

# Geo-Environmental Hazard Issues, Challenges and Adaptation for Livelihood Security and Disaster Risk Reduction in Rudraprayag District, Uttarakhand

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## ABSTRACT

Anthropogenic activities often disrupt the environment and geo-hydrology of Garhwal Himalaya and its significant impacts are visible on the hydrological behaviour of Mandakini River Basin, Rudraprayag District, Uttarakhand. Important factors causing flood and accelerating several hydrological hazards during monsoon periods in the Mandakini river are heavy rainfall, cloudburst, avalanches, slope failure, GLOF (Glacial Lake Outburst Flood), landslides, soil erosion, rampant tree felling, deforestation, drainage congestion due to unregulated urbanization etc. These changes and some important factors causing the disaster have been attempted to be understood through primary survey, secondary data and with use of Geospatial (GIS and Remote Sensing) techniques are used to find out the situation and analysis the characteristics of geographical conditions for sustainable development. This research used a cross-sectional study design for disaster risk reduction planning wherein it attempts to assess the livelihood security, disaster-related knowledge, preparedness, adaptation, awareness, and risk perception among the stockholders. This paper also suggests a sustainable policy to accentuate and transform scientific indigenous knowledge into programmes and policies to increase better mutual understanding, collaboration and partnership for better sustainable policy outcomes in the goal of sustainable development and disaster management in Rudraprayag district, Uttarakhand.

**Key words:** Hazard Prone Area, Livelihood Security, Sustainable Development, Preparedness Plan and Disaster Risk Reduction

## INTRODUCTION

In present years, population growth, haphazard construction and urbanisation in the fragile landscape of Uttarakhand have greatly increased the impact of natural disasters. The Himalayan range is made up of small geological formations and is tectonically very active. Large numbers of hydrological and meteorological hazards occur and cause extensive environmental degradation, substantial loss of life, property and natural resources. In these areas, how to mitigate the effects of hazards is extremely difficult, as more methods that are expensive are needed to manage risks through engineering frameworks and rational land use planning (Ives and Messerli 1990). Therefore, a new issue is to implement early warning systems and land use regulations aimed at reducing the loss of life and property without investing in long-term, expensive projects for early stability. Governments around the world and research institutes have long sought to

assess the risks and hazards and to map out their spatial distribution on a map. Different methods were proposed or implemented to assess the risk of hazards.

Natural disasters, frequent and catastrophic natural disasters that occur annually around the world (United Nations International Strategy for Disaster Risk Reduction (UNISDR 2015). and different economic, political, and cultural factors in the Himalaya region (Dolan and Walker 2006). High population growth, degraded agricultural land, total use of natural resources, degraded biodiversity resources and an increase in the number of vehicles and transportation have completely exacerbated environmental degradation, disaster and life-threatening pressures (Singh and Mal 2014). Climate change and environmental hazards have become major environmental, social and economic hazards especially in natural areas, land use patterns, biodiversity, and the survival of agricultural and forest communities (Sinha 2007, Ranjan et.al. 2020).

Several studies of disasters have been undertaken in recent years until 2021. The identification of hazards in the highest mountain area involves includes shallow, deep and complete operations, mapping and zonation with the interpretation of geographical landform, slope failures, rock falls, and debris flows, accelerated soil surface erosion and flash flood and its responsible causes (Gupta et al. 2013).

Human survival is dependent upon its ability to cultivate and grow crops for consumption as food. The land is the prime site and most valuable one for the livelihood of mountain societies. The Common Property Resources (CPRs) is an important option for livelihood in the Mandakini river basin, Rudraprayag. A strong fusion is visible between livelihood security and access to Common Property Resources (Roy and Tomer 2000). An over-exploitation of CPRs in the study area has rendered the environment more fragile and vulnerable augmenting exposure to risk from natural hazards. Enhanced land use capacity, however, can minimize the vulnerability of a region (Asthana et al. 2007). The Sustainable Livelihoods Approach (SLA) is a tool for a better understanding of the livelihoods of rural people and common property resources (Pandey 2002, Haigh 1984). It helps in planning new development programs and in assessing the contribution of existing activities for sustaining livelihood (Maurya 2020, Rawat et.al. 2018). Mandakini river is a prone zone in Uttarakhand, India. One has to learn from the Kedarnath catastrophe of 2013 and the 2021 Rishi Ganga and the Tapovan catastrophe in Uttarakhand especially those examined in the context of the recurring indications of extreme weather and hydrological events. Sustainable environmental development is a basic need for disaster risk reduction. Sustainable development will reduce vulnerable issues, environmental challenges and disasters.

## STUDY AREA

The study area i.e., the entire Rudraprayag district, Uttarakhand lies in the North-western part of Garhwal Himalaya, which is drained by the Mandakini river, Alaknanda river and its tributaries. The Mandakini River, the most important river tributary that originates from the Chorabari Glacier

(the peak of Kedarnath), joins the Alaknanda river at Rudraprayag district (DMMC 2014). The latitude and longitude of Rudraprayag district (Fig. 1)  $30^{\circ} 10' 36''$  to  $30^{\circ} 48' 50''$  N and  $78^{\circ} 48' 46''$  to  $79^{\circ} 21' 45''$  E with a land area of 1984 square Kilometres at an average elevation of 2274 feet (DMMC 2014).

Rudraprayag district has three Tehsils; Ukhimath, Jakholi and Rudraprayag (Basukedar Tehsil has been carved in 2014) and there are 688 villages in the district of which 28 villages are uninhabited. The Rudraprayag district has three Community Development (C.D.) blocks named Ukhimath, Augustmuni and Jakholi (Census of India 2011). The study area, Rudraprayag District falls in Survey of India (1:50,000) and toposheets Numbers are 53J/14, 53/J15, 53J/16, 53N/1, 53N/2, 53N/, 53N/4 and 53N/6 (Negi and Kumar 2016).

