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Vegetation Loss and Ecosystem Disturbances on Kedargad Mandakini Subwatershed in Rudraprayag District of Uttarakhand due to Torrential Rainfall during June 2013

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Abstract Uttarakhand is one of the hilly states in the Indian Himalaya. It lies in the Northern part of India between the latitudes 28^0-31^0 N to longitudes 77^0-81^0E having a maximum dimension of east - west 310 km and 255 km; north - south covering an area of 53,484 km^2 with the elevation ranging from 210 to 7817 msl. It is the home to many holy rivers originating from the nearly 1439 glaciers. In view of the changing climate followed by factors responsible for varying nature of climate and its effect on environment basically related to vegetation phenology, biodiversity as well water resources especially in mountain region of Uttarakhand Himalaya which is well known for its rich biodiversity in perspective of socio-economic well-being of the rural people and forest dwellers; the natural devastation or any kind of calamity affect the native of the region due to their dependencies in the services provided by the nature which we call ecosystem services. The devastation caused during 16^{th} & 17^{th} June 2013 in Kedarnath valley on Kedargad micro watershed, of Mandakini sub watershed in Mandakini valley of Rudraprayag district, Uttarakhand Himalaya is one of the major devastations that have ruined the climate and ecosystem of the area to a greater extent. In the present study it is studied that how this devastation has affected vegetation by perturbing ecosystem services. It was noticed that after devastation forests and alpine is major region where a remarkable change was detected. A major change in river is also noticed.

Keywords *Vegetation; Ecosystem Services; Kedargad; Rudraprayag; Climate Change*

1. Introduction

Global change, whether generated from climate, land use change, biological invasion, global economic forces etc., will certainly affect the relationships that are part of the land and economies of the Himalayan region. Recognizing that global change and in particular global warming has and will have serious impacts on biophysical environment and the socio-economic conditions and livelihoods of people in Himalaya and adjacent plain areas. It will also affect species composition and diversity, habitats and the occurrence of rare and endangered species as well as invasive species in high

altitude areas, thus jeopardizing the conservation value of Himalayan protected areas and their wider environment (Maikhuri et al., 2000, 2001; Rao et al., 2002; Nautiyal et al., 2001). Further it is impacting glacial retreat – thereby affecting freshwater supplies etc. The Himalayan region is one of the most dynamic and complex mountain ranges in the world due to tectonic activity and they are vulnerable to global climate change and increasing human activities. Recent climate changes have had significant impact on high-mountain glacial environment. The previous study shows that the formation and expansion of moraine-dammed lakes, creating a potential danger from dammed lake outburst floods are the result of rapid melting of snow/ice and heavy rainfall (Dobhal et al., 2013). Because of altitudinal variation in the Himalaya, climate differs from high to low elevations, similarly natural resources, water etc.

Uttarakhand is one of the hilly states in the Indian Himalaya. It lies in the Northern part of India between the latitudes 28^0-31^0N to longitudes 77^0-81^0E having a maximum dimension of east - west 310 km and 255 km north - south covering an area of 53,484 km^2 with the elevation ranging from 210 to 7817 msl. It is the home to many holy rivers originating from the nearly 1439 glaciers. Total snow and ice reserves of the State constitute about 20% of its total area. Due to rich biodiversity this area provides many eecosystem services, in a strict sense, all those services generated as a result of interaction and exchange between biotic and abiotic components.

1.1. Ecosystem Service in the Mountain of Uttarakhand

The flow of energy is mediated by interacting organisms within ecosystems, and material which contribute towards many ecological services and goods to all the organisms including human beings. The important, undetectable but essential services include formation of good humus soil, decomposition of raw material, carbon sequestration and exchange of gases and their balance in atmosphere, derivative of climate and mitigation of climatic change, nutrient cycling, facilitation, assembly of community and succession and climax, water recycling recharge structure and air filtration, flood and drought control, regulation of water supply and many other services such as of recreation, aesthetic and religious values. The important Ecosystem goods and services include food, fodder, fiber, resin and drugs derived from many valuable plants or medicinal plants. This results in high biodiversity, forest cover up to considerable altitude, dominance of evergreen forest, rapid soil formation, agriculture, sericulture and many more.

1.2. Natural Disaster; Its Vulnerabilities in the Region

The region is seismically and ecologically very sensitive and fragile and even small disturbances (natural or anthropogenic) triggers changes that rapidly assumes dimension of the disaster.

