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Response of Hydro-Meteorological Hazards to Environmental Degradation in Kohima District of Nagaland, North East India

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ABSTRACT

Nagaland is one of the most multi-hazard-prone states in India. About 13.19% population of the state is affected by hydro-meteorological hazards, which are increasing in frequency and quantum year by year. The hilly catchments receive heavy rainfall at an average of about 2500 mm annually. The turbulent velocity of runoff and soil erosion in the jhum fields results in the average loss of 30.62 metric tonnes of soil per hectare annually. Climate and land use changes are accelerating these hazards, such as flash floods, cloudbursts, floods, erosion, landslides, debris flows, storms and hailstorms in the monsoon months and drought in non-monsoon months as drying up of springs and decreasing stream and river flows. Heavy thunderstorms and incessant rains with landslides in many areas and flooding and submerging low laying hills and plains every year require hectic evacuation and rescue operations resulting in several causalities and damage to properties, crops and livestock. In the months of July and August 2018, incessant rainfall in the study area led to multiple landslides and debris flows in several places. A total of 118 houses were damaged, 167 families were affected, many roads were damaged, and about 108 roads were cut-off. Kohima district is extensively abounded by drainage systems which are, to a large extent, rainfed and seasonal and plays a vital role in the ecological functioning of the district. Monsoon seasons show extensive flash floods, while winters witness the drying up of streams and rivers, causing drought-like situations in most parts of the study area. Due to the extensive drainage system distribution, the district's ecosystem is primarily influenced by the streams and river systems, with different regions experiencing slight variability in causative factors and outcomes of integrated interrelations between land and people. It has been attempted in the present study to address the recent hydro-meteorological hazards that occurred in Kohima district (Area 1463 km²) with particular reference to the detailed studies conducted in 4 micro-catchments, each representing a different kind of landscape and landuse.

Keywords: Hydro-meteorological Hazards, Environmental Degradation, Micro Catchments, Kohima District, Nagaland

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I. INTRODUCTION

Hydro-meteorological hazards are atmospheric, hydrological or oceanographic phenomena that may cause loss of life, injury or other health impacts, loss of livelihoods and services, property damage, social and economic disruption, or environmental damage. Hydro-meteorological hazards are caused by extreme meteorological and climate events, such as high-intensity rainstorms, floods, droughts, hurricanes, tornadoes, or landslides (Huan Wu et al., 2016). They are atmospheric, hydrological and oceanographic in origin, accounting for a significant fraction of natural hazards. Jayawardena (2015) pointed out that out of the three main types of natural disasters in the world, geological, hydro-meteorological and biological, hydro-meteorological disasters account for over 75% in terms of the damages, including casualties, economic losses, infrastructure damage and disruption to everyday life. Such risks are expected to worsen given projected climate changes, degradation and ecosystems, population growth and urbanisation (Laddaporn Ruangpan et al., 2020). Hydro-meteorological risk is the probability of damage due to hydro-meteorological hazards and its interplay with exposure and vulnerability of the affected humans and environments (Merz et al., 2010).

Climate change is increasing the frequency of natural hazards such as intense landslides, floods and storms (Bilwa *et al.*, 2015). Climate variability results in adverse impacts on the biophysical and social sectors, especially in the developing regions where adaptive capacity is low, and the sector which is highly affected by it is the agriculture sector which is the highest consumer of water. Thus variability in water supply ultimately affects crop production. The intensity and frequency of most of the hydro-meteorological hazards in Nagaland are compounded by climate change and its impact on agriculture, horticulture, human settlements and human and animal health (NSDMA, 2021). Kohima is a mountainous region bounded by numerous drainage systems and has a surficial bedrock that is quite unstable. Owing to its placement in the most unstable region of India, it is highly prone to several geomorphic hazards such as landslides, earthquakes, flash floods, and erosion, most of which are hydro-meteorological in nature. The instability of the region is, to a large extent, due to the highly intensive rainfall it experiences during the monsoon season. The rocks in Kohima are mainly Disang and Barail formation, which includes slate, clay, shales-splintery and sandy, gravels and conglomerates, which are highly pervious due to the presence of joints, bedding planes, crack, and fissures in the rocks, causing water to pass freely through these rocks and thus the instability persists. Studying drainage systems' effects or influence on the environment becomes vital while trying to study the impact of hazards on the environment. As the state's capital, the district has been growing in the concentration of population and developmental activities, causing sheer stress on land and the environment. As a result, the already naturally unstable land becomes susceptive to additional degradation due to human interference.

