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Critical Analysis of Challenges of Darjeeling Himalaya: Water, Natural Resources, Hazards, and the Implications of Climate Change

Dhiman Mukherjee
Regional Research Station, Uttar Banga Krishi Viswavidyalaya,
Kalimpong (Darjelling), West Bengal -734301

Abstract **– The environment of which land is a vital component, acts as a highly sensitive system to provide the means of sustainability to all forms of life. Darjeeling Himalaya has been bestowed with some of the outstanding natural features, however presently this beautiful hill station faced severe problem from various natural hazard, climate change and other regional specific problem. Keeping this point in mind the present study was conducted from 2008 to 2012 at Regional Research Station (Hill Zone) under the aegis of Uttar Banga Krishi Viswavidyalay, Kalimpong, with a view to find out the impact of various natural resources on Darjeeling himalaya ecosystem. Landslide was a major problem, which can be caused due to deforestation, illegal mining, unplanned transportation and big dam construction. Hilly communities at villages or village cluster with sometimes scattered settlement in Darjeeling Himalayas have made their land into terraced fields, which generally prevents sliding of mud. On the other hand construction of irrigation system and avoidance of slope area for any developmental activity have considerably reduced the occurrence of landslides. Step cultivation is the right choice for mountain production system that could reduce scope for natural hazard. The major source of water supply in agricultural sector is springs or small rivulets locally known as *Jhoras* with only limited discharge available during post monsoon period. Availability of water resource in the form lakes, rivers and streams, and natural springs is one such example in this respect. Sustainable utilization of this natural endowment becomes critical in this part of Himalayan. Loss of biodiversity is another problem which can be very much influenced by climate shifting patterns.**

Keywords **– Biodiversity, Climate Change Impact, Darjeeling Himalaya, Natural Resources.**

I. INTRODUCTION

Darjeeling himalaya environment, has some unique characteristics as it constitutes high and sloping lands, low laying valleys, forests and vegetations of various types as well as river beds and meadows. They are rich repositories of biodiversity and water and providers of ecosystem goods and services on which downstream communities (both regional and global) rely [17]. These unique features of mountain environments tend to be quite sensitive to disturbance and disruption by external factors. Therefore, environmental degradation is an adverse alteration of natural system's integrity, diversity and productivity. This part of himalaya is home to some of the world's most threatened and endemic species, as well as to some of the poorest people, who are dependent on the biological resources [3]. This part of himalaya facing enormous pressure from various drivers of global change, including climate change. Under the influence of climate change, mountains are likely to experience wide ranging effects on the environment, natural resources including biodiversity, and socioeconomic conditions. Realising the importance of mountains as ecosystems of crucial significance, the Darjeeling Himalaya play a crucial role. Darjeeling district lies between $26^0$31' – $27^0$13' N latitudes and $87^0$59'– $88^0$53''E longitudes [2]. The district has two topographical features. Darjeeling, Kurseong and Kalimpong form the hill areas whereas Siliguri is stationed at the foothill in a vast stretch of the plains. The shape of the district is triangular. The total area of the triangular shaped district is 3254.7 sq. km. which is 3.68 percent of the total areas of West Bengal state. The hilly region covers 2320 sq. km. and the remaining 934.7sq.km of the area falls in the Terai and plains. The altitudinal variations of the district range from 150 m at Siliguri to 4036 m at Sandakphu-Phalut with a sharp physiographic [10].

Little is known in detail about the vulnerability of Darjeeling ecosystems to climate change. Intuitively it seems plausible that these regions, where small changes in temperature can turn ice and snow to water, and where extreme slopes lead to rapid changes in climatic zones over small distances, will show marked impacts in terms of biodiversity, water availability, agriculture hazards, and that this will have an impact on general human well being. Nature of the Darjeeling mountains is fragile and poorly accessible landscapes with sparsely scattered settlements and poor infrastructure, means that research and assessment are least just where they are needed most. There is considered opinion about the fact that Darjeeling Hilly Region is one of the richest biological reservoirs among the other hilly regions in the country. As far as record tells us that the richness of its biodiversity is due primarily to its great climatic variations and corresponding to the diverse habitats [19]. Much of the interesting factors that contribute to its wonderfully attractiveness of this sub- Himalaya Region lies in the possibilities of seeing a vast varieties of plant species, animals, birds, butterflies, insects within a short distance. It is nothing but the altitude that causes to happen various climatic conditions at different heights which further combine together to create contrast in forest formation, topography and the physiographic of the land surface, soil type, habitat of animals, availability of varieties of food for biotic components [27]. Geo-climatic variation is so finely defined that an ordinary lay man living in the vicinity of the forest could tell the occurrence of particular species of plants, animals, birds etc at certain pockets of

the hilly region very easily and accurately. Sultry sub tropical zones to the freezing zones of the semi- Alpine Region are the diverse climatic factors in which diverse biological components are known to occur enabling them to not only survive but they have become successful in their life cycle in the best niche. Inspite of all these natural factors combined together to harbour a vast variety of flora-fauna, avifauna in the hills of Darjeeling a number of certain species of these are becoming endangered and their presence in the physical environment at this present situation counts to be very scarce. The tragic scenario is such that some of the plants, animals, birds have become very much threatened and if the trend is not checked in time and concerted efforts are not being made for reverse the ensuing trend these species will surely get extinct from this area [5]. However, little is known about the vulnerability of mountain ecosystems to climate change particularly the Himalayan region.

