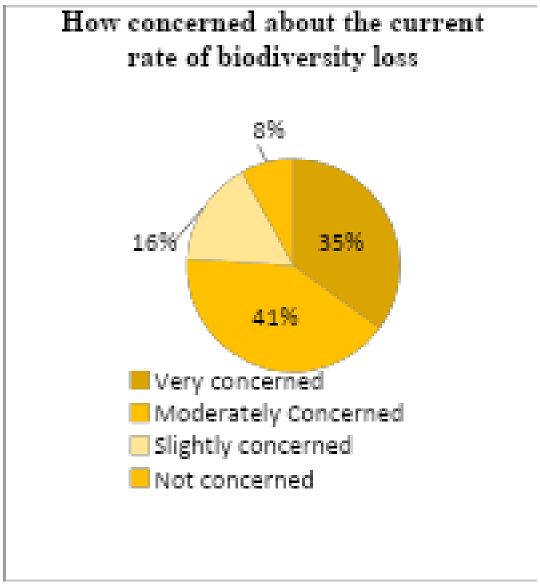

Think that individuals can make difference in biodiversity conservation
14%
40%
46%
Yes, individuals actions are impactful
No, only collective efforts matter
Not sure

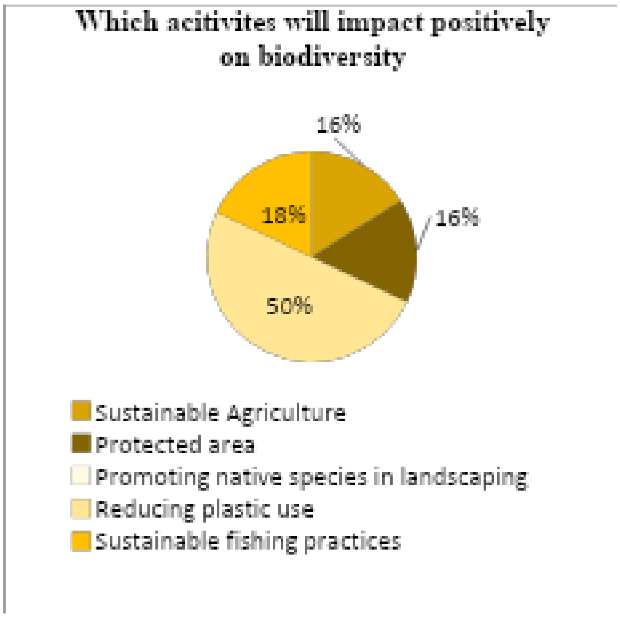

Major contribution to biodiversity loss
16%
49%
20%
16%
Deforestation
Presticide use
Overfishing
Urbanization
climate change


Familiar with the concept of ecosystem services provided by biodiversity
31%
69%
Yes
No


Biodiversity loss can impact human well being
16%
43%
41%
Yes, it can have severe consequences
Not sure
No, it has no significant impact


Loss of Biodiversity is reversable
16%
34%
50%
Loss of biodiversity is reversable
Yes,with adequate measures
No,it is irreversable
Not sure


How concerned about the current rate of biodiversity loss
8%
16%
35%
41%
Very concerned
Moderately Concerned
Slightly concerned
Not concerned



Calculation table for respondent persons in natural hazards on upper Teesta River.

Frequency	fo	fe	(fo-fe)	(fo-fe) /fe
Yes	319	600	78961	131.6
No	281	600	101761	169.6

Σ= 301.20

Therefore, the degree of freedom= (r-1)(c-1)

=(2-1)(2-1 =1

On 0.5% the significance the value came as 3.841

As we can see that the tabulated value is more so we can consider that null hypothesis is rejected and alternative hypothesis accepted.