Chaurabari Glacier (3895m) is the origin source of the Mandakini river with a catchment area of 1641 km<sup>2</sup>. It is a major river of the district which flows south from the Greater Himalaya and meets the Alaknanda River at Rudraprayag (Fig. 2). With three Community development blocks, Uttarkashi district is in the north of Rudraprayag district, Pauri Garhwal district is in the south, Chamoli district is in the east and Tehri Garhwal district lies in its west. The district headquarters of the study area i.e., Rudraprayag town categorised as Nagar Palika Parishad is endowed with nature's abundance. Lush green forests, small waterfalls, a confluence of Mandakini and Alaknanda pose mesmerizing beauty to hold on to.

Despite its diversity and abundance, landslides, rockfall, soil erosion, earthquake, flood, flash flood, forest fire, frequently hit district and wild animal attacks. Several streams flowing through mountains often accelerate flooding and landslide across the district.

## METHODOLOGY

The research is based on primary and secondary sources Primary survey involved data collection from 16 villages and 4 towns (Rudraprayag, Tilwara, Augustmuni and Ukhimath) consisting of 200 households. For this purpose, a pre-structured questionnaire, observation, focused group discussion has been conducted for obtaining primary data on livelihood, natural hazards and their related

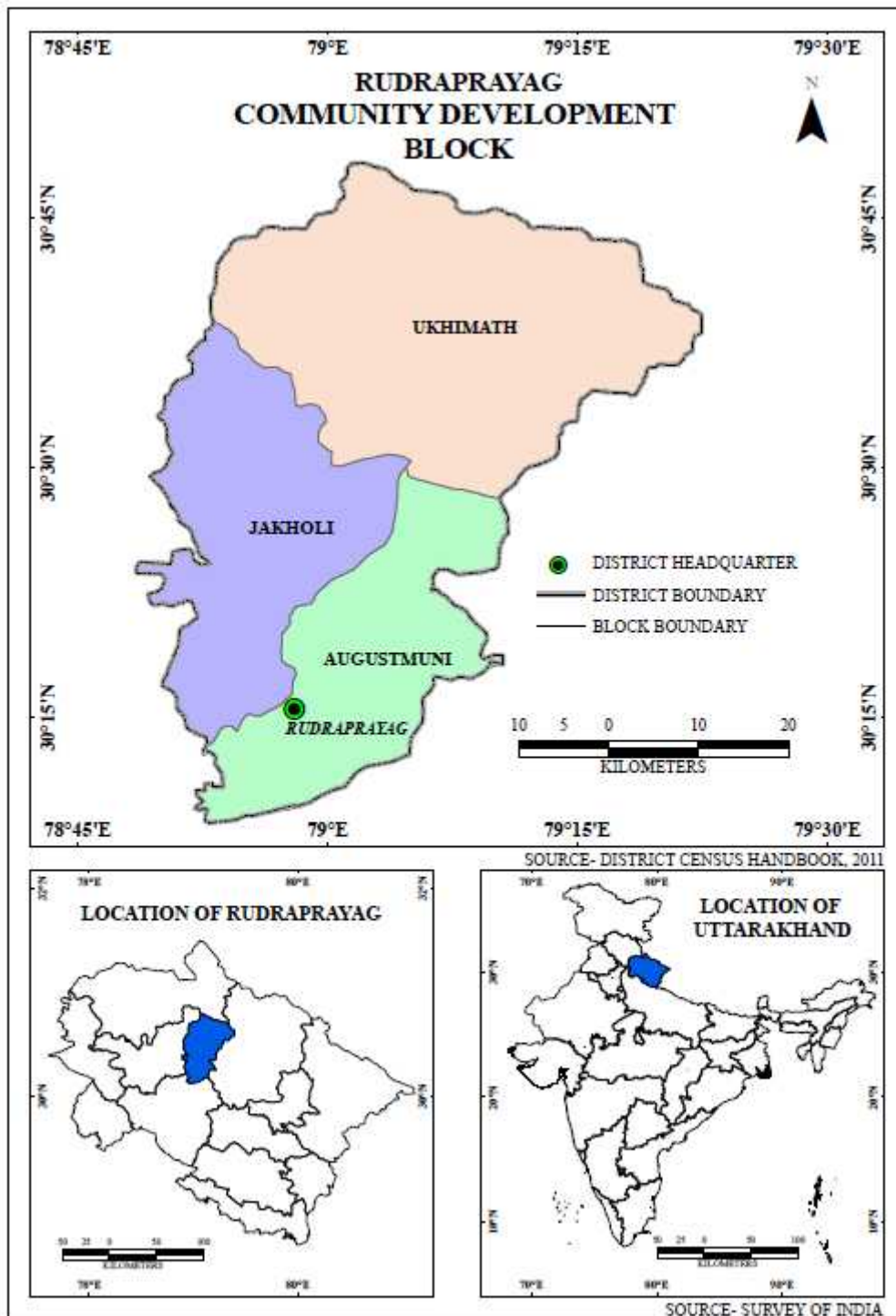


Figure 1. Study Area

dimensions. Villages and towns were chosen by incorporating Stratified Random Sampling (SRS). For the primary survey field visits were done to collect the required data from Ukhimath, Sari, Guptkashi, Phata, Triugi, Sonprayag, Semi, Gaurikund, Bhainsari, Jakholi, Chaka, Jaily, Kandali, Mayali, Rudraprayag, Augustmuni, Tilwara, Barsu,

Saud and Ranigarh etc. Self-Help Groups (SHGs), Non-Governmental organizations (NGOs) and institutions working on issues related to community strengthening and resilience building in the study area were also consulted. Subsequently, Participatory Rural Appraisal (PRA) at different villages was conducted to involve the real stakeholders affected