The Darjeeling farmers are facing numerous unpredictable scenarios related to global warming and climate change [9]. The exponential population increase in recent decades has increased the practice of agricultural land conversion to meet demand for food which in turn has increased the effects on the environment. Clearly much more, and more precise, information will be needed to corroborate the present findings with the various problem associated with the environment of Darjeeling himalaya. This paper highlights the vulnerability of the Darjeeling Himalayan ecosystems to various natural hazards and climate change as a result of their ecological fragility and economic marginality. It is hoped that it will both inform conservation policy at national and regional levels, and stimulate the coordinated research that is urgently needed.

II. Material and Methods

The present study was conducted from 2008 to 2012 at Regional Research Station (Hill Zone) under the aegis of Uttar Banga Krishi Viswavidyalay, Kalimpong, with a view to find out the impact of various natural parameters on Darjeeling himalaya ecosystem. The intensive field survey was conducted in the entire Darjeeling hills including the forests. The authors visited Singhalila National Park, Darjeeling and Neora Valley National Park in Kalimpong and remote far flung areas covering all the altitudinal ranges as low as Siliguri to the as high as Sandakphu. Activities included rapid surveys at block level, thematic workshops, interaction with farmer, scientist and other intellectuals at national and regional levels along with the individual experts in collaboration with institutions that synthesised the available information of the region. The region receives plenty of rains (> 1900 mm annual rainfall) and has a wide range of climates from tropical to sub-alpine. However, 2324.0 mm of monsoon rainfall and 537.8 mm of non monsoon rainfall observed during our study period. The forests in and around Darjeeling have delightful flora and fauna. The soil was sandy loam in texture, high in organic carbon (0.63 to 0.92%), available N (221.15 to 289.36 kg/ha), P_2O_5 (18.32 to 22.36 kg/ha) and K_2O (156.19 to 269.11 kg/ha) content with pH 4.9 to 5.6.

Problems and issues of the region

Darjeeling district forms the hill region of West Bengal under Eastern Himalaya. The eastern frontier of the hill region lies along the rivers Tista and Rangit; beyond it is Rishi-La and Bhutan. The lower regions of the Labyrinth hilly forest-clad ridges have been cleared for the cultivation of world famous Darjeeling tea. The region is located in very strategic position of North Bengal, which touches international borders, viz. Nepal in west, Bhutan in north-east, and Bangladesh in south-east; its northern and southern boundaries touch Indian states Sikkim, West Bengal and Bihar, respectively. Due to their great variation, a wide array of climatic zones is available, which favor the luxuriant growth of diversified and rich vegetation. This region is also the abode of many endemic elements and a number of species which have become rare, threatened or endangered. People living in villages and far-flung areas depend completely on forest resources for maintaining their day-to-day needs like medicine, food, fuel and household articles. Unlike tea estates in Darjeeling-Kurseong region; the sub-division of Kalimpong is covered with dense forestry, some agricultural land and orange gardens along with sericulture. Trends reflecting exploitation of natural resources at rates much higher than those at which these resources get replenished, are presently evident all through the hill. While dramatic increase in per capita resource demand is identified to be the basic cause of widening the gap between resource exploitation and replenishment in the affluent regions, population explosion is argued to be the strongest determinant of such trends. Consequence of these trends appear as deterioration in environmental quality in terms of deforestation, poor biological productivity and utility potential, soil erosion, hydrological imbalances, other natural hazards and socio-economic disparity. With increasing elevation the Darjeeling hill are characterised by i) lower rates of abiotic, biotic and cultural exchanges, ii) slower rate of growth, iii) slower ageing and late maturity, iv) poorer reproductive efficiency, and v) higher resistance. Such areas exhibit less visible impact of environmental problems at present. However, the impact of natural hazards increases with increasing elevation. Keeping this aspect in mind present investigation was conducted, to accumulate knowledge about the various challenges faced by Darjeeling Himalaya due to extreme harbours of natural resources and uncareful attitude towards the ecosystem.

III. Result and Discussion

Darjeeling ecosystems were a biosphere reserve, which harbour a wide range of significant resources including animals, plants as well as minerals. Functionally, this plays a critical role in the environment and economic process of the state. The great economic importance's were the uses of the forestry, horticulture, mineral extraction, livestock rearing, tourism, and recreation [24].

This mountain act as orthographic barrier to the flow of moisture bearing wind and control the precipitation in the neighbouring regions. In the upper regions of Darjeeling himalays, large volumes of water were stored in the form of ice. These provide the necessary melt flows into the rivers during the hot, dry seasons. Before roads snaked up the mountains, an upland-lowland interaction was based primarily on the convenience of the upland community. With the increasing population and transport facilities, natural resources and men moved down while the environmental degradation and social ills climbed uphill. Our day to day observation revealed that deforestation, landslides, land degradation, desertification, Glacier Lake Outburst Flooding (GLOF) were some of the common environmental issues in this part of himalaya regions. Mountain areas are also more susceptible to natural hazards and disasters, such as avalanches, landslides, debris flow and flashing floods from landslide dam failure [7].