In the Himalaya region, tectonics, topography, and rainfall facilitate the supply and transfer of massive amounts of water and sediment through river network systems to their piedmonts. Vegetation density modulates the relations between rainfall, topography, and sediment transport in these highly active young mountains. Human activities can further intensify or reduce the delivery and transfer of sediment through deforestation, road building, settlement development, and the construction of dams across rivers). Most of these factors controlling the sediment fluxes are characterized by large variabilities, which are also reflected in a large spatiotemporal variability of suspended sediment dynamics.

Various factors have also been attributed a decisive role in the sediment supply to the river network in the Himalaya region found an increased sediment load in streams in the arid part of the north-western Himalaya region during a year with enhanced annual rainfall. By contrast, the densely vegetated lower parts of this region did not show increased denudation rates suggested, for the Nepal Himalaya, that material transport in the rivers depends on the hillslope sediment supply, which is controlled not by extreme rainfall events, but by moderate ones with a high recurrence interval ,proposed a dominance of tectonics over rainfall in Himalayan region denudation, pointed out that the deforestation of small catchments along the margin of the Eastern Himalaya had significantly increased the sediment loads in the river channels in their piedmonts. indicated that the sediment load in Himalayan catchments is susceptible to changes in vegetation cover and topographic steepness on time scales of up to 100 years. However, only general information on the suspended sediment load (SSL) has been presented for the Eastern Himalaya region, drained by the Brahmaputra and its tributaries.

The Sikkim–Darjeeling Himalaya region, as a part of the Eastern Himalaya, receives the highest annual rainfall (up to 6,000 mm) and the most frequent heavy rains (up to 600 mm/d) along the whole southern Himalayan margin. The catchment of the Teesta River (8,150 km^2), the main river draining this part of the Himalaya region, is known for the occurrence of extreme hydro meteorological and geomorphological events. The rainfall of about 1,000 mm over three days in October 1968 caused a 20-m-high flood wave in this catchment. This was the highest level for any river in India in the previous 70 years. Measured data have indicated that the Teesta River has one of the highest suspended sediment yields in the Himalaya region, exceeding 12,000 t/(km^2·y) (and large variations in its maximum annual discharge of between 2,000 and 10,000 m^3/s at the outlet from the Himalaya.

Unfortunately, studies on the suspended sediment in the Eastern Himalayan rivers are constrained due to an inadequate gauge network, the poor availability of data in the open domain, and hydrological alterations caused by dam construction or extreme hydro meteorological event). Thus, most of the research on the Teesta

River catchment has focused on the sources of the sediment supply, observed enhanced hillslope erosion and increased suspended sediment flux in the Teesta River catchment during the 1968 extreme rainfall and flood event. Infrequent extreme rainfall events, the low resistance of the lithology to weathering, and 70%–80% deforestation of the catchment have been found to be of the greatest importance in the supply of material to the river network.

On 4 October 2023, heavy rains caused the glacial South Lhonak lake in Sikkim, a state in north-eastern India, to breach its banks, causing a glacial lake outburst flood. The flood reached the Teesta III Dam at Chungthang at midnight, before its gates could be opened, destroying the dam in minutes. Water levels downstream in the River Teesta rose by up to 20 feet (6.1 m), causing widespread damage.

It was the deadliest flood in the area after the 1968 Sikkim floods when around 1000 people were killed.

In early October 2023, a cloudburst caused Sikkim to receive more than double its normal rainfall, between 3rd and 4th October alone, the state received five times the usual precipitation. The South Lhonak burst its shores, causing a flash flood. Satellite images from the Indian Space Research Organisation's RISAT-1A show that the lake's surface area shrunk by more than 100 hectares (247 acres). Based on a warning from the Indo-Tibetan Border Police at midnight, the operators of the Teesta III Dam at Chungthang rushed to open the dam's gates, but were too late; the flood quickly destroyed the dam, as well as the bridge to its 1200-MW hydroelectric powerhouse, which was submerged.

Water levels downstream in the River Teesta subsequently rose by 15 to 20 feet (4.6 to 6.1 m), flooding many areas in Mangan, Gangtok, Pakyong, and Namchi districts in Sikkim, and Kalimpong, Cooch Behar, Jalpaiguri and Darjeeling districts in West Bengal. The flood also went onwards to Bangladesh, where it affected hundreds of villages along the Teesta River and Char areas.