The region has history of natural devastations i.e. various landslides and flash floods in the past. The occurrence of recent devastation caused due to torrential rainfall during 16^{th} to 17^{th} June 2013 in Kedarnath (one of the important pilgrims place out of four Religious places/Dhams situated in Uttarakhand State) witnessed unprecedented damage to the life and property, infrastructure, and landscape. The well exposed central crystalline rocks groups in the Higher Himalaya of Kedarnath valley form the oldest crystalline basement of the Himalaya, which shows fragile nature of this region. This might be one of the triggering agents in the region for landslides etc., which lead to further devastation.

The mountain region of Uttarakhand Himalaya which is well known for its rich biodiversity in perspective of socio-economic well-being of the rural people and forest dwellers, needs an understanding the impacts of this devastation and its forthcoming climatic effect in relation to vegetation phenology, biodiversity as well water resources there is a need of carrying study and analyzing climate implication vegetation loss and perturbing ecosystem services on Kedargad micro

watershed, of Mandakini subwatershed in Rudraprayag district, Uttarakhand Himalaya after June devastation 2013.

2. Study Area

The present study was carried out along an altitudinal gradient in the temperate forest of Kedargad Micro watershed Mandakini Watershed of Rudraprayag district, Uttarakhand, India. It lies in the Central Himalaya between the latitude 30°37'45.47"N and 30°48'23.93"N and longitude 78°59'59.91"E and 79°2'7.582"E with a total area of 9515.46 hectare (95.15km^2). A total study area lies from 1,648 m – 7,000m altitudes from msl.

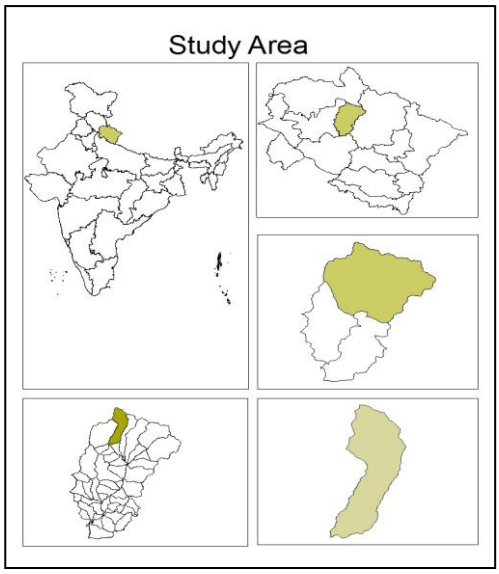

Figure 1: *Study Area Locating Kedargad Microwatershed in Uttarakhand Himalaya, India*

2.1. Geology of the Regions

The Kedarnath region is situated in the lap of two glaciers i.e., Chaurabari & Companion. The covered area of Chorabari glacier is nearly 4.23 sq.km upto a distance of 7 km approximately while that of Companion Glacier which is around 3.59 km in coverage and spreading upto a length of 5.79 km approximately (Dobhal et al., 2013). The area represents wide range of altitude (1600 m at Sonprayag to 6500 m at upper reaches), most of the area covered by snow-glaciers. Geomorphologically this area comes under valley glaciers and highly dissected hills and valley with moraines and piedmont slopes.

2.2. Climate & Soil

The elevation of the study area ranges from 1600 m to 6500 m from above sea level the climate of the region very largely depends on altitude. The winter season is from about mid-October to April. As most of the region is situated on the southern slops of the outer Himalayas, monsoon currents can enter through the valley, the rainfall being heaviest in the monsoon from June to September. The slope of the study area is lies between 30-60^0 and towards the South-East aspect. The alpine habitat usually starts at timberline or the tree line i.e. 3500 masl and are characterized by the complete absence of tree. The soil of the Kedarnath valley is dark brown to brown at surface and brown to yellowish brown in the sub soil and endodynomorphic (Singh and Singh, 1992).

2.3. Floristic Composition of the Region

The floristic composition of study area shows mixed forest of *Rhododendron*, *Quercus leucotrichophora* (Banj), *Quercus floribunda* (Moru) and *Quercus semecarpifolia* (Kharsu), *Buxus wallichiana* (papri), *Acer spp*. (kaijal), *Betula alnoides* (katbhuj), Anyar (*Lyonia* spp.), *Alnus nepalensis* (Utis) upto an elevation and rest the alpine pasture. There are three distinct climatic seasons of Kedarnath, rainy season, summer season and winter season. Majority of the plant species having flowering and fruiting in rainy season, summer season is represented by lesser no plants than rainy season and the rest and very low plant species are representing to winter season. The area is very rich in Medicinal and aromatic plant diversity. This has traditionally occupied an important position in the socio-cultural, spiritual and medicinal arena of rural and tribal lives of India.