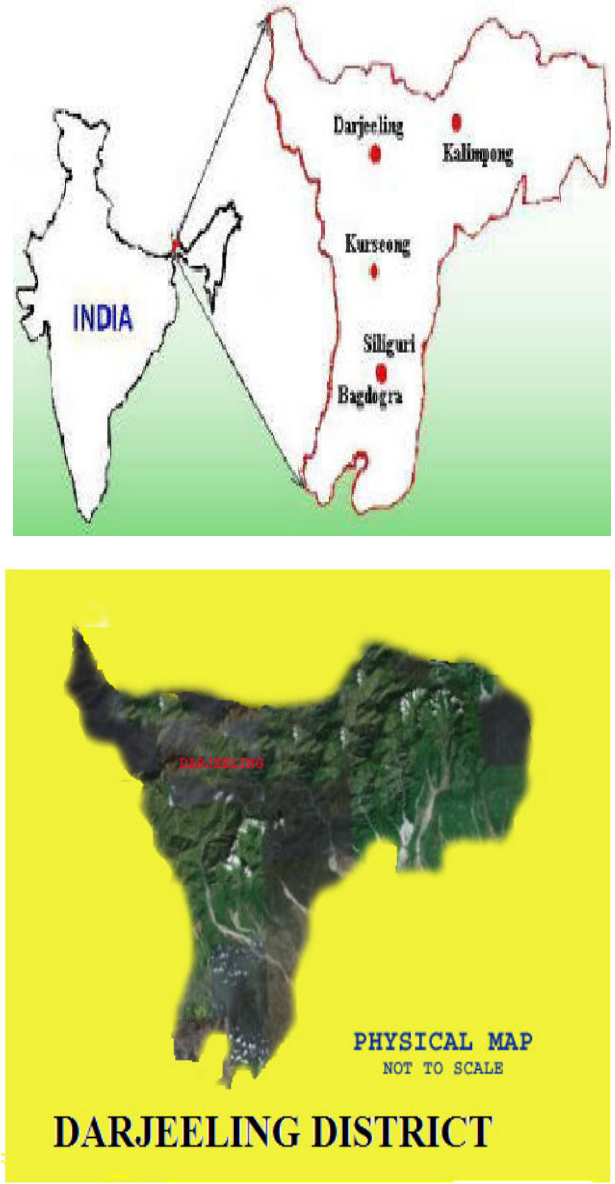

Fig.1. Location of Darjeeling district (study area) of West Bengal, India.

Darjeeling forests were dominated by evergreen broadleaved trees like *Quercus* in the lower reaches from about 2000-2500 m and mixed conifers like *Taxus, Tsuga* and winter deciduous broadleaved species like *Acer, Betula, Magnolia* in the upper reaches from 2500-3000m. The drier south facing slopes support extensive stands of arboreal *Rhododendron* species that were associated with oaks. These forests support rich epiphytic plants of various dicots, orchids, ferns and mosses. Bamboo (*Arundinaria spp*.) is dominant in the understorey. Observation revealed the emerging issues were environment degradation, impacts of global warming and climate shifting. Moreover, terrace systems of cultivation were more sensitive to climate changes.

Environmental Degradation

1. Deforestation

One of the most publicized aspects of degradation was deforestation. Deforestation is the conversion of forested areas to non-forested ones. According to an estimate, almost 19 per cent forests have been lost in the Darjeeling hill. The present scenario of deforestation is particularly grim in this mountain range [18]. In Sandhapukh, Rimbhik and part of Lolegao, Lava,and Rishav in particular of Darjeeling hills, trees are being felled at an alarming rate to provide more land for agriculture and for human shelter. Trees are axed for timber, firewood, cattle ranching and for several other purposes. Observation revealed this would leads to threatening the survival of many endemic and endangered plant species viz . *Swertia chiraytia, Podobhyllum hexandriu* etc. This would effects to enhanced carbon dioxide concentration in the atmosphere because trees that could hold a lot of carbon in their biomass were lost with deforestation. Loss of biodiversity was observed due to habitat destruction, disturbs hydrologic cycle, causes soil erosion, and may lead to desertification in extreme cases [7]. This might be due to trees stabilize the soil with their roots, reduce the intensity of rainfall that hits the ground, and help soils retain moisture. When they are removed, heavy rain can quickly wash soil away, and, during dry periods, bare, desiccated soil may be removed by wind.

2. Soil degradation

Unscientific coal excavation, deforestation, excess pressure in the road transport, rapid urbanization and plastic pollution were the five main reasons of soil degradation and landslides in Darjeeling Himalayas [28]. But degradation of soil cover in somewhat interior region is subjected to crop cultivation and mainly due to loss of top soil by water erosion. Soil on the steep hill slope is shallow in depth with poor water retention capacity and excessively drained with high potential for erosion. The soil of the foothill slope and valleys are moderately deep and well drained with moderate erosion hazards.