Though not much of a series of contributions have been made by geologists and Geographers in the light of land instability and hazards in Kohima district and other parts of Nagaland, the situation is familiar to all regions. The 'Terrain evaluation of Kohima district Nagaland with special reference to geomorphology' by Thingo in 1994 has shed massive light on the knowledge of the landform of Kohima alone, which has proven to be of excellent reference for further geographical study in the respective region. Geologists

have also made a commendable contribution in light of the geology of Kohima. Likewise, the District Disaster Management Authority proves to be working extensively on reaching out and making a positive contribution in the light of disaster management. However, there is a lot that has to be done from a geographical point of view. Though Kohima is infamous for the number of hazards and disasters it suffers causing a great deal of urgency and unrest not only on land but also on the economic development of the region, little has been done and researched to bring about enlightenment not only on the decision makers but also on every layperson on how to deal with the naturally unstable land. Much research and practice are required to minimise the impact of human interference on land degradation and introduce or shed light on management prospects. The research is a conscious attempt to delineate the different types of disasters to which the district of Kohima is especially prone to, with more emphasis on hydro-meteorological disasters and an intensive approach to assessing the cause and effect of such. Therefore, a comprehensive and sustainable development strategy can help reduce the impact of natural disasters, and a scientific approach can help prevent technological disasters from occurring, thus making a significant contribution to sustaining our environment and improving our quality of life sustainably.

A. Study Area

Kohima is a hilly district in India's North-Eastern state of Nagaland sharing its borders with Assam state and Dimapur District in the West, Phek District in the East, Manipur state and Peren District in the South and Wokha District in the North with an area of 1463 sq. km and a total farming population of 1,48,605. The study area lies between 25º40' N and 25.67º N Latitudes and 94º07' E and 94.12º E Longitudes with an elevation of 1261 meters above mean sea level. It experiences heavy rainfall during monsoon, and its average annual rainfall is 2500 mm. The temperature rises to 32ºC during the peak summer and reaches 2ºC in winter. Kohima district has a climatic type of warm summer and mild winter with seasonal dry spells extending from November to April.

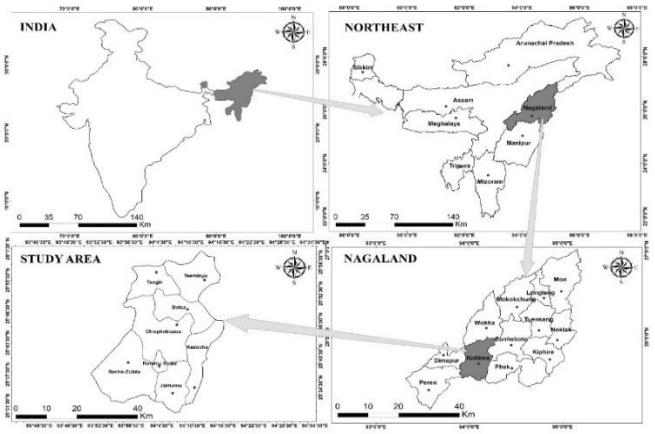

Figure 1: Location map of the study area viz., Kohima district of Nagaland

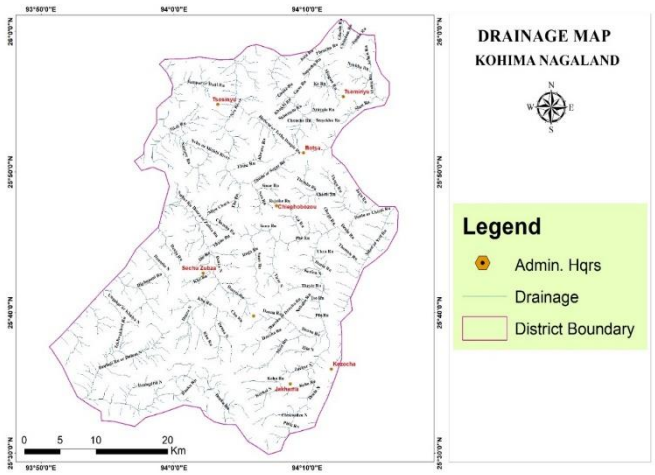

Figure 2: Drainage map of Kohima district of Nagaland

The satellite imagery considered for the maps was LANDSAT-8 (OLI/TIRS) on 27th November 2020, based on the absence of cloud cover through ArcGIS. Survey of India (SOI) toposheet numbers a83 k/1 and 83 k/2 were consulted to geo-rectify the maps. Field visits to each of the 4 sample watersheds were carried out for observation and ground truth data, which was further incorporated with the satellite imageries and analysed.