Fifteen bridges across the state were washed away, and the north of the state, including the capital Gangtok, was cut off from the rest of India as parts of National Highway 10 collapsed. Three thousand tourists were stranded across the state. Towns and cities like Chungthang, Dikchu, Singtam, Rangpo, Melli, and Teesta Bazaar were very heavily damaged. The government of Sikkim declared the flood a disaster, and the Indian central government released ₹48 crore (5.76 million) in disaster relief funds. Additionally, the state government announced an ex-gratia compensation of 4 lakh ($4804) to the families of those who died, as well as an immediate payment of ₹2,000 ($24) to those in relief camps. The National Disaster Response Force and the Indian Army are involved in the ongoing relief operations. Two thousand four hundred people were evacuated from flood-hit areas, and 7,600 others were in relief camps. Ten thousand more were evacuated in West Bengal.

Fourteen people were believed to be trapped inside the tunnels of the destroyed Teesta III Dam; a 60-strong team of the National Disaster Response Force — including scuba divers — was assembled to rescue them.

At least 40 people were killed and 22 injured, while 75 were reported missing as of 6 October. By 18 October, 92 were confirmed dead, with more bodies being retrieved. Among the missing were 23 Indian Army personnel, of whom seven were subsequently found dead and one rescued alive. One of the dead soldiers was found floating in the Teesta in Nilphamari, Bangladesh; the Border Guard Bangladesh handed over the body to the Indian officials through a flag meeting. One child was killed and six injured in the neighbouring state of West Bengal when a mortar shell carried downstream from Sikkim exploded after being picked up by locals. Total 15 bridges got damaged during this time.

Heavy rainfall during the 2024 monsoon season resulted in severe flooding and landslides across several regions of India. Rainfall caused significant flooding first in Assam State and later end of August also in Gujarat, India.

The floods in Sikkim and other affected states have had a significant impact on the local population, with over 351,000 people displaced and 7.7 million people impacted. The floods have also resulted in the loss of life, with 719 reported deaths and 412 non-fatal injuries.

Ecological systems are extraordinarily complex. With an ecosystem often composed of thousands of different species within a single hectare, these local systems are strongly connected and integrated into more extensive and more complex entities that build up our landscapes and scale up to entire biospheres. These biospheres exert a significant influence on the physical and chemical properties of our planet.