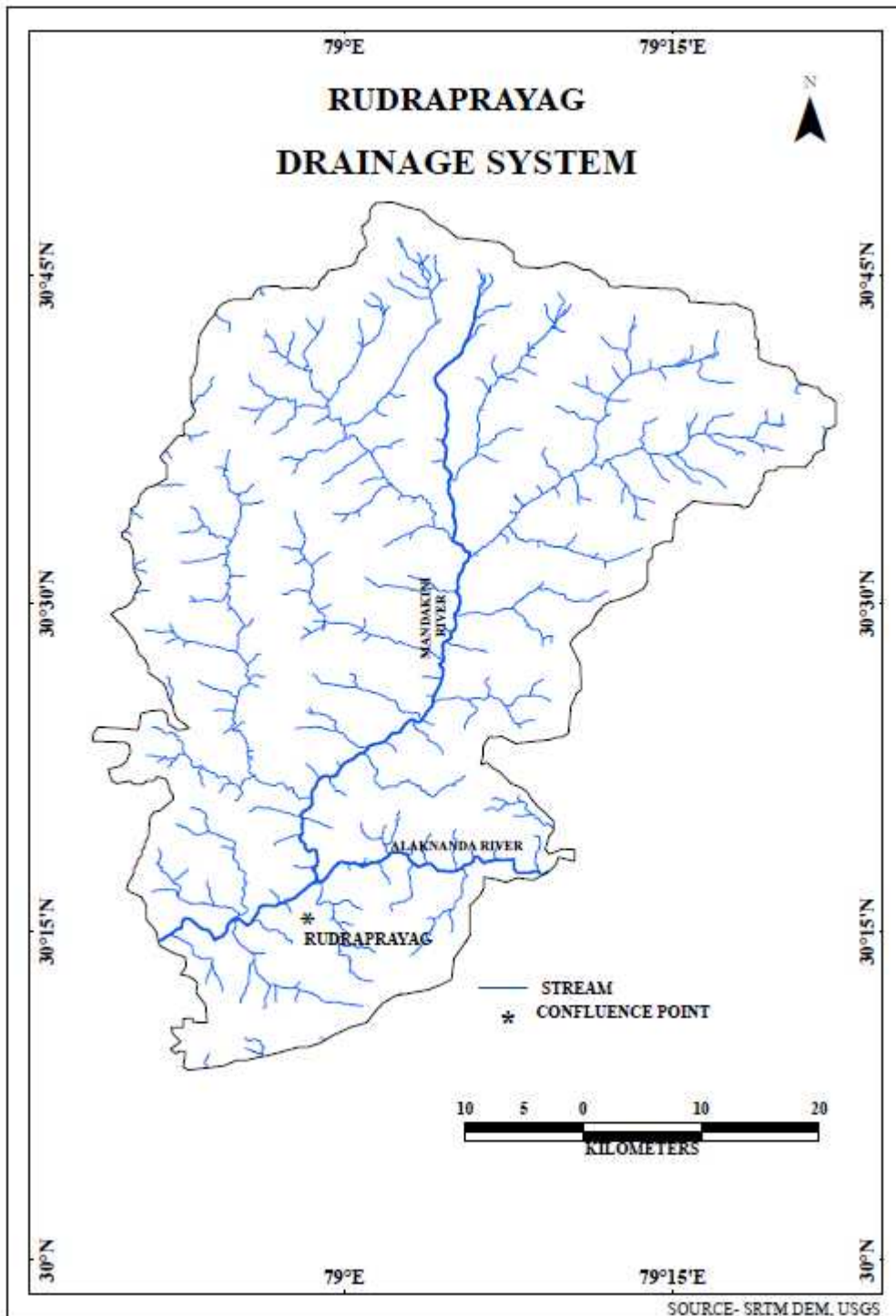


Figure 2. Drainage System, Mandakini River, Rudraprayag

by natural hazards and find out the indigenous and local adaptation techniques for disaster management and livelihood diversification. GIS and Remote Sensing (Geo-Spatial) technique has been used to find out and detect land use & land cover change and to carry analysis work.

## RESULTS AND DISCUSSION

### Land Use & Land Cover Changes and its impact on Geohydrological Disaster and Livelihood Security

Garhwal Himalaya, Uttarakhand is a major biodiversity hotspot in the western part of the

Himalaya. The Himalayas region is facing a major problem in environmental challenges, forest destruction, deforestation, haphazard settlement, encroachment of drainage systems, soil erosion, and landslides. According to the Department of Environment, Forests and Climate Change (MoEFCC 2012, 2018), 44,868 ha of forest land have been converted to non-forest land since 1980, of which 9,500 ha have been converted road construction, followed by 5,500 ha of hydro projects and 3100 ha of transmission lines in Uttarakhand (Batar 2018, FSI 2018) (Figs. 3, 4).

More than 70% of the human population is, directly and indirectly, dependent on primary occupations mainly in agricultural activities, leading to over-exploitation of natural resources, forest resources, improper land-use practices and encroachment of forest area in Rudraprayag. With the fragile characteristics and nature of the Garhwal Himalayas and increasing anthropogenic activities, there is a great natural risk, especially the forest environment and create hydrological hazards. Therefore, forest cover in this area has been under pressure for the last few decades due to improper land-use practices (Chandra et al. 2010). Natural resources, agriculture, agroforestry system on wastelands and livestock development through improving the breed, particularly dairy husbandry, medicinal plant, food processing, juice processing are the main livelihood options in Rudraprayag district. Rudraprayag district is constantly experiencing deforestation due to agricultural expansion, urbanization, tourism development, road constructions, and haphazard construction due to tourism area development.