Secondary data on rainfall were collected from the Directorate of Soil and Water Conservation, operated a meteorological station at Kohima, Nagaland, which

was then analysed and incorporated along with various reports and records collected from the Nagaland State Disaster Management Authority and newspaper articles, specifically of the year 2018 and 2021.

II. METHODS AND MATERIAL

The state of Nagaland, which generally witnesses heavy monsoonal rainfall from June to September, has begun to experience a flood-drought cycle within a year. The rains come in quick bursts and flash floods in many parts, followed by elongated dry periods bordering drought.

Between 1909 and 2018, the state showed a significant decreasing trend in monsoon rainfall. It received less than average rainfall of 1143 mm for several years and only received the maximum rainfall in 30 years, with variability of almost 30 per cent. The overall monsoon rainfall variation was also as high as 24.5%.

The gradient of the rivers is moderate. Hence the rivers are less prone to flooding. Nevertheless, recent instances of heavy rainfall events have brought floods to places that had not witnessed the calamity in decades.

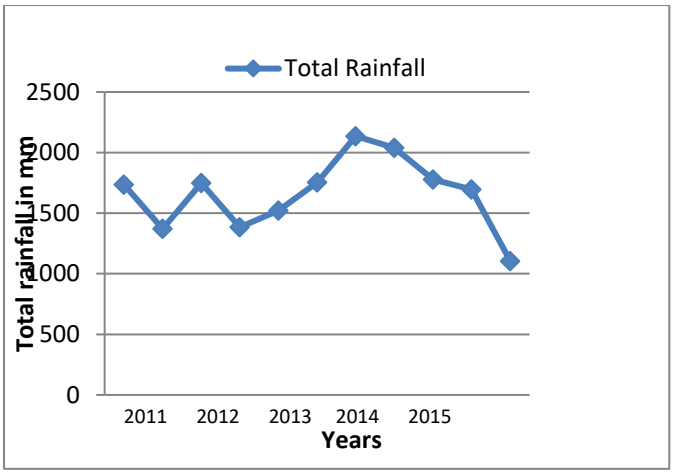

Figure 3: Total annual rainfall (mm) of Kohima between the years 2011 to 2021

Fig. 3 indicates a high rainfall intensity ranging above 2000mm in 2017 and 2018. It has been recorded that Kohima, as well as other parts of Nagaland, faced a dreading situation due to various disasters, such as landslides and floods due to the incessant downpour, with its effect being mainly observed in the late month of July 2018. The year 2018 was regarded as the year hit with the worst calamity in recent memory due to sinking land, landslides and mudslides posing a severe threat to the settlement areas and even forcing families to evacuate. In Nagaland, since the wake of the 2018 monsoon, it was recorded by the Nagaland State Disaster Management Authority that a total of 12 lives were lost, 532 villages and 48821 families were affected, and 13.19% of the state's population bore the brunt with about 359 roads cut off sending the state into a restless situation.

Various streams and rivers, such as the Sano ru in Kohima, Dzuna river in Kohima and Sidzu river in Phek, experienced mudflow and landslides leading to massive debris blocking the river flow, thus posing a severe threat to the habitations downstream. The year 2021, however, shows the lowest rainfall record, just at a range of approximately 1000 mm. this year was recorded to have experienced a drought-like situation with its massive impact on the agricultural sector. It was reported by the Ministry of Science and Technology and Earth Science on 1st December 2021 that the actual rainfall the state of Nagaland received during the monsoon was 919.9 mm against the normal rainfall, i.e. the Long Period Average (LPA) of 1261.8 mm which shows a -27% departure from the LPA.