3. Methodology

In this study the High resolution remote sensing pre and post disaster satellite imageries (Table 1) acquired over the Kedargad a micro watershed (Kedarnath area to Sonprayag) of Mandakini watershed have been used for detail analysis and damage area assessment. The biomass study was done just a few month back in the area. The occurrence of medicinal plants wealth was also recorded from ground survey as well as literature consultation.

Table 1: *Details of Satellites Data used for Analysis*

S. No.	Satellite Name	Resolution	Date of Acquisition	Pre and Post Event
1.	LISS IV & Cartosat Merged	2.5m	June 2011	Pre-event
2.	LISS IV & Cartosat Merged	2.5m	June 2013	Post-event

Source: Satellite Data Sets were collected from NRSC, Hyderabad

3.1. Data Integration and Analysis

In the present work Integration of Satellite Data & SOI Toposheets by geometric correction was done for the micro watershed. The Digitization on pre and post image was done and Clipping and Marking of damaged area for Analysis and Interpretation of Data was done. Outset of all this was made for Assessment of Pasting vegetation and perturbing ecosystem services in the region.

4. Results

This study was based on pre and post satellite data analysis and a brief reconnaissance survey with additional information from previous research in the study area. The results are presented in form of maps, profiles, charts and statistical tables. The main objective of the present work was to know the loss of vegetation in the area due to flash flood and landslide. The Table 1 depicts the pre and post devastation area.