The forests cover area has been converted to roads construction (187.52 ha), hydro-power projects (62.93 ha), or other construction. In 2018, a study was conducted by the Uttarakhand Forest Department activities (299.08 ha) in the Rudraprayag district of Uttarakhand from 1976 to 2020 (Figs. 3, 4). Natural and manmade hazards e.g., floods, landslides, soil erosion, cloud burst, flash flood, mass movements, rock falls due to soil erosion and landslide, and forest fires have risen in the past few decades and have led to deforestation in the Rudraprayag region. In 2018 year, the study was conducted by the Department of Forest, Uttarakhand,

and find out the approximately more than 81 areas affected by forest fires in Rudraprayag, while the loss of forest cover area was 169 ha (Diwakar et al. 2019). The results show that changes in land use and land cover in the Rudraprayag district changed significantly between 1976, 2010 and 2020. General practice shows that the forest area in the Rudraprayag region has declined and the non-forest area has increased. The total loss of forest from 1976 to 2010 was 122.35 km<sup>2</sup> (Batar et al. 2017).

Local communities of Rudraprayag are highly dependent on forest resources, agricultural activities and tourism, which is expected to result in a reduction in forest coverage. Figure 3 and Figure 4 show that the maximum agricultural activities, anthropogenic activity and settlements areas are allocated to roads and river basins at lower and middle altitudes regions of Rudraprayag district. Significant increases in agricultural and residential land or development are contributing to the change in forest cover and land use & land cover changes, indicating a possible decline in forest coverage in the near future. Contribution to non-forest land in the study area due to increased desertification and barren land, which could lead to significant loss of topsoil and further affect the health of nearby forests. During heavy rainfall, significant downpours across a barren landscape can also contribute to increased landslides, mass movement soil erosion and flash flood across the Rudraprayag district.

According to satellite imagery of land use (Fig. 3), in 2010, the forest occupies 51.24% of the total geographical area of Rudraprayag district and is followed by agriculture (20.25%) and open tree (12.25%). Land use/land cover map (LULC), 2020 based on Landsat TM. Overall, the habitat of the Evergreen / Semi-evergreen Forest and the lush forested areas have the largest area (989.17 km<sup>2</sup>) 49.89% and (72.76 km<sup>2</sup>) 4.03% of the total study area. Snow cover land accounts for (371.37 km<sup>2</sup>) 18.73%, agricultural land and rural settlements (322.90 km<sup>2</sup>) 16.28%. To explore the sub-regions of the LULC, another part of the world lies in the Scrub Forest (87.17 km<sup>2</sup>) 4.39%, the rocky terrain (48.0 km<sup>2</sup>) 2.42%, the grazing land (47.10 km<sup>2</sup>) 2.37% and the construction (2.54 km<sup>2</sup>) 2%.

According to the Land use / Land cover map (LULC) (Fig. 4), in 2020; Evergreen / Semi-