3. Landslide and agriculture

The land use practices play the most important role in determining the stability factors in respect of landslide hazards. The land use map of Darjeeling Hill Areas explains that there were agricultural activities, tea and medicinal plant plantations, construction works along with forests, rivers, jhoras etc. The main problem in respect of

land use in the Darjeeling hill areas was related to high density of population. There was very limited scope for extension of agricultural land to cope up with increasing pressure of population. As a result pressure on forested and other restricted areas was gradually increasing. Landslide was a major problem in the Darjeeling Himalayas that can be caused due to deforestation, illegal mining, unplanned transportation and big dam construction (presently two hydro power project work is going on tessta river). Step cultivation was the right choice for mountain production system that could reduce scope for natural hazard. The Blockwise landslide affected areas explain itself the comparative intensity of landslides in the blocks. It appears that the Kalimpong I, Kalimpong II and Rangli – Rangliot blocks are comparatively vulnerable or severely vulnerable regarding landslides. The rate of vulnerability was also high in Kurseong and some parts of Bijanbari and Gorubathan blocks. But as a whole the condition was critical in Kalimpong sub-division, where the land under agriculture exceeds that of the area under plantation or forests. Moreover, these areas were cultivated with root crops like potato, ginger, cardamom and onions. These root crops are harvested just after monsoon in the month of September – October. This particular practice changes the cohesiveness of the soil and makes it vulnerable to erosion

Some basic reasons for landslide in Darjeeling Himalayas

Exploitation of forest resources: Due to result of physiographic, climatic and biotic factors this region till now contains a very rich variety of vegetation. The configuration of mountain and the impact of strong moisture-laden monsoon winds greatly influence the characters of vegetation. The forest areas were heterogeneous but mainly intercepted by terraced cultivation land. Hill forests cover approximately 28% of the North Bengal forests. There is a good scope for community specific study on ethno-medicinal use and forest/biodiversity management of local people that indirectly help in protection of the Himalayan geo-morphology and reduce the scope of landslide. Use of alternative energy resources such as solar energy systems despite fuel wood collection and/or settlement of small-scale hydroelectric dams here and there may also reduce harmful effect of soil erosion.

Illegal mining: Darjeeling rocks of pre-cambian age are lying above the lower Gondwana rocks of permian age. This thin bed lower Gondwana rocks consists of quartzitic and carbonaceous sandstone. This is sandwiched between Daling rocks and Siwalik rocks of Tertiary. As a result of thrusting and tectonic events during the post-permian upliftment of Himalayas, these Lower Gondwana carbonaceous rocks in Damuda series have been greatly crushed as seen in the forms of coal and shale. Illegal mining in this Damuda daling series is also responsible for soil erosion in some pockets.

Road construction: The construction of a hill road involves felling existing vegetation, cutting and blasting stable slopes, and rolling down of resultant debris that in turn destroys vegetation and causes severe erosion resulting landslides. Another problem related to land use and consequent landslide was that in Darjeeling hill areas, roads have never been examined with its carrying capacity respect with geology etc.

Table 1: Altitude variation of Darjeeling along with ecological adaptation and valuable crop under various cropping system.

Area Climate	(Altitude In Meter)	Ecological Adaptation Crops	Agriculture And Horticulture
Lower hills	Tropical (150 – 00 m)	Wet and dry agriculture, sedentary farming, horticulture, livestock. Newly introduce concept of Integrated farming system.	Rice, maize millet, pulses, oilseeds, vegetables, potato, lime, lemon, mango, ginger, mandarin.
Mid hill	Sub-tropical (800 – 1700 m)	Wet and dry agriculture, livestock, horticulture and minor forest produce. Mainly Saal dominated forest	Rice, maize, millet, pulses, oilseeds, vegetables, potato, mandarin, plum, peach, pear, large cardamom.
High hills	Temperate (1700 – 2600 m)	Dry agriculture, Bhutia, Tibetian and Nepali indigenous practices follow	Maize, Blackgram, Soyabean, vegetables, potato, apple, plum, peach, peas
Extreme high hills	Sub-alpine (2600 – 3500 m) Alpine (3500 – 5000 m)	Yak herding, horticulture, pastoral economy (wool, cheese, butter, hides, and potato are commercial commodities)	Mainly used for rangelands, seed potato and vegetables and cultivation of high altitude medicinal plant.