A total of 4 selected watersheds, namely Mezi ru, Zachar ru, Dzuna ru and Sano ru, have been taken into study. These four watersheds illustrate slightly different landscapes and landuse from each other to represent the different kinds of landscapes/landforms and landuse that are found in and around the district and the type of hydro-meteorological hazards it experiences with an emphasis on the cause and effects to bring about an awareness of the threats of hazards the different parts of the district is exposed or prone to initiate further proper practices of management prospects. Kohima district is dominantly affected by meteorological factors. Most importantly, the incessant and massive amount of rainfall it experiences, particularly during the monsoon seasons, puts a hold

on many activities owing to the hazards it causes, such as flash floods and landslides in most cases. The four kinds of catchments were being studied to analyse the effects hydro-meteorological hazards have on landforms and the area in general based on its natural setting and the kind of human interference it experiences.

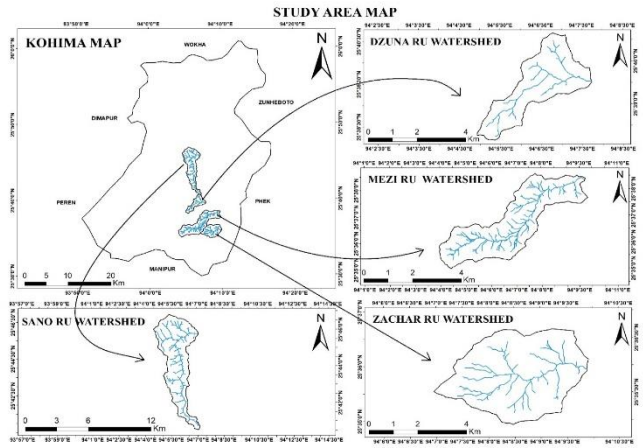

Figure 4: Location of the selected sample watershed in the Kohima district of Nagaland

A. Mezi ru

Mezi ru micro catchment representing an undisturbed landform lies between 94°02- 94°20' E longitude 25°55'- 25°68' N Latitude at an elevation ranging between 914 m-2945 m above MSL covering an area of 24.5 sq. km. This catchment is classified as an undisturbed landscape because of its dense forest covering an area of 15.24 sq. km, yet with a small number of agricultural practices such as terrace cultivation and irrigation. However, it is observed that the agricultural practices carried out in the catchment are done for leisure and not for livelihood, where abandoned cultivation sites were also seen mainly owing to unsuitable climatic factors of heavy rainfall causing erosion and soil displacement as well as in the search for a more urbanised way of livelihood.

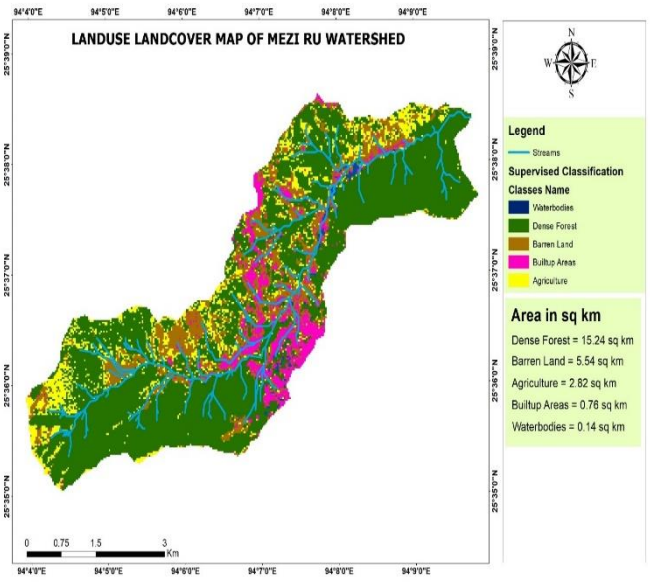

Figure 5: Landuse landcover map of Mezi ru- Sample watershed in Kohima district of Nagaland

Plate 1: Stream flow of the Mezi ru micro catchment during the pre-monsoon month of May 2019.

Heavy monsoon rainfall highly impacts the river, causing heavy overland flow and land degradation. Huge and rounded boulders downstream indicate the impact of heavy floods during monsoon season. Also, with the seasonal agricultural practices of paddy cultivation, there is an indication of human interference in stream flow due to water diversion for irrigation purposes. Though the watershed is dominated by dense forest cover, the environment around the terrace fields has a feeble forest cover with more rocks than soil which add to the cause of landslides, debris flow and rockfall.