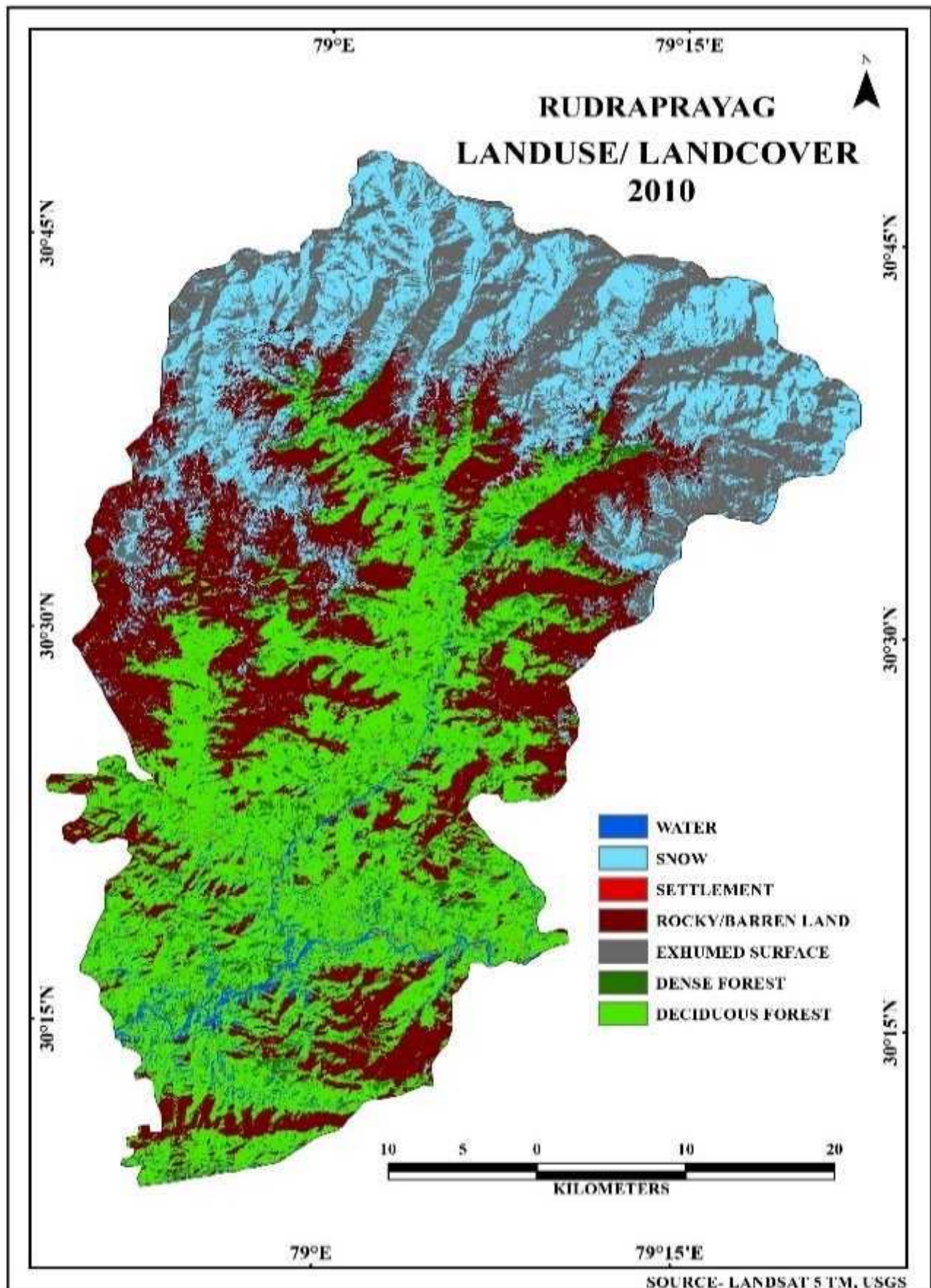


Figure 3. Land Use/ Land Cover Map of 2010

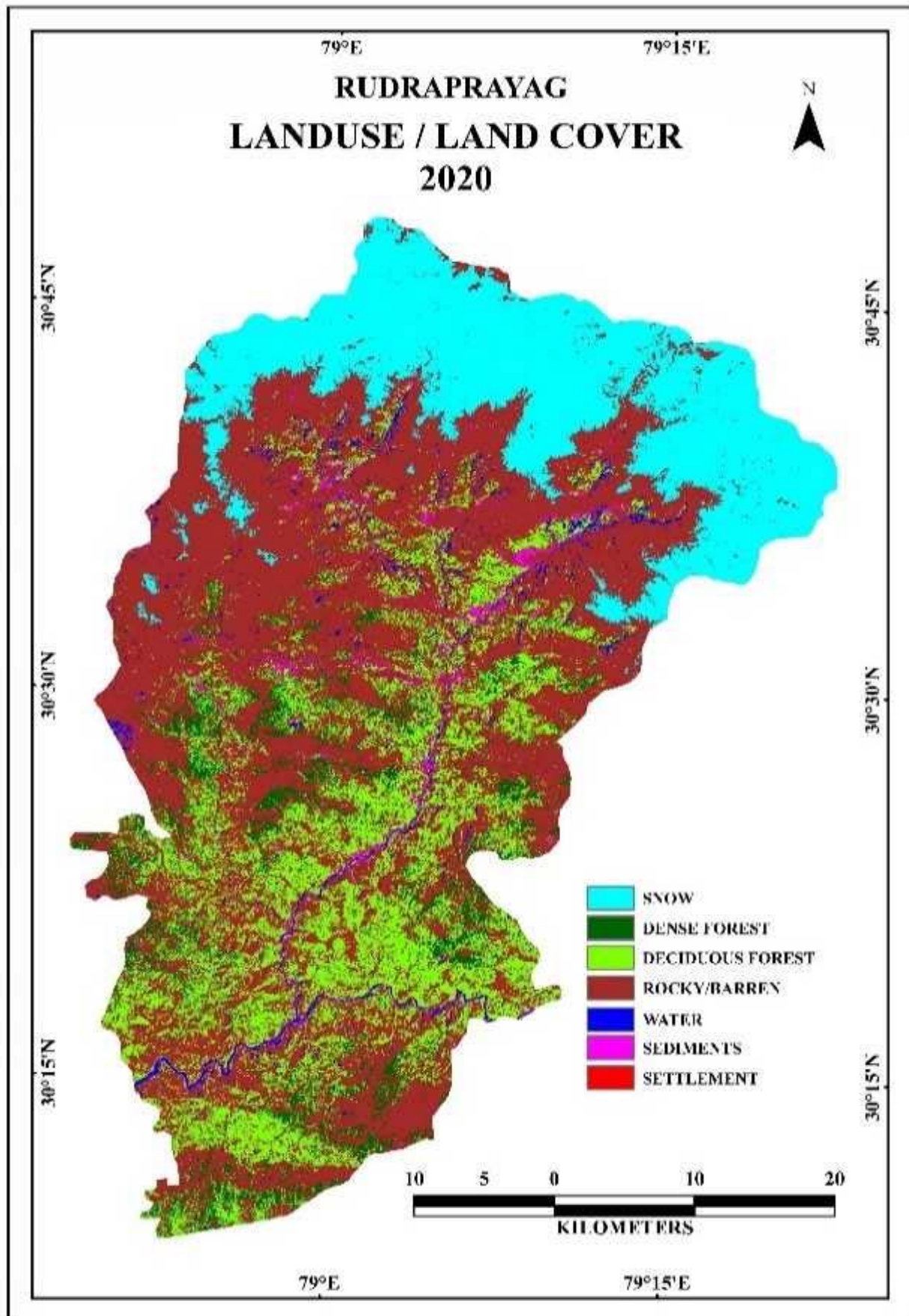


Figure 4. Land Use/ Land Cover Map of 2020

evergreen Forest and the lush forested areas have the largest area (989.17 km<sup>2</sup>) 49.89% and (72.76 km<sup>2</sup>) 4.03% of the total geographical area of Rudraprayag district. Snow cover land accounts for (371.37 km<sup>2</sup>) 18.73%, agricultural land and rural settlements (322.90 km<sup>2</sup>) 16.28%. Assessing minor LULC categories, some portion of Rudraprayag district is occupied by Scrub Forest area (87.17 km<sup>2</sup>) 4.39%, barren rocky land (48.0 km<sup>2</sup>) 2.42%, pasture land (47.10 km<sup>2</sup>) 2.37% and built-up (2.54 km<sup>2</sup>) 0.13%.