4. *Implications on water system and hazards*

Darjeeling hill is the water towers for the plains below them. The last one-decade has invoked tremendous discourses with reference to misuse of water resource, over exploitation and misuse of water resource and possible threat to our future generations in this regard if this resource is not utilized in scientific and sustainable way [21]. Teesta and Rangeet have their own basins with distinct watersheds and sub-watersheds contributory of Sikkim hill to Darjeeling. These rivers are not only fed by the glaciers but they also benefit from various *jhoras* that flow across their basins. Therefore, conserving and

maintaining small *jhoras* becomes critical in order to maintain the volume of big rivers and the ecological linkages there in [26]. Their conservation and optimal utilization is also crucial as they are the only source of domestic and drinking water across the villages of Darjeeling and other parts of the pressing need for conservation of water resources as it is the most important element in the biosphere since it sustains all sorts of life on the Himalayas [22]. Due to the climate change there have been major trends in the water system and hazards in recent years. These trends are obvious even to the most casual observers. Unpredicted river flows, and frequent floods, droughts and crop failures are becoming annual events last four year in this hill area. Many high altitude lakes are potentially very dangerous. Teesta dams are comparatively weak and can break suddenly, leading to the sudden discharge of huge volumes of water and debris. They can cause catastrophic flooding downstream, with serious damage to life, property, forests, farms, and infrastructure in the doors and Siliguri area of Darjeeling district. The local people of Darjeeling and Sikkim himalaya have over the years evolved efficient water harvesting systems together with their traditional land management systems [23]. Construction of water channels, regulation of water flow and drawing of drinking water were traditionally organized as community enterprises. Our observation revealed that common traditional sources of drinking water are natural springs (locally called dhara, pandhera etc), and streams locally called jhoras or kholas. The locals have traditionally evolved an indigenous method of transporting water from these sources to their houses by using bamboo poles. However, in recent years, rubber pipes have replaced most of these bamboo channels.

5. Biodiversity

Darjeeling Himalaya enjoys the dignity of being blessed with ideal climatic and edaphic factors which favour and add richness to the medicinal plants wealth of the region [1, 3]. It harbours one of the richest biodiversity in the world [4]. Both in a biophysical sense and in terms of the human dimensions of the problems, mountains form a highly heterogeneous landscape. Largely occupied by traditional societies, those living close to nature and natural resources, these mountain societies are linked to the natural forest ecosystem and the human managed agroecosystems through biodiversity driven traditional ecological knowledge [29]. Deforestation on a human scale results in decline in biodiversity, and on a natural global scale is known to cause the extinction of many species [13]. The removal or destruction of areas of forest cover has resulted in a degraded environment with reduced biodiversity. The Himalayan region has lost more than 70% of its original habitat, and is one of the 34 biodiversity hotspots of the world (Conservation International) [8, 15]. The steadily increasing human population in the region has led to large-scale conversion of forests, wetlands and Grass lands for agriculture, and for settlements [10,16]. The erosion of plant biodiversity is a matter of global concern. One by one, the building blocks of entire ecosystems are disappearing. The 2008 IUCN Red List shows that the number of threatened plant species is increasing gradually [2]. Ecological change as a result of global warming, it is estimated, will also be especially catastrophic for Himalayan MAPs because of their habitat specificity and narrow range of distribution. Analysis of tree ring samples of *Taxus baccata, Albies pindrow*, *Abies spectabilis* from various forest stands have provided valuable information on the plant growth and climate relationship [6]. The impacts of climate change are going to be more pronounced for the highly sensitive sub-alpine and alpine species like *Saussurea* spp. Thus, a greater understanding and vulnerability assessment of various species and habitats are necessary, with a focus on their adaptability range. Forests support biodiversity, providing habitat for wildlife; moreover, forests foster medicinal conservation [12]. With forest biotopes of Darjeeling himalaya being irreplaceable source of new drugs (such as taxol), deforestation can destroy genetic variations (such as crop resistance) irretrievably. Our study realised that removal or destruction of significant areas of forest cover has resulted in a degraded environment with reduced biodiversity [25].

I found that few of the most important factors were mostly responsible for the depletion of medicinal plant bio-diversity. These are mainly

- Increasing demand of herbal products, i.e., medicine as well as cosmetic has resulted very high demand of raw plant parts causing tremendous pressure on their natural habitat.
- Shrinking of natural habitat of medicinal plants due to population pressure and other developmental activities.
- Indiscriminate and over exploitation from natural sources.
- Lack of agro-technology of highly demanded medicinal plants such as *Podophysllum hexandrium*, *Taxus baccata*, *Swertia chirayita* etc.
- No serious efforts for commercial scale cultivation.
- Forest fire plays a very devastating role in the destruction of small medicinal plants.
- Illegal trading of banned high value medicinal plants. This situation is being quite common in Sandhapukh and Lava region of Darjeeling hill.
- Excessive grazing by domestic as well as wild animals.
- Cutting of medicinal trees for fuel, timber, etc., and lopping of leaves for fodder and cattle bedding.
- Change in climate and weather pattern.
- Lack of awareness towards this valuable heritage.

6. Climate change and its Implications

The Darjeeling Himalayan region encompasses a diversity of climatic conditions from tropical in the lower elevations to alpine in the high altitudes, which were the regions of complex topography [11]. The hydrological system was largely governed by the South Asian Monsoon, while the relationship between the timing and quantum of monsoon rainfall across the altitudinal variation was less understood. Traditional agriculture is dependent on the specific micro-climatic variations in the localised ecosystems, and thus climate change has major implications on agriculture and adaptation. Global assessment of climate change has concluded that changes

in the atmosphere, the oceans and glaciers and ice caps show unequivocally that the world is warming [9]. These changes have been accompanied by changes in precipitation as well, including an increase in precipitation in the higher latitudes and a decline in the lower latitudes. These changes have also been accompanied by an increase in the frequency and intensity of extreme precipitation events.