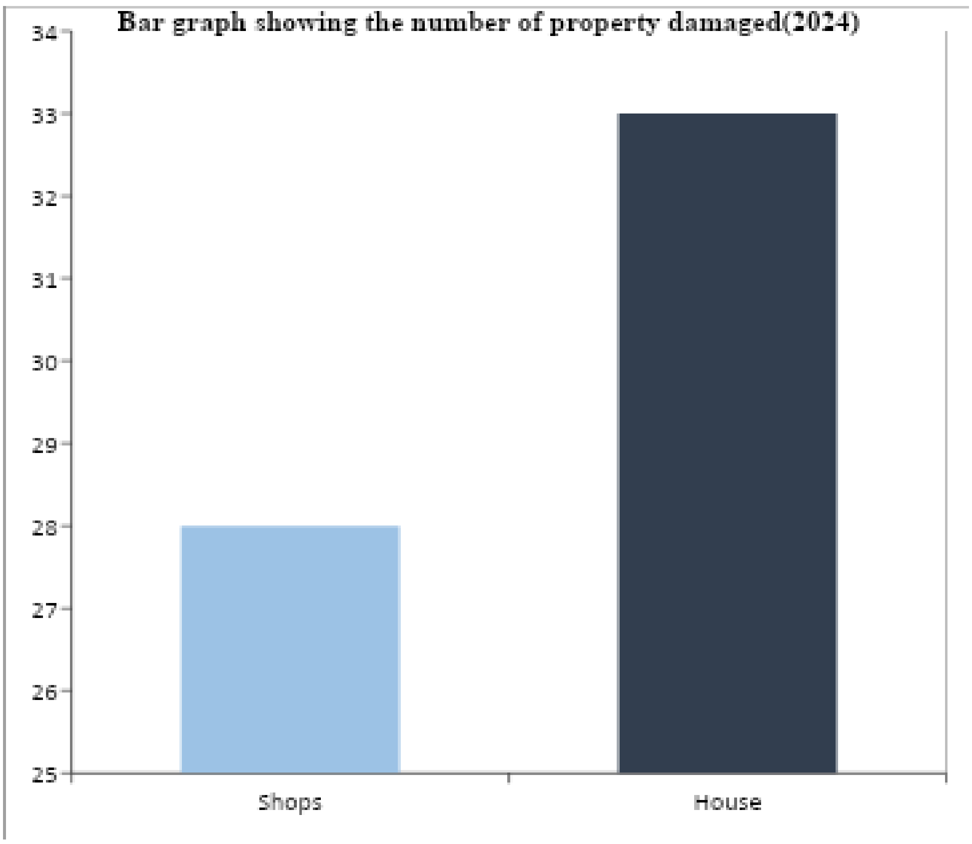
Ecological diversity is the largest scale of biodiversity. On a global scale, ecological diversity would look into the variation in ecosystems such as deserts, grasslands, forests, oceans, and wetlands. Within each ecosystem, there is a great deal of both species and genetic diversity. Ecological diversity considers the variation in the complexity of a biological community, looking at the number of niches and trophic levels there are and ecological processes. We will discuss how variation among species is essential for ecosystem stability and how this, therefore, connects to our planet's ecological diversity. Furthermore, we will look at how diversity acts to stabilize existing ecosystems functioning in environmental fluctuations.

Ecological diversity is the variety of ecosystems in a region or the planet, and the variation in the complexity of biological communities within those ecosystems. It's the largest scale of biodiversity.

Ecological diversity is important because different species provide different benefits to the environment and to humans. For example, forests contain plants that absorb carbon dioxide and provide oxygen, and animals like deer and bears that help regulate populations.

From the above figures it can be analysed that most of the people live in hazard prone areas i.e, near mountains, and got affected by different types of hazards. And most of the hazards are enlarged by anthropogenic activities

like railways construction and dams. Many of the shops, houses and other property got affected by the flood, as they live in hazard prone areas.
From the fig(i) and (ii) it can be estimated that all of the respondents got affected by natural hazards. In this recent year it has been observed that the flood is caused by railways and dam construction.
From figure(iii) it is seen that 93% of the people got affected personally as their property got diminished badly.
From fig(iv) it is analysed all of them experienced flood as a hazard that day. But landslide, wildfire, earthquakes are most prominent hazards that can be seen in day to day life.
From figure(v) it can be seen that only 35% of the people were actively prepare for natural hazards and 65% of the were not prepared for the disaster that happened that day. As it happened at 4p.m noon and that time most of the people take rest taking relief from work. Only few of them said that they got informed by the officials but most of them said that they were not informed by the officials.
From figure(vi) it is estimated that 48% of the people taken precautionary measures as creating an emergency kit, 21% said that they develop an evacuation plan, 20% of the people used to secure their home and rest 11% said they got informed by the official channels. They are used-to with this kind of hazards so they form emergency kit which includes torch, water bottle, some food etc. And for evacuation plan they usually form a safety door as way to escape speedily during this kind of hazards. The purpose of an evacuation plan is to protect people and assets by moving them to a safer location before, during or after a hazardous events. From fig(vii) it can be estimated that 85% of the people did not get any information during the natural hazard. From fig(viii) it is seen that only 1% of the people got training or education to cope with the hazard. From the fig(ix) it is seen that 53% of the people have designated a safe meeting place during an emergency. And 47% of the people haven't designated a meeting place. From the fig(x) it is estimated that only 6% of the people have insurance coverage and 94% of the people don't have any insurance coverage.
From fig(xi) it is analysed that 31% of the people think that biodiversity is extremely important for the environment. Other than that 1% of the people feel that it is not important. 11% of the people think it is moderately important. As varied people have variety of thoughts. Most of forest ecosystem got destructed by this as most of them use earthen stoves for making food and due to flood the water level rose up to 3 feet from the original level for this reason the water went up to the catchment area where variety of trees are grown. And thousands of trees got killed due this hazard.
From the next figure it is seen that 33% of the people think that it is due to climate change, 33% think that it is due to habitat loss and other think that it is due to anthropogenic activities that is over exploitation.
49% of the people think that due to deforestation the ecological diversity got damaged and 19% people think that it is due to urbanization.