An assessment of the period from 2010 to 2020 indicates an increase of 12.13 km<sup>2</sup> built-up area across Rudraprayag district which indicates that the natural landscape was greatly altered to cater to the needs and demands of the growing population (Mondal et al. 2015). In Rudraprayag district experienced a decrease in forest cover between 2010 to 2020 and an increase in agricultural area, barren land, scrub and settlement area. The forest cover is likely to decline further due to commercial exploitation, urbanization and expansion of agricultural land. It has been observed that the Mandakini River and all its tributaries, is complicit in accelerating soil erosion, mass movements and degradation of banks due to improper land-use practices and landslides that have started in Rudraprayag. These sediments were dumped at various places along the river and in many places the river also changed its course. In this way, Rudraprayag is changed into highly vulnerable due to improper land-use practices and decreases in forest cover areas likes Augustmuni, Sari, Guptkashi, Phata, Sonprayag, Semi, Gaurikund, Tilwara, Rudraprayag, Barsu, Saud and Ranigarh in Rudraprayag.

According to the physiographic division of Rudraprayag (Fig. 5), the North part (Ukhimath) is more vulnerable to flood hazards. The topography of the surrounding area appears to be controlled by structural and lithological factors. Kedarnath Peak (6,940 m), Bisuri Dhar (4,008 m), Kheri Dhar (3,768 m), Ragsi Dhar (2,818 m), Sumeru Mountain (6,350 m) and Bharat Khunta (6,578 m), Mahalaya (5,970 m), Tungnath (3886 m) and Hanuman Top (5,320 m) are the most famous peaks but these are all area is the highly vulnerable area (Khanduri et al. 2018). The area thus exhibits high relative relief. The presence of overburden on steep slopes and high precipitation makes this area prone to landslides.

### **Causes of Hazards in Mandakini River Basin, Rudraprayag**

The Likert scale was used to assess people's perception of the causes of hazards in the Mandakini river basin, Rudraprayag. Issues of eco-development practices within the village and city community were identified, assessed and analyzed. It was also designed to determine and identify the subject's opinion. The categories in the Likert scale are specified in five values. the most Vulnerable causes are numbered 1, while the least vulnerable causes have a numerical value of 5, in this way we have categories the 5 types of vulnerabilities or responses that have been identified, such as Strong Agree (5), Agree (4), Uncertain (3), Disagree (2), and strongly disagree of responses (1) (Likert 1932; Pandey and Prasad, 2018.) Urbanization, improper land-use practices, overgrazing, steep-slope cutting and various development works, Steep-slope cutting, deforestation, haphazard construction, encroachment of drainage system and heavy rainfall are the main driving factors for geo-environmental, topographical and geological hazards particularly soil erosion, mass movement, landslides and rockfall in the Rudraprayag district (Table 1).

Hazards and disasters are caused by both causes of man-made activities and natural causes. Slope cutting due to road construction, haphazard settlement, deforestation, and encroachment of drainage systems are major causes as the source of soil erosion, landslides and major floods. Heavy rains, excess food, tourism and associated activities have been identified as other risk factors and factors associated with landslides and major floods. Deforestation and slope cutting are major causes of natural disasters in the Mandakini River basin. Extreme levels of a flood, flash flood, landslides, soil erosion, forest fires, the impact of Glacial Lake Outburst Flood (GLOF), and mass movement, rock falls are major hazards in the Rudraprayag district.

### **Agriculture Practices and Tourism Challenges in Mandakini River Basin, Rudraprayag**

It is traditional agriculture practice that has become a way of life, as it provides livelihoods to the local people/communities. Being far away from the main stream development, throat cut capital generation and modern waves of civilisation, people of this region