The impact of such climate changes in Darjeeling ecosystem is multi dimensional and can be summarized as under:

- ✓ Threat to biodiversity with adverse implications for forest dependent communities.
- ✓ Adverse impact on natural ecosystems such as wetlands, mangroves and mountain ecosystem.
- ✓ Impact on human health due to the increase in vector and waterborne diseases such as malaria.

In the last few decades, farmers in the heavily-forested Darjeeling Hills of the Himalayas had noticed something strange. Rivers and streams were drying up, crop yields were plummeting, and trees have begun to flower long before spring arrives. This is mainly due to, the growth and yield of crops are directly related to the rate of photosynthesis and phenology and their response to temperature, solar radiation and rainfall. The experiences of these villagers match satellite data, according to a new study, suggesting that local knowledge may help climate and biodiversity researchers better track the devastating impacts of global warming in specific areas [20]. Considering the impacts of climate change in terms of changes in rain fall, temperature, blue water flow, green water flow and green water storage, it is clear that the this part of West Bengal is likely to remain water replete. During mid century, the post monsoon rain fall during October-November is likely to experience no change but will decrease in Jan-February period with respect to the base line (1970s). Increase in intensity of rain fall is also a possibility therefore retaining that water for ground water recharge will be a challenge. Even today, the water received as precipitation in the northern areas flows away due to the gradient towards the plains as well as to the neighbouring country. Therefore the strategies in the hill areas to ensure water security in the context of climate change can be as follows:

- ➢ Undertaking rain water harvesting along the hill slopes, especially in the recharge zones, to increase the percolation of rain water and thus result in the recharge of ground water. This can be achieved through digging up of staggered trenches with hedge row. Actions would also include identification of natural aquifers in the region.
- ➢ Initiate development of reservoirs intercepting river and other rivulets for transfer of water from surplus basin to deficit basin in this region.
- ➢ Construct check dams, wherever, feasible for the creation of water reservoirs for harnessing surface water.
- ➢ Increase water storage capacity by building household, community and village level reservoirs and repairing, renovating and restoring existing water bodies
- ➢ The Teesta Barrage Project is an ongoing project having a huge ultimate potential of 9.22 Lakh ha. Out of which, nearly 2 Lakh Ha of potential has been created. A detailed analysis need to be carried out to understand the whether the water flow in the 100 year period from now will remain as per the potential of the barrage perceived now, or it would reduce or increase.

Table 2: Critical ecosystems in the Darjeeling hill with respect to climate change, as revealed during the consultation processes.

S.No.	Critical Habitat	Change Indicator	Example of Observed Changes
1.	Alpine/Subalpine ecosystems nestled between the treeline in 3500 m	✓ Changes in ecotones. ✓ Declining snowfall, glaciations events ✓ Changes in species composition ✓ Growth in unpalatable species, decreasing productivity of alpine grasslands	Transformation of earlier *Taxus*, *Quercus* - *Betula* forest type of vegetation comprising of species of *Rhododendron, Salix, Syringia.*
2.	Cool-moist forests	✓ Loss of habitat ✓ Blockage of migration routes ✓ Less cool and moist weather observed	Decline in population of species of Mantesia, Ilex, orchid and insectivorous plants. Increase population of mosquitoes etc.
3.	Cloud forests of temperate elevations where moisture tend to condense and remain in the air.	✓ Less precipitation and cloud formation during warmer growing season ✓ Loss of endemics /specific flora and fauna ✓ Upward range shift ✓ Desertification of soil, affecting the water retention capacity of forests	Diminish population of *Taxus baccata* and valuable medicinal plant species.

4.	Area with intensive agriculture i.e Mid altitude range.	✓ Reduced agro biodiversity (monoculture) ✓ Low employment/gradual loss of traditional knowledge. ✓ Degradation of soil quality ✓ Potential increase of GHG emissions.	Loss of traditional variety, such as upland variety of rice, indigenous bean, cucurbits and citrus variety. Further loss of underutilized crop also being observed. Pest increase in citrus species.