From the graph it is seen that several shops and houses got damaged along with their assets.

So, it can be said that the people should have to be more concern about accelerating mountain exaggerations, construction of roads by cutting the mountains, over-exploitation of forests and others. The officials should be more concerned about the preparedness before the disaster. As it will lessen the heavy toll of lives.

7.0. FINDINGS:

The in-depth analysis of the effects of Natural Hazards on upper Teesta River banks of ecological biodiversity has led to the following findings:

1. The data that we have collected shows 100% of the people in the area feels and are fully aware that they live in a Hazard Prone Area.
2. The data shows that 90% of the people are familiar with different types of Natural hazards.
3. The data shows that 93% of the people are affected by Natural hazards.
4. The data shows that 100% of the people have experienced the flood in that area.
5. The data shows that 65% of people the where actively prepared for natural hazards.
6. The data shows that 48% of the people had created an emergency kit, 21% of people had developed an evacuation plan, 20% of the people made their home secured and remaining 11% had been informed through official channels as for their precautionary measures.
7. The data shows that only 15% of the people were well informed during this natural hazard.
8. The data shows that 58% of the people where confident enough to protect themselves and their loved ones during a natural hazards.
9. The data shows that 99% of the people did not received any training or education on natural hazard preparation.
10. The data shows that 55% of the people have designated meeting place in case of emergency.
11. The data shows that 94% of the people do not have insurance coverage.
12. The data shows that 31% of the people think biodiversity is extremely important, 56% of them think it is very important, 11% of them thinks it is moderately important, 1% of them thinks it is slightly important and other 1% of the people thinks it is not at all important.
13. The data shows that 33% of the people thinks the biggest threats to biodiversity is habitat loss, other 33% of the people thinks climate change is the biggest threats, 10% of them thinks pollution is the biggest threats, 16% of the people thinks Over-exploitation and remaining and remaining 8% thinks invasive species is the biggest threat to the biodiversity.
14. The data shows that 75% of the people think that the biodiversity conservation efforts are adequate, 18% of them thinks more efforts are needed and 7% of them are not sure.
15. The data shows that 40% of the people think that individuals can make difference in biodiversity conservation, 46% of the thinks only collective efforts matters and 14% of them are not sure.
16. The data shows that 49% of the people think Deforestation is the major contribution to biodiversity loss, 16% of them thinks it is because of Overfishing, 19% of them think it is because of Urbanization and the rest 16% thinks it is because of Climate change.
17. The data shows that only 31% of the people are familiar with the concept of ecosystem services provided by biodiversity and other 69% of the people are not familiar with this concept.
18. The data shows that 43% of the people think biodiversity loss can impact human being in severe consequences, 41% of them are not sure, and the rest 16% of them thinks it has no significant impact.
19. The data shows that 50% of the people think the loss of biodiversity is irreversible, 34% of them are not sure and remaining 16% says yes, but with adequate measures.
20. The data shows 35% of the people are very concerned about the current rate of biodiversity loss, 41% of them are moderately concerned, 16% of them are slightly concerned and remaining 8% are not at all concerned.