Plate 2: The environment around the Mezi ru micro catchment

A total of two springs were found in the catchment. The springs were connected to the groundwater table, where the larger spring possessed a volumetric flow of 2 litres per second while the smaller spring had a volumetric flow of 0.5 litres per 16 seconds. The catchment though undisturbed and with fewer settlements around, suffers from heavy land and soil degradation during monsoon season owing to the high-intensity rainfall the catchment experiences as well as the composition of the soil, which has a mixture of sand and rock types which are mostly shale and sandstone. The settlements that are found in the watershed are primarily indicative of livestock rearing.

B. Sano ru

Sano ru is geologically a disturbed landscape because of the presence of a major fault along the river which contributes to multiple landslides in the catchments almost every annual monsoon season. It is located between 94°03'- 94°21'E longitude and 25°67' - 25°79' N latitude at an elevation ranging between 909 m-1520 m covering an area of 23.42 sq. km. The catchment has a sinking nature due to the major fault in the area. Also, the prevalent heavy rainfall experienced in the study area causes the catchment to experience massive landslides almost yearly. The road along the river, which connects the rest of the district to the civil secretariat, is always under heavy modifications by building huge barriers along the river to control excessive flash floods, which causes great inconvenience to the settlements in and around. The catchment upstream is densely forested. However, it becomes densely populated with built-ups and settlements downstream. The catchment though naturally and geologically disturbed, has become an urban disturbed landscape and landform because of immense additional disturbance by road constructions, settlements and huge disposal of waste in the river itself, all of which collectively intensify the effect of hydro-meteorological hazard, particularly landslide and flash flood in the area.

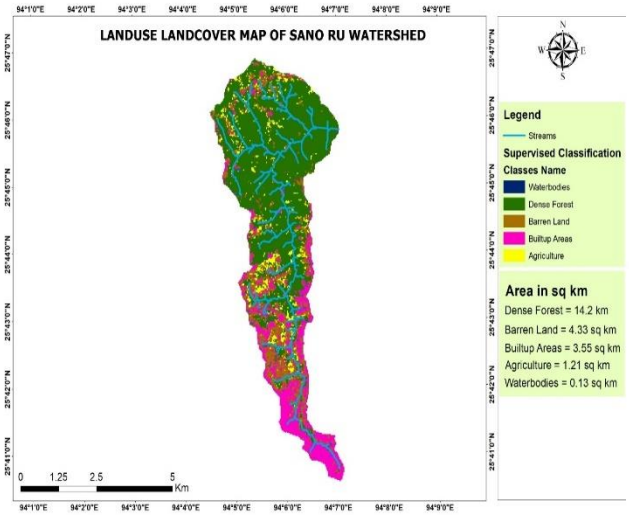

Figure 6: Landuse landcover map of Sano ru-Sample watershed of Kohima district Nagaland

Plate 3: Landsliding along the bank of the river Sano ru.

Plate 4: Landslide and subsidence along Sano ru, where a road connects the Secretariate with the rest of the district

Plate 5: The newly constructed bridge along the river where the old road has been abandoned

C. Dzuna ru

Dzuna ru micro catchment, located at an elevation ranging between 1083 m-2296 m above msl between 94°084' - 94°134' E longitude and 25°634' - 25°676' N latitude having an area of 7.93 sq. km, is an urban landform where water upstream is used for drinking purpose through pipelines while downstream has been appointed as a waste disposal site by the Kohima Municipal Council (KMC). The catchment, both on the extreme upstream and downstream, is covered by dense forest. At the same time, the stream's vicinity has become almost entirely a built-up area covering the maximum area of the catchment.

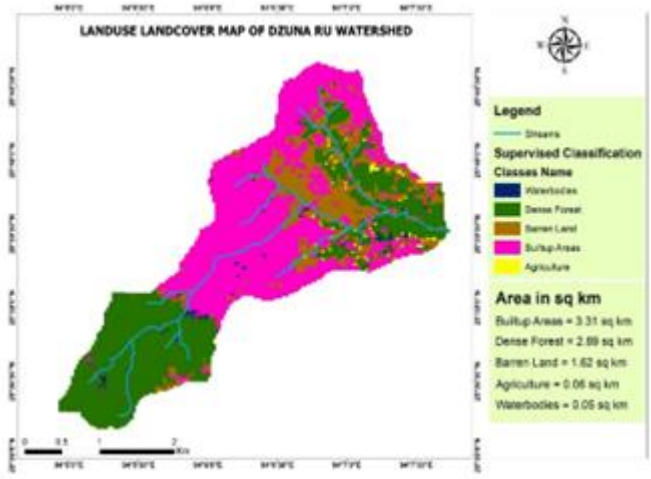

Figure 7: Landuse Landcover map of Dzuna ru sample watershed in Kohima district of Nagaland

Plate 6: Upstream of Dzuna ru

Plate 7: Downstream of Dzuna ru.