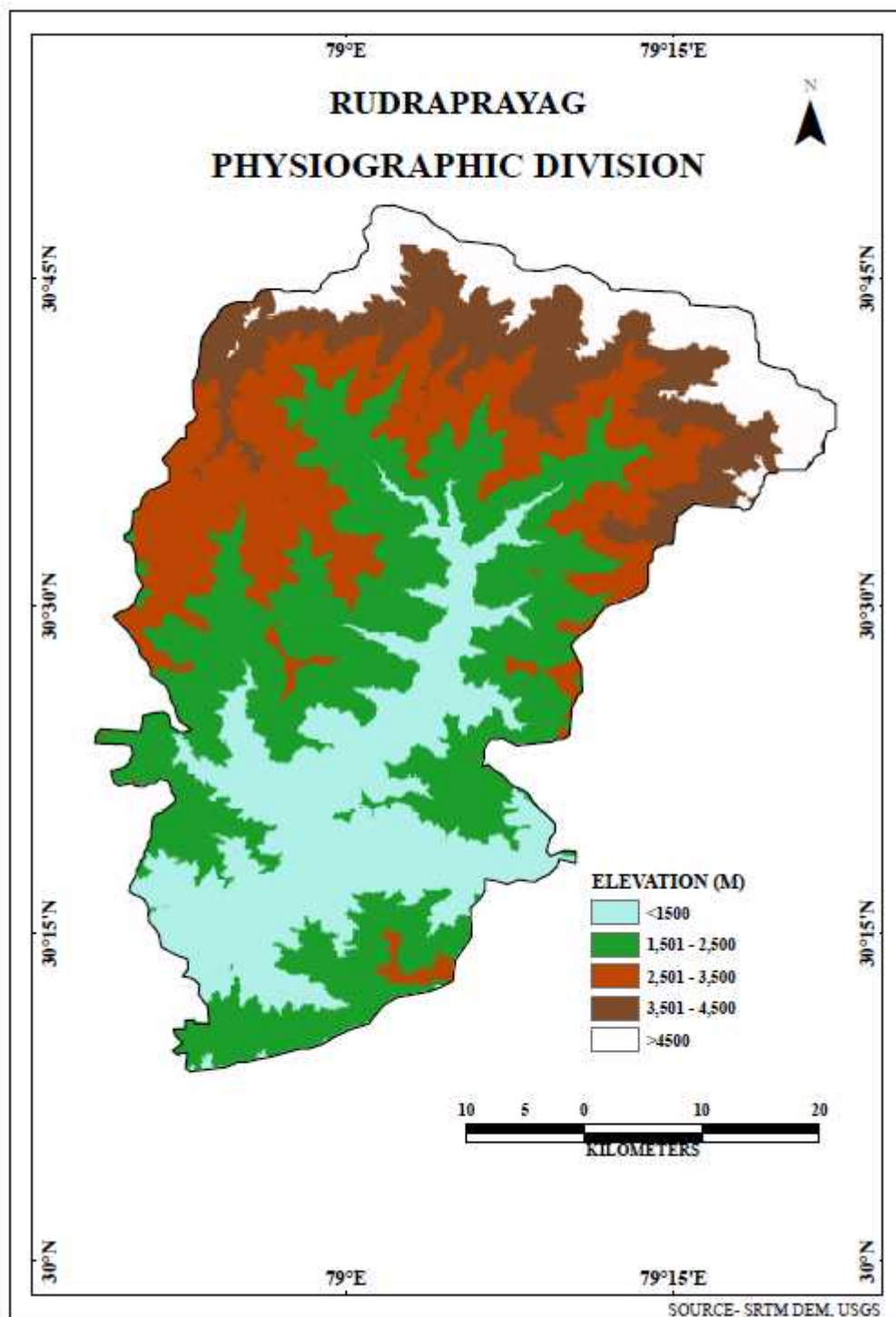


Figure 5. Physiographic Division of Rudraprayag District

are minimal wealth generators, rich at their social and cultural knots as they are mainly dependent on the output of traditional agriculture farming for carrying their livelihoods (Fig. 6).

Rich in natural resources and biodiversity, the benefits are drawn by the community is minimal, just to fulfil their requirements. Natural resources

are less commercialized across the district and still, the optimal benefit from natural resources is not drawn. Further, sustaining livelihood through traditional agriculture practices has limited scope.

The Garhwal Himalaya is an abode of pilgrimage, sacred sights and is famous for eco-tourism worldwide. Visiting highland shrines from Kedarnath

Table 1. Causes of Hazards in Mandakini River Basin, Rudraprayag (in Likert scale: 1 to 5)

Cause of Hazards/ Disaster	Landslides	Flood	Avalanches	Cloudburst	Rock-fall	Soil Erosion
Deforestation	5	5	3	4	4	5
Slope cutting and construction of Roads	5	0	2	0	5	5
Haphazard Constructions and Settlement	4	4	1	0	2	5
Improper Draining on slopes area	4	1	1	0	2	5
Overgrazing	3	0	0	0	3	4
Steep Slopes Cutting	3	1	4	0	3	3
Heavy Snowfall	0	1	5	0	1	1
Glacial Lake Outburst Flood (GLOF)	0	4	1	0	1	2
Heavy Rainfall	5	5	2	3	2	4
Improper Land Use Practices	2	1	1	2	1	2
Tourism Activities	2	1	1	1	2	1
Faulty or Improper Agricultural Practices	1	1	1	1	3	5



Figure 6. Traditional Agricultural Practice, Triugi Village, Rudraprayag, Uttarakhand

(abode of Lord Shiva), Tungnath, Trijuginarayan, Ukhimath, Guptkashi and many more shrines, organising local fairs and festivals and performing rituals has its importance across India and the world. Pilgrimage tourism, eco-tourism, adventure-tourism therefore, may be promising sectors for socio-economic development. Such tourism sector has both positive and negative impacts on the socio-economy and the environment respectively (Sati 2005, 2014). On the one hand, pilgrimage tourism provides

employment opportunities for the local people which can enhance the socio-economic status of the people; on another hand, it degrades the cultural and natural environments. It has already been noticed that the areas where pilgrimage tourism is performed, have attained a reasonable socio-economic development in the Garhwal Himalaya (Sati 2015). It is the impact of anthropogenic activities on the natural ecosystem. Anthropogenic activity has led to devastation in the form of landslides, debris flows, mass evacuation

and flash floods due to development constructions and environmental degradation in the Mandakini river basin, Rudraprayag.

### Management and Planning for Livelihood Security and Disaster Risk Reduction

**Land use and Open Space Planning:** Land use & land cover control management and open space planning are most important for adaptation and management practices to flood management. Open space planning and land use mapping are used in the identification of risk zone areas and planning for disaster risk reduction (Prasad et al. 2016).

### Structural measures for flood management and its Sustainability in Rudraprayag

In general, there is a tendency of the meander to shift progressively downstream area in Garhwal Himalaya. The banking erosion process, therefore, operates consistently and banking protection measures are a recurring requirement. Anti-erosion activities are often taken to protect the area of nearby the river basin, tourist area, densely populated areas, riverbanks, slope area, deforested area, high altitude area and roads (Fig. 7).

Dams, flood embankments, levees and the works taken up for their protection against erosion etc. are regularly inspected during floods for identification of vulnerable spots and immediate measures to strengthen them are implemented. We can propose soil erosion control plans on steep slopes or high-altitude areas by covering the ground with grass or

possibly elsewhere covered with stones in the nearby area of a drainage system.