The data shows 16% of the people think that Sustainable Agriculture will impact positively on biodiversity, 16% think protected area, 50% of them think reducing the use of plastic will help and 18% of them think sustainable fishing practices

8.0.SUGGESTIONS:

The Teesta, a trans boundary river that originates in the Paohunri Mountain range of the Eastern Himalayas, flows through the Indian states of Sikkim and West Bengal through Bangladesh, and meets the mighty Brahmaputra-Jamuna River as a tributary. The total river length is 414 km with a catchment area of 12,160 km2, of which only 19% falls within Bangladesh. The river is well known for its braided nature. In addition, the Teesta basin is highly human-intervened: three barrages exist (two in India and one in Dalia, Bangladesh) along its course. Flooding is a very common hydrologic phenomenon in the Indian and Bangladeshi parts of the basin. The previous devastating floods happened in 2025, 2000, 1996, 1993, 1978, 1976, 1975, 1973, 1968, and 1950.
Several studies have been conducted over the last two decades to improve flash flood forecasting. However, damages have not been significantly reduced.

1. Short-term measures.
To mitigate floods in the Teesta River, short-term measures are essential. Enhance flood forecasting and warning systems to alert communities. Strengthen embankments and repair damaged sections to prevent breaches. Conduct regular dredging to maintain river depth. Evacuate people from flood-prone areas during heavy rainfall. Provide relief materials and emergency services. Timely action saves lives and property. Effective short-term measures reduce flood impacts.

2. Long-term measures
Long-term measures ensure sustainable flood management. Watershed management through sustainable land-use practices reduces runoff. Afforestation and reforestation programs stabilize soil. Soil conservation measures prevent erosion. Construct flood-resistant infrastructure to protect communities. Promote eco-tourism to conserve riverine ecosystems. Integrated long-term measures enhance resilience. Sustainable practices benefit future generations.

3. Policy reforms
Policy reforms support effective flood management which enact and enforce strict building codes to prevent unsafe construction, regulate land use in flood-prone areas, strengthen environmental regulations to protect ecosystems, increase funding for flood mitigation, encourage public-private partnerships. Policy reforms ensure long-term sustainability and effective governance supports flood management.

4. Specific initiatives for Teesta River
The Teesta River requires tailored initiatives to implement the Teesta River Basin Management Plan, execute the National Flood Control Programme, enhance cooperation with Bangladesh for trans boundary water management, restore and protect Teesta's natural floodplains. Develop eco-friendly tourism infrastructure. Community-led conservation initiatives ensure local participation. Integrated initiatives address unique challenges.

5. Community engagement
Community engagement ensures effective flood management. Educate communities on flood risks and management. Involve local communities in decision-making. Support community-based initiatives. Provide training and capacity-building programs. Encourage community-led conservation. Foster partnerships among stakeholders. Community engagement enhances resilience.

6. Technological integration
Technological integration enhances flood management. Utilize remote sensing and GIS for monitoring. Implement flood forecasting models. Use mobile apps for flood warnings. Leverage social media for critical information. Integrate technology with traditional knowledge. Effective technological integration saves lives. Innovative solutions support sustainable management.

7. Infrastructure development
Infrastructure development plays a critical role in flood mitigation. Building flood-control structures like dams and barrages regulates water flow. Enhancing drainage systems prevents waterlogging. Constructing flood shelters and relief camps provides safety. Upgrading water treatment plants ensures clean water supply. Flood-resilient infrastructure protects communities.

8. Water Management
Effective water management is crucial for the Teesta River. Watershed management involves sustainable land-use practices. Rainwater harvesting promotes rooftop collection. Water conservation educates communities on efficient use. Groundwater recharge restores natural recharge areas. Water storage develops small-scale structures. Integrated water management ensures sustainability.

9. Flood Management
Flood management is vital for the Teesta River. Flood forecasting enhances early warning systems. Embankment maintenance regularly inspects and repairs. Floodplain management regulates development in flood-prone areas. Watershed protection preserves natural flood buffers. Community-based initiatives engage local communities. Effective flood management saves lives.