Table 3: Agricultural crops and indicators of change

Crops	Crops Indicators of change
Ginger	Due to variation in temperature regime, cultivation of this crop become quite challenging. The biggest challenge for ginger cultivation has been to control the soil borne diseases, soft rot, dry rot, bacterial wilt and so on due to shifting of climate. Stunted growth, shrinking leaves, blights etc has been observed in the last five years.
Large cardamom	Shifting of cultivation pattern of large cardamom is quite common and from lower to higher altitude this is now shifting. Spread of fungal disease *Colletotrichum* blight and viral diseases commonly called *chirkey* and *furkey* since early eighties have drastically reduced the production (60 %) and plantation area (almost 50 %).
Cereals and pulses	Cultivation of pulse becomes problematic due to adverse climate change and irregular rainfall pattern. Further, several traditional varieties of rice disappeared such as *Kalo Dhan*, *Punaro, Kanchi Attey, Kagey Tulasi, Thulo Attey, Ghaiyya Dhan, Sanu Tulashi, Seto Tulashi, Thulo Marshi, Tauli Dhan, Baghey Tulashi*. The roots are infected by termites when the rice is in fruiting stage.
Broom grass	Broom grass is a multipurpose agroforestry species in the mountain farming system all along the Himalayas. In the last 10 years, this grass is infested with yellowing of leaves and leaf blight. During winter especially after October the broom grass bushes develop this disease and dry up making the fodder un-palatable to farm animals.
Orange	Test of orange has been changed overtime due to climate change effect. Recently, the productivity has declined owing to diseased trees where potential fruit bearing potency is lost. In addition to this, the old plantations have lost the vigor and majority of them are affected by viral and other disease infestations.
Fodder species	In the recent years, farmers have witnessed that tree fodder production has significantly declined. One of the reasons is pests eating up the leaves before they mature for harvesting especially during the lean season. Some of these preferred trees are *Artocarpus lakoocha* (Badar), *Ficus cunia* (Khasreto), *Ficus benghalensis* (Pate Bar), *Ficus roxburghi* (Nibaro), *Ficus lacor* (Kabro), *Ficus semicordata* (Khanew), *Ficus hispida* (Khasreto), *Morus alba* (Kimbo), *Bauhinia* sp. (Koiralo), *Ficus hirta* (Khasre Khanew), *Saurauia fasciculata* (Gogun), *S. griffithi* (Tatey Gogun), *S. napaulensis* (Gogun), *S. punduana* (Auley Gogun).

7. Improper resource utilization and maintenance

The degradation of natural resources can occur, not just by the action of human interference but also by improper resource utilization practices. Soil erosion and desertification were two of the important cause of wipe out natural resources from Darjeeling hills. The development of the fertile top-soil takes centuries. But, it can be removed very easily due to human activities like over-cultivation, unrestricted grazing, deforestation and poor irrigation practices, resulting in patches of land in Darjeeling. Waterlogging and soil acidity was another problem in high altitude hill to lower dooars part. These were some of the problems that have come in the wake of the Green Revolution under this part of himalaya. Soil erosion from farmland threatens the productivity of agricultural fields and causes a number of problems elsewhere in the environment. An average of 10 times as much soil erodes from Darjeeling – Sikkim himalaya fields as is replaced by natural soil formation processes [14]. Because it takes up to 300 years for 1 inch of agricultural topsoil to form, soil that is lost is essentially irreplaceable. The consequences for long-term crop yields have not been adequately quantified. Our studies to various block levels (Kalimpong Block I) revealed that, amount of erosion varies considerably from one field to another, depending on soil type, slope of the field, drainage patterns, and crop management practices; and the effects of the erosion vary also. Long term loss of soil reduced farmland productivity and damage to the environment from eroded sediments. In recent years Darjeeling farmers have increasingly adopted conservation tillage as a method of cutting soil and water losses by

leaving a protective crop residue on the soil surface [23, 24]. This residue protects the soil from wind and rain and can greatly reduce cropland erosion. Agriculture research at various organizations including UBKV, Kalimpong under this hill zone, has begun to focus on ways of maintaining environmental quality while producing acceptable crop yields.

7.1. Renewable energy

In the past century, it has been seen that the consumption of non-renewable sources of energy has caused more environmental damage than any other human activity in this part of himalaya. Use of solar energy is quit often one can observe in Lava, Rishav and Pedong area of Kalimpong Block I. Solar energy has been used since prehistoric times, but in a most primitive manner. They cause less emission and are available locally. Their use can, to a large extent, reduce chemical, radioactive, and thermal pollution. They stand out as a viable source of clean and limitless energy. These non-conventional sources of energy were quite popular in Darjeeling – Sikkim himalaya. Most of the renewable sources of energy are fairly non-polluting and considered clean though biomass, a renewable source, is a major polluter indoors. Under the category of renewable energy or non-conventional energy are such sources as the sun, wind, water, agricultural residue, firewood, and animal dung.

7.2. Wind energy

Wind energy is the kinetic energy associated with the movement of atmospheric air, and one can observed in the high hill area of Rishav and part of Darjeeling area. It has been used for hundreds of years for sailing, grinding grain, and for irrigation. Wind energy systems convert this kinetic energy to more useful forms of power. Wind energy systems for irrigation and milling have been in use since ancient times and since the beginning of the 20th century. Windmills for water pumping have been installed in many parts particularly in the rural areas of Darjeeling – Sikkim belt under high altitude range. Wind turbines transform the energy in the wind into mechanical power, which can then be used directly for grinding etc. or further converting to electric power to generate electricity.

7.3. Biomass

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities, and its play critical role in village part of Darjeeling himalaya. It is derived from numerous sources, including the by-products from the timber industry, agricultural crops, raw material from the forest, major parts of household waste and wood from this part of north eastern himalaya. Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. Its advantage is that it can be used to generate electricity with the same equipment or power plants that are now burning fossil fuels. Bio-energy, in the form of biogas, which is derived from biomass, is expected to become one of the key energy resources for hill sustainable development. At present, biogas technology provides an alternative source of energy in rural area of extreme east part of Darjeeling himalaya for cooking. It is particularly useful for village households that have their own cattle. Through a simple process cattle dung is used to produce a gas, which serves as fuel for cooking. The residual dung is used as manure. Biogas plants have been set up in many areas and are becoming very popular, through some Govt. project. Using local resources, namely cattle waste and other organic wastes, energy and manure are derived.