The forest vegetation upstream accounts for 70-80%. However, due to increasing water pipelines upstream and low rainfall during the winter and pre-monsoon months, stream flow has reduced a great deal experiencing drought-like situations except during the

heavy rainfall months from June to August when the river becomes overflowing not only because of the incessant rainfall but also owing to the decreasing breadth of the river because of unceasing construction of houses and retaining walls by property owners in and around the catchment causing a dangerous threat of flash flood and man-induced damage to properties. The water holding capacity of the river is mainly decreasing because of extensive interference of human habitation in the area. Also, due to the heavy dumping of household wastes in the river, the monsoon season brings flash flooding, leading to the inundation of the NH-29 bridge connecting Dimapur and Imphal.

The Dzuna ru catchment downstream is a different scenario owing to the construction of the KMC waste disposal site. The water downstream is exceptionally polluted due to improper practices of waste disposal by the municipal. The surrounding area of the watershed is bounded by road cutting and construction connecting the North to the southern part of the Angami region, Kohima. This has led to massive deforestation with only a little vegetative cover, and the rocks found downstream are seen to be changing in formation because of the highly polluted water. Also, during the monsoon season, due to the clogging of the river by waste materials, the river becomes flooded and stagnant with contaminated water, causing land degradation and vegetation along the stream. Heavy road construction around the catchment has also resulted in deforestation leading to landslides. This watershed's landuse system can be considered an urbanised landuse system with massive disturbance on the river's natural ecosystem, leading to decreasing water flow, flash floods, decreased forest cover, landslides and contaminated water. The catchment located at the heart of Kohima town becomes comparatively exposed to human-induced threats. Despite its very high potential of serving as a source of providing drinking water to the people, proper monitoring is necessary for the catchment to suffer more threats than the valuable service it can provide.

D. Zachar ru

Zachar ru is considered a rural landform because of its prominent agricultural practices prevailing in the area and low population and settlement. It is located between 94°10’ - 94°28’ E longitude and 25°56’ - 25°68’N latitude at an elevation between 973 m-1959 m a.s.l covering an area of 10.47sq.km.

The catchment is surrounded by a good number of other streams flowing alongside, which makes it very prone to flooding and sheet-wash erosion and landslides in some cases, which will ultimately intensify during the monsoon season. Though there is no water scarcity in the area, there is a considerable threat of hydro-meteorological hazards in and around this sample watershed. It is interesting and commendable to witness that to combat this substantial natural disadvantage of the area. The land has been extensively modified and used for terrace cultivation, where the flowing water is extensively used for irrigation purposes, with numerous artificial small streams flowing in every corner. The materials deposited due to sheet-wash erosion are used for agricultural purposes. For this reason, the stream water flows moderately during the monsoon season. About 10% of the area has been highly modified into agricultural lands.

Zachar ru may be an example of almost every rural landscape and landform with the same threat of geomorphic and hydro-meteorological hazards.

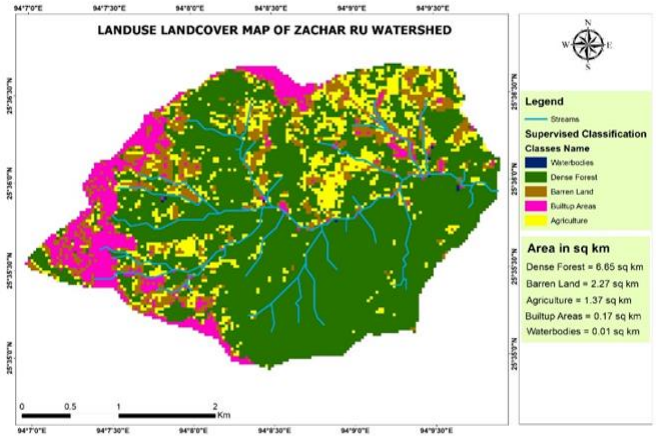

Figure 8: Landuse landcover map of Zachar ru sample watershed in Kohima district, Nagaland