10. Structural Measures
Structural measures support flood management. Dams and barrages optimize operation for flood control. Flood-control gates and levees protect communities. Bridge design ensures flood-resistant construction. Flood shelters provide safe refuge. Regular maintenance ensures effectiveness. Strategic planning prevents flood damage.

11. Specific Initiatives for Teesta River

The Teesta River requires tailored initiatives. The Teesta River Basin Management Plan addresses unique challenges. The National Flood Control Programme enhances protection. The Ganga River Basin Management Plan provides guidance. Sikkim and West Bengal State Water Policies ensure local implementation.

12. Soil Erosion Prevention

Afforestation prevents soil erosion through root stabilization. Tree roots hold soil, preventing landslides. Vegetation covers reduce soil exposure to rain. Soil conservation reduces sedimentation, maintaining river depth. This protects riverbanks, preventing erosion. Afforestation ensures soil stability. Sustainable land use practices support ecosystem balance.

13. Flood Peak Reduction

Afforestation reduces flood peaks by slowing runoff. Forests increase roughness, reducing water flow velocity. Reduced flood peaks decrease downstream damage. Afforestation regulates water flow, preventing sudden surges. This protects communities and infrastructure. Effective afforestation mitigates flood impacts. Sustainable forest management ensures long-term benefits.

14. Groundwater Recharge

Afforestation facilitates groundwater recharge through infiltration. Increased infiltration reduces surface runoff. Recharged groundwater reduces flood severity. This maintains river flow during dry periods. Groundwater recharge supports irrigation. Afforestation ensures sustainable water supply. Effective groundwater management supports ecosystem balance.

15. Afforestation Strategies

Effective afforestation strategies involve planting native species. Degraded forests and watersheds are prioritized. Community-led initiatives ensure local participation. Agroforestry practices promote sustainable land use. Monitoring and maintenance ensure long-term success. Afforestation strategies adapt to local conditions. Collaboration between stakeholders ensures effectiveness.

16. Government Initiatives

Government initiatives support afforestation efforts. The National Afforestation Programme (NAP) promotes reforestation. The National Mission for Green India (NMGI) enhances ecosystem services. The Forest Conservation Act (1980) protects forests. The Teesta River Basin Management Plan integrates afforestation. Government initiatives ensure policy support. Funding and resources support afforestation efforts.

17.NGO and Community Involvement

NGOs and communities play a crucial role in afforestation. Local NGOs (e.g., WWF-India, The Himalayan Club) promote conservation. Community-based afforestation initiatives ensure participation. Public awareness campaigns educate locals. Collaborative forest management ensures sustainability. NGOs and communities support government initiatives. Partnership ensures effective afforestation.

9.0. OTHER SUGGESTIONS:

- The government suggestion and campaign for natural hazards should be benefit to the people who is living near River bank.
- People are familiar with different types of natural hazards like flood or nature destruction which had occurred in the year 2023 so idea and suggestion is very clear to everyone.
- Awareness program for people living in near river area suggestion taken by the government or any local bodies should be effective and work full.
- Suggestion for people not to build houses near river area as it adversely affects life of human being as well as animals too.
- The pie chart shows that hazard prone areas has many suggestion on Teesta river bank areas where due to uncertain increase of river water people suffered great loss. Specially during rainy season before hand information and relief kits are most important for people before any destruction of lives, properties and other things occurs.

10. CONCLUSION:

The Teesta River, a vital resource for communities in Sikkim and West Bengal, has become increasingly unstable due to frequent and severe floods. Triggered by heavy monsoon rains, glacial lake outburst floods (GLOFs), sedimentation, and human activities such as deforestation, these floods have devastating effects on local communities and ecosystems. While the Teesta once supported agriculture, water supply, and livelihoods, it now often brings destruction, with areas like Teesta Bazar facing significant displacement, infrastructure loss, and economic hardship. Local residents, whose lives are deeply intertwined with the river, face mounting challenges, including destroyed homes, ruined crops, and exposure to waterborne diseases from stagnant floodwaters. Climate change threatens to further intensify these issues, raising the risk of more frequent and severe flooding, increased migration, and long-term instability.