Focus on natural resource management

Production, consumption, preservation and distribution are the key processes characterizing resource dynamics. They are also used as social, environmental and economic indicators of development for a given region. In conventional economic perspective, production is looked as a process operating at two levels: primary level - dealing with raw material available from biological (farms, forests and livestock) or non biological systems (minerals), and - secondary level - dealing with value addition to raw material using labor, capital and technology inputs. Production was viewed merely as a means of securing livelihood by the mountain societies and obtaining monetary profits, the core of economic growth, from the production process is recent concern. Surplus of primary produce such as food grains used to be appropriated as contingencies in the event of natural catastrophe or to secure commodities that are not available locally (e.g., farmers settled in high altitudes exchanging surplus potatoes, amaranths and buckwheat with paddy from farmers in low altitudes). Darjeeling hill people values need based exchanges more than opportunities for monetary profits through cash driven market. Realizing the monetary benefits from production processes by the local populace is a recent consciousness in response to growing markets for resources of the region together with emerging technologies of value addition to locally produced raw material at distant places in the lowlands. A critical issue in the present scenario is the growing incompatibility of regional and local development priorities - local populace pressing for improvement in infrastructural facilities, industrial growth and cash crops in order to realize economic benefits and regional imperatives for avoiding the risks of environmental degradation and regenerating the environment degraded in the past (particularly reforestation/afforestation activities). Preservation/conservation owes importance because of fragility of the Darjeeling himalayan environment and considerable damages, whatever be the causal factors, to the Himalayan landscape in the past. Values for conservation of resources are deeply embedded in the religion and culture of traditional societies. With advancement of administered development, the state came forward with legislative/administrative mechanism ensuring environmental preservation/conservation. Agricultural land was the only land use where land ownership rights and use rights of individuals were recognized. Under difficult Himalayan terrain restricting mobility, mountain societies evolved as small cohesive set-ups where decision making process operated locally. Promotion of agroforestry is often advocated to achieve the duel objective of promoting cash economy and environmental conservation. The ineffectiveness of the

afforestation/reforestation programmes is clearly felt, though not quantified precisely. However, the fact that Darjeeling mountain trees are more productive than others, the existence of rich tree germplasm useful to man for his present needs and the capability of many indigenous trees to improve rather than exhaust the soil fertility must be recognised and realized for future research and development in the himalaya. Cultivation of medicinal plants has the possibility of getting ready acceptance by the people as it would help in strengthening the economy over short periods [26]. This is an area which should be given priority in the development planning of the region. There is immense scope for making use of existing production systems to improve the well-being of the people inhabiting harsh hill environments. In the present circumstances when ecology and economy of the region have deteriorated to serious levels, development programmes ought to be framed for both short term and long term gains.

IV. Conclusion

Darjeeling Himalaya suffers from a vicious cycle of development process. This part of Himalaya gone through variable type of human interferes and changes in ecosystem by diverse modification in climate. Climate change is real and underway, so there is a need of impact identification and adoption to cope with vulnerabilities in agricultural sector. Better management practices hold the key to adaptation and mitigation. Little is known in detail about the vulnerability of Darjeeling mountain ecosystems to various biotic and abiotic factors. Intuitively it seems plausible that these regions, where small changes in temperature can turn ice and snow to water, and where extreme slopes lead to rapid changes in climatic zones over small distances, will show marked impacts in terms of biodiversity, water availability, agriculture, and hazards that will have an impact on general human wellbeing. But the nature of the Darjeeling mountains are fragile and poorly accessible landscapes with sparsely scattered settlements and poor infrastructure are means that research and assessment are least just where they are needed most.

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AUTHOR'S PROFILE

Dr. Dhiman Mukherjee

obtained Ph.D degree in Agronomy in 2005, from Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. He has experience in research and extension work in agronomy in various ways for last 12 years. He has an excellent academic record. Presently he is working as Assistant Professor (Senior Scale) and incharge of All india Coordinated Research Project on Medicinal and Aromatic plants & Nodal officer of Agromet Advisory Services, under the aegis of Uttar Banga Krishi Viswavidayalaya. He has to his credit of more than 45 papers published in International and National scientific journal, six review papers, 14 article, 11 book chapter and 3 books. He is recipient of fellow of Hind-Agri Horticultural society and member of editorial board of several reputed journals. He has been coveted with Bharat Jyoti and Indira Gandhi Shiromany Award in 2011 for outstanding achievement and contribution in the field of agricultural sciences and valuable input in the field of rural upliftment in the Darjeeling hills. He receives Bharat Shiksha Ratan Award and Young Scientist Award in the year 2012, for his colossal involvement in the field of research and teaching activity. He has attended several national and international conference and life member of 22 reputed scientific societies.