Plate 8 : Terrace cultivation is done in the watershed area

Table 1: Geographic Characteristics and Management Attributes of the four selected sample watersheds in Kohima district of Nagaland

Sl. No.	Name of the Watershed	Co-ordinates	Main Villages and Towns	Landuse/Landcover	Range of Altitude (m)	Area (Km2)	Length (km)	Water Discharge (m^3/sec)	Identified Hydro-meteorological Hazards
1	Mezi ru	94º02'-94º20' E Longitude 25º55'-25º68' N Latitude	Jakhama village, Kigwema village	Dense forest- 62.20%, Barren land- 22.61%, Agriculture- 11.51%, settlement- 3.10%, Rivers and streams- 0.57%	914-2945	24.5	10.617	0.0369	1)Flash floods during monsoon 2) Rockfalls 3) Debris flow 4) Landslides on the valley sides and massive soil erosion
2	Sano ru	94º03'-94º21' E Longitude 25º67'-25º79' N Latitude	Kohima town, Thizoma village	Dense forest- 60.63%, Barren land- 18.49%, Agriculture- 5.17%, settlement- 15.16%, Rivers and streams- 0.55%	909-1520	23.42	11.935	0.0058	1)Landslide 2) Subsidence due to fault 3) Massive Road induced landslides 4) Accelerated soil erosion
3	Dzuna ru	94º084'-94º134 E Longitude 25º634' 25º676' N Latitude	Kohima town	Dense forest- 36.44%, Barren land- 20.43%, Agriculture- 0.76%, settlement- 41.74%, Rivers and streams- 0.63%	1083-2296	7.93	5.439	0.059	1)Flash floods due to heavy pollution 2) Landslides and degradation of land due to road construction 3) Drought-like situation during winter 4) Drying up of springs and stream flow
4	Zachar ru	94º10'-94º28' E Longitude 25º56'-25º68' N Latitude	Jakhama village, Mima village	Dense forest- 63.51%, Barren land- 21.68%, Agriculture- 13.08%, settlement- 1.62%, Rivers and streams- 0.90%	973-1959	10.47	5.068	0.0073	1)Mudflow during heavy monsoon 2) Flash floods 3) Accelerated soil erosion

III. CONCLUSION

Kohima district is an unstable mountainous region with every environmental aspect, such as landform and climate, inclining towards the formation of disaster. It can be well ascertained that Kohima is a hazard-prone area even without the influence of human beings. However, the situation has been aggravated by human interference, with a considerable aspect contributed by the ever-increasing population concentration owing to several factors, such as development in the search for jobs and better opportunities being the state's capital city. Firstly, the unstable landform and disturbed landscapes the district is placed on, then the ever-changing climate coupled with extensive human interferences has all aggravated the situation. Owing to the natural instability of the district, one of the most common phenomena the district suffers from is a landslide in various forms. Road construction, settlement built-ups and the incessant monsoon rainfall play a considerable role. It is only wise to adapt to several management aspects, such as in the case of Zachar ru, where extensive terrace cultivation has almost prevented a major mudslide from ever occurring. Also, human interference in the likes of Dzuna ru, which possesses a very high potential of serving the community in terms of drinking water and irrigation purposes needs strict adherence to proposed rules and regulations for the conservation of the watershed. Sano ru, which represents a geologically unstable area along with intense human interferences, is one region where scientific planning is necessary. Lastly, the Mezi ru indicates that Kohima was originally a troubled region and requires humans' interference in degrading it and managing it for the sustainability of not only the natural environment but of the human population as well. Several management aspects such as terrace cultivation, water harvesting for agricultural and horticulture development, irrigation, watershed conservation, scientific development practices, and land degradation control measures should be practised to prevent or control the already unstable region from going through any severity in the situation. Due to the extensive drainage system distribution, the district's ecosystem is primarily influenced by the streams and river systems, with different regions experiencing slight variability in causative factors and outcomes of integrated interrelations between land and people.

IV.ACKNOWLEDGEMENT

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