Despite the urgent need for support, these areas have often been neglected by the government. Flood-prone communities along the Teesta receive limited disaster-prevention resources, and emergency responses tend to be reactive rather than proactive. Many local residents feel abandoned, facing recurring losses without consistent aid or compensation. Though some flood management measures have been taken, such as riverbank reinforcements and emergency relief provisions, they are often inadequate, lacking the scale and sustainability required to address the underlying causes of flooding. Government initiatives, like early warning systems or investment in climate-resilient infrastructure, have either been insufficiently implemented or are yet to reach the most vulnerable communities. This oversight has left residents to bear the brunt of the crises, with little assurance of future stability.

To meaningfully address the challenges posed by the Teesta River floods, a comprehensive government response is essential. Investment in durable, climate-resilient infrastructure—including elevated roads, flood-resistant housing, and robust drainage systems—would help safeguard communities. Expanding afforestation projects in the catchment area, enforcing stricter land-use policies, and regulating construction along the riverbanks could also mitigate flood risks. The government could enhance early warning systems, monitoring glacial lakes and weather conditions more closely, allowing timely evacuation and preventive measures. In terms of immediate support, increased financial assistance, crop insurance, and compensation for affected families would provide much-needed relief for those who suffer recurrent losses.

Cooperation between India and Bangladesh on water-sharing and sustainable river management is another crucial step to alleviate cross-border flooding impacts. On a community level, local governments could improve disaster preparedness by training residents in emergency response and providing resources for rebuilding efforts.

In conclusion, while the Teesta River is an essential resource, it also poses significant risks that need immediate, sustainable solutions. Effective flood management, stronger infrastructure, and ecological conservation are critical in ensuring that the Teesta continues to support, rather than endanger, the lives of those who depend on it. The government's active involvement and commitment to these initiatives will be crucial in securing a safer, more resilient future for Teesta's vulnerable communities.

References:

1. AbuziedS., YuanM., IbrahimS., KaiserM. & SaleemT.2016Geospatial risk assessment of flash floods in Nuweiba area, Egypt. Journal of Arid Environments133, 54–72. https://doi.org/10.1016/j.jaridenv.2016.06.004.
2. Basnet, k. & Thapa, M. (2019) . Elevational migration of species in response to climate change in the teesta region. Mountain ecology, 11(2), 99-110 .
3. ChaubeyP. K., MallR. K. & SrivastavaP. K.2023Changes in extremes rainfall events in present and future climate scenarios over the Teesta River Basin, India. Sustainability (Switzerland)15 (5). https://doi.org/10.3390/su15054668.
4. FerdousJ. & MallickD.2019Norms, practices, and gendered vulnerabilities in the lower Teesta basin, Bangladesh. Environmental Development31, 88–96. https://doi.org/10.1016/J.ENVDEV.2018.10.003.
5. MondalM. S. H. & IslamM. S.2017Chronological trends in maximum and minimum water flows of the Teesta River, Bangladesh, and its implications. Jamba: Journal of Disaster Risk Studies9 (1), 1–11. https://doi.org/10.4102/jamba.v9i1.373.
6. Prasai, S. And Mandakini D.S., Political economy Analysis of the Teesta River Basin, New Delhi: The Asia Foundation, March 2013. https://asiafoundation.org/resources/pdfs/TheAsiaFoundation.PoliticalEconomyAnalysisoftheTeestaRiverBasin.March2013
7. Shrestha, R., & Bhandari, P. (2017). High sedimentation effects on water quality and aquatic life in the teesta river, environmental monitoring and assessment, 189(5), 215.
8. Sinha, A., &Singh, V. (2018), Sediment deposition impacts on primary productivity in the teesta river, Journal of Freshwater Ecology, 33(1) 1-12.