### Rural Livelihood and Sustainability for Disaster Risk Reduction (DRR)

Agriculture, livestock husbandry, local tourism, forest resources provide the basic needs for a subsistence economy in the rural area of Rudraprayag. The use of non-timber forest products (NTFPs) provides the basis for a market economy, with marketable products (Srivastava et al. 2020). This diversification clearly shows a steady rise in the importance of off-farm incomes in contributing to the family income as compared to farm incomes and a corresponding rise in the household expenditure on food (Joshi 2014, Mishra et al. 2019). The rural population is realising that just glorifying traditions can no longer sustain a growing population because the carrying capacity of 'Jal, jungle, and Jameen' (water, forest and cropland resources) has exceeded to sustain the present population (Singh and Hietala 2014). The risk facing discriminated or marginal communities in Rudraprayag must be addressed directly with adaptation measures. (a) reducing the risk of major impacts (b) increasing resilience to environmental changes affecting health. and (c) improving the cohesive social environment. This includes crop insurance to reduce losses due to planting failures or weather events, an early warning system to prevent loss of life and property in extreme cases, flood mitigation measures and water resource



Figure 7. Anti-erosion work, Rudraprayag



Figure 8. Diversity of Livelihood Options, Ukhimath, Rudraprayag

management. (d) Increased resilience: Resilience to climate change can be built by promoting resource conservation and conservation of biodiversity and livelihoods that these communities must maintain their livelihoods. (e) Livelihood diversification (Fig. 8) and (f) creation of alternative and sustainable livelihood opportunities are essential if these communities have to preserve their way of life.

Capabilities of local communities to adapt to climate change by enabling decision making through better data and information, supporting systems such as crop insurance, enabling micro-scale institutions and social-finance networks, indigenous knowledge sharing, marketing, etc. needs to be increased (Sati 2012). Warning and Monitoring Systems Earth viewing satellites provide complete and timely coverage of large areas in real-time and at regular intervals, which can be used for detailed monitoring, damage testing, and long-term relief management. However, a system is needed to provide quick access to land view data in a way that applies to those on the ground in an emergency.

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depends on how well a community makes use of available natural resources in its adaptive strategies.

In the agriculture field, some adaptive steps can be included for sustainable and diversified development. (Fig. 9): (a) Intensity in agriculture, (b) Crop diversification, (c) Value addition crop (d) Indigenous technology, (e) Marketing, (f) Crop cycle management which includes pre-flood cultivation, cropping with floods; Finally post-flood farming (planting late varieties that can withstand waterlogging).

To cope effectively, with their traditional practices and knowledge, people living in flood stressed zones manage their life effectively. But it is observed that policymakers and the brass concerned are least concerned about such traditional knowledge and methods. Documentary efforts of such information can help to make dynamic practices more widely known and more widely publicized for sustainable policy.

Changes in the land use pattern, application of scientific methods of cultivation, commercial exploitation of the forest cover and illegal felling of trees are some other important factors affecting the ecological system of the river basin. As already pointed out, most of these changes in Rudraprayag that have taken place over the years in the land use pattern include: (i) bringing of the larger part of the cropped area under the network of modern methods of cultivation namely, double cropping, high-yielding varieties and multi-



Figure 9. Diversification and Intensification of Agriculture Pattern, Rudraprayag

cropping patterns: (ii) a large increase in the area under orchard cultivation. Some suggestions are for the land use and land cover practice for improvements through local communities: (1) The right to the forest must be granted to the Panchayati Raj Societies (Gram Panchayat, Block Panchayat and Jila Panchayat) for cultivation, protection and management. (2) The functions of a community-based institution such as Van Panchayat, Mahila Mangal Dal, Youvak Mangal Dal, Self Help Group (Fig. 10) must be clarified by

the Government and the Department of Forestry on their protection, investment and management. (3) Public and community awareness campaigns should be conducted to educate people about the causes and effects of climate change and how to reduce these changes. (4) The prevention and control of forest fires through public participation and awareness. (5) A clear forest protection and management policy must be applied to the relevant government departments. (6) The Department of Environment, Forestry and



Figure 10. Mahila Mandal Samooh, Rudraprayag

Climate Change or irrigation must take steps to conserve rainwater through Chals and Khals. (7) More and more plantations and cover the grass should be done around the water bodies and drainage system.

Policies for environmental conservation and socio-economic development need to be framed and implemented. Currently, there is a growing awareness of the impact tourism has on the local economy, environment and society. With increasing awareness, sustainable tourism ideas have become increasingly accepted. It states that tourism must be part of a balanced economy that must respect local culture, and be a provider of long-term economic benefits, must have a positive attitude towards the environment, and address the needs of the people involved.

The Mandakini valley is home to many pilgrims and tourists centre as a religious, pilgrimage and eco-tourism e.g., Kedarnath temple, Trijuginarayan temple, Ukhimath, Kalimath, Madhyamaheshwar, Makkumath, Tungnath and Chopata in Rudraprayag. Therefore, this area is visited by a large number of tourists.

## CONCLUSION

The Uttarakhand calamity in the Mandakini river basin turned into a disaster mostly due to the construction of settlements, encroachment of river basin, improper land use/land cover practices along the streams and major rivers, as it was found that most of the casualties occurred in these locations. Non-Structural planning, mock drill, training programme within the community are good practices for disaster management. Mock drills in every affected village were conducted. In Rudraprayag district, many local or community disaster management committee/cell has been formed or ongoing process likes in Khariya and Phata village (Ukhimath block), Koti, Falai, Balsundhi and Arsoudandia village (Agustyamuni block), Ginda, Kishanpur and Mastari village (Bhatwari block), Dewara and Benol village (Mori block) of Rudraprayag district, Mandal, Maithana and Mandaprayag village (Dhasoli block) of Chamoli district. Thus, wherever NGOs and Panchayats work in coordination, the community was sensitised to various activities of Disaster management.

Rural families use good practices of diversified livelihood options, and a diverse range of income to meet their needs, including agricultural practices, using Common Pool Resources (CPRs) and other economic activities. The study suggests that community-based vulnerability and adaptations assessment awareness programmes can be addressed at the grassroots level by helping farming communities adapt to the system around their water bodies and mountainous regions, and it also indicates what those communities can do to recover from future floods events under climate change conditions.

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**Conflict of interest:** Authors declare no conflict of interest.

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