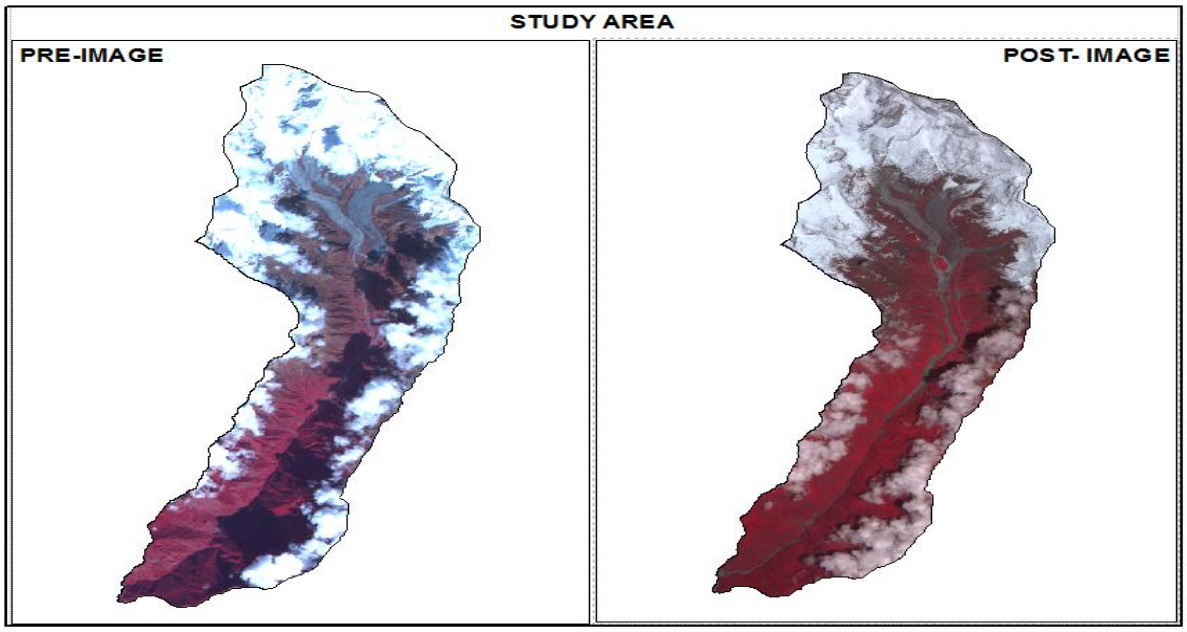

Figure 2: *Kedargad Study Area Showing Pre and Post Image*

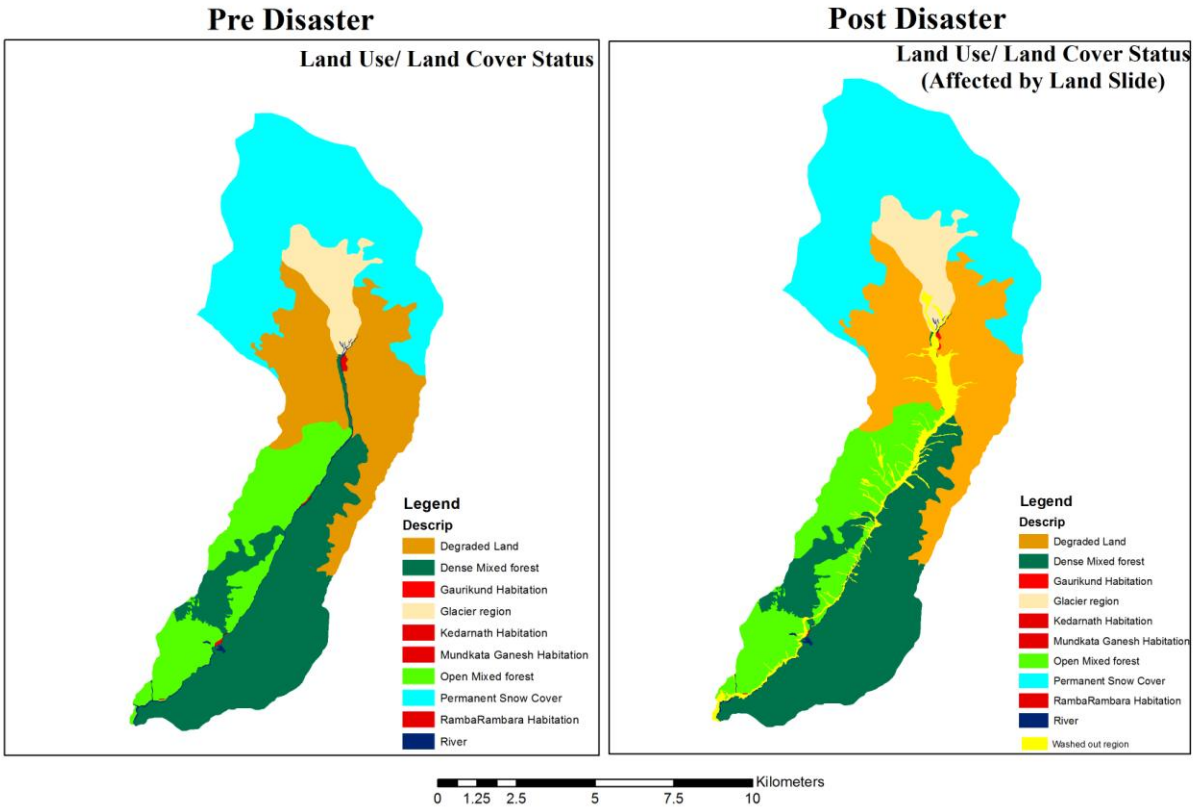

Figure 3: *Landuse Landcover Status of Area Pre and Post Disaster*

Table 2: *Description of Study Area Analyzed and Devastated During Torrential Rainfall of 2013*

Description	Area (ha) (Before Devastation)	Washed out Area (ha) (After Devastation)	Total Remaining Area
Seasonal Snow Cover	3425.76	270.55	3155.20
Dense Mixed forest	1240.98	33.16	1207.80
Permanent Snow Cover	3058.25	0.09	3058.20
Wasteland	92.88	2.23	90.60
Rambara Habitation	1.91	1.91	0.00
Open Mixed Forest	596.55	59.28	537.30
Mundkatiya Ganesh Habitation	0.66	0.25	0.40
Kedarnath Habitation	8.94	8.94	0.00
Gaurikund Habitation	2.84	2.79	0.00
Rambara Habitation	0.33	0.33	0.00
River	48.32	35.57	12.80

The result of present study area is depicting that the main region under seasonal and permanent snow cover. After that the major area is falling under forest and alpine pastures. The river and adjacent habitation are one of the main and affecting units in the region. The pre and post satellite image analysis is showing that there is a major change in seasonal snow cover. After that forests and alpine area is the major region where a remarkable change was detected. A major change in river is also noticed. The increasing river bank was the main cause of devastation of the region. The habitation of Kedarnath, Gaurikund and Rambara was totally washed out.

5. Discussion & Conclusion

In Himalayan region livelihood is directly related to its natural resources. Due to this recur devastation in the region the natural resources has lost to a greater extent. The upper Himalayan region is famous for alpine pastures (a region having rich bio diversity for medicinal and aromatic plants). The hilly region has also been associated with the local tradition and ethical culture. The damage in the region will therefore, will affect the ecological as well as socio-ethno culture of the region. These affect and damage will impact the following as:

5.1. Ecological Damage

The effect of this devastation resulted in ecological damage and further trigger to climate changes that will have significant impact on high-mountain glacial environment. The disturbance in dense mix forest (33.16 ha) and open mixed forest (59.28 ha) clearly indicate a greater loss to ecological cycling. As forests are important natural resources and play a vital role in social, cultural, historical, economic and industrial development of any country and in maintaining its ecological balance. Besides it forests also maintain and improve the moisture regime and provide fresh air and help in nutrient cycling. Floods and perennial streams are moderated by forest. Soil fertility, diversity in climatic and physical setting produces a markedly diverse flora and fauna. Due to this catastrophes (mass wasting, cloud bursts, avalanches) forests have been severely fragmented at many places degraded, causing threat to local extinction to many wild species of plants.

5.2. Climatic Implication/Biomass Loss in the Forest Area

In the present area the biomass estimation study were conducted during 2012 by sampling at ten random plot laid at open and dense forest site. The biomass obtained from that study had shown the 242.24 to 322.97 ton/hac for the mixed forest at the area. The total washed out area from forest was nearly an average 92.44 (open and dense forest). This showed that nearly 22392.66 to 29855.35 tons biomass from the total area is lost at a glance. In natural condition for vegetation growth and

productivity it will took many thousands of year under for regeneration. The biomass and thus carbon sequestration process are directly linked to an ecosystem. From the present area the loss in biomass form the available species extinction is a greater loss for the ecological cycle.

5.3. Medicinal and Aromatic Plants Wealth Loss

This region is well known for the medicinal plants wealth. The high altitude area are the habitats of medicinally important plants due to the varied /or microclimatic condition. The presence of many species according to a survey conducted earlier had shown a greater loss in the region. The plant list present in the area is as follows:

Abies pindrow, Aconitum balfourii, Adhatoda zeylanica, Aesculus indica, Angelica glauca, Artemisia roxburghiana, Boehmeria rugulosa, Boerhavia diffusa, Brugmansia suaveolens, Centella asiatica, Foeniculum vulgare, Geranium nepalense, Geranium wallichiana, Berginia ciliata, Bidens pilosa, Berberis aristata, Berberis lycium, Oberonia falconeri, Ocimum tenuiflorum, Ajuga lobata, Polygonatum multiflorum, Polygonatum verticillatum, Rosa sericea, Satyrium nepalens, Sida rhombifolia, Stephania glabra, Swertia chirayita, Taxus baccata, Vanda cristata, Vitex negundo etc (Bhatt and Vashishta 2008).

5.4. Cloudburst and Landslide Proximity and Losses

The melting of snow and glacier and heavy rainfall has resulted in the formation and expansion of moraine-dammed lakes, creating a potential danger from dammed lake outburst floods. The heavy rains together with moraine dammed lake (Chorabari Lake) burst caused flooding of Saraswati and Mandakini Rivers in Rudraprayag district of Uttarakhand, completely washed away Gaurikund (1990 m asl), Rambara (2740 m asl) and Kedarnath (3546 m asl) towns. The roads and footpath between Gaurikund and Kedarnath were also damaged. There are reports of loss of large number of human lives and damage to the property and livestock.

5.5. Socio-ethno Damage and Livelihood Insecurity

This region is socio ethnically very rich and thus is considered highly vulnerable to climate change, not only because of high physical exposure to climate-related disasters but also because of the dependency of its economy on climate-sensitive sectors (e.g. agriculture, forests, tourism, animal husbandry, fisheries etc.). The dependency on natural resources is highly conferred to local people. The cloud burst has washed out the forest area to greater extend. These forest areas are rich sources of flora and fauna. Beside it the loss in seasonal snow cover and alpine pastures shows a possibility of extinction of the important medicinal and alpine herb of the area. Their socio-ethnic culture depends on the local surrounding which shows that the loss in this region will negatively affect the people. The effects of Climate change lead by disaster was directly on people in their livelihoods, health, and natural resource security. Poverty, poor infrastructure (roads, electricity, water supply, education and health care services, communication, and irrigation), reliance on subsistence farming and forest products for livelihoods all were affected by this disaster.

Recommendation

The natural regeneration process takes many years for a particular area with many changes. The present day environmental condition and demand for today's need can be fulfilled by knowing and utilizing the today's natural wealth.

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