UNDERSTANDING THE LINKAGES: CLIMATE CHANGE AND BIODIVERSITY IN THE KANGCHENJUNGA LANDSCAPE

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ABSTRACT

The Kangchenjunga Landscape (KL), geographically comprising of a part of western Bhutan, Sikkim and Darjeeling of India and eastern Nepal is one of the most biodiversity rich landscapes in the eastern Himalayas. Although an integrated system of protected areas (PAs) and conservation corridors exists in the landscape, challenges of maintaining the ecosystem services in the context of rapidly changing climate still remains. The paper discusses the trends and projection of climate variability, peoples' perception to climate change, and the implications of climate change on biodiversity and socio-economic systems in the KL. The annual and seasonal temperature trends in the landscape indicate an increase at the rate 0.01 – 0.015^0 C/year, with higher altitudes experiencing greater warming. Considering adaptive capacity, exposure and sensitivity indices, majority of ecosystems in the landscape showed a high vulnerability index range; among the PAs, Mahananda Wildlife Sanctuary had the highest vulnerability. Likewise, among the administrative units, Darjeeling was the most vulnerable compared to Sikkim, eastern Nepal and western Bhutan. Perception studies indicated substantial awareness on part of the communities, showing also considerable concurrence with the scientific research on climate change trends, phenology and agriculture productivity in the landscape. In future, statistical downscaling of the regional climate models would be essential to accurately predict the changes, and to strengthen the regional biodiversity management interventions for the landscape.

KEYWORDS: *Climate change, Impacts, Vulnerability, Biodiversity, Sikkim*

The multi-layered forests of the Eastern Himalayas are specially vulnerable to climate change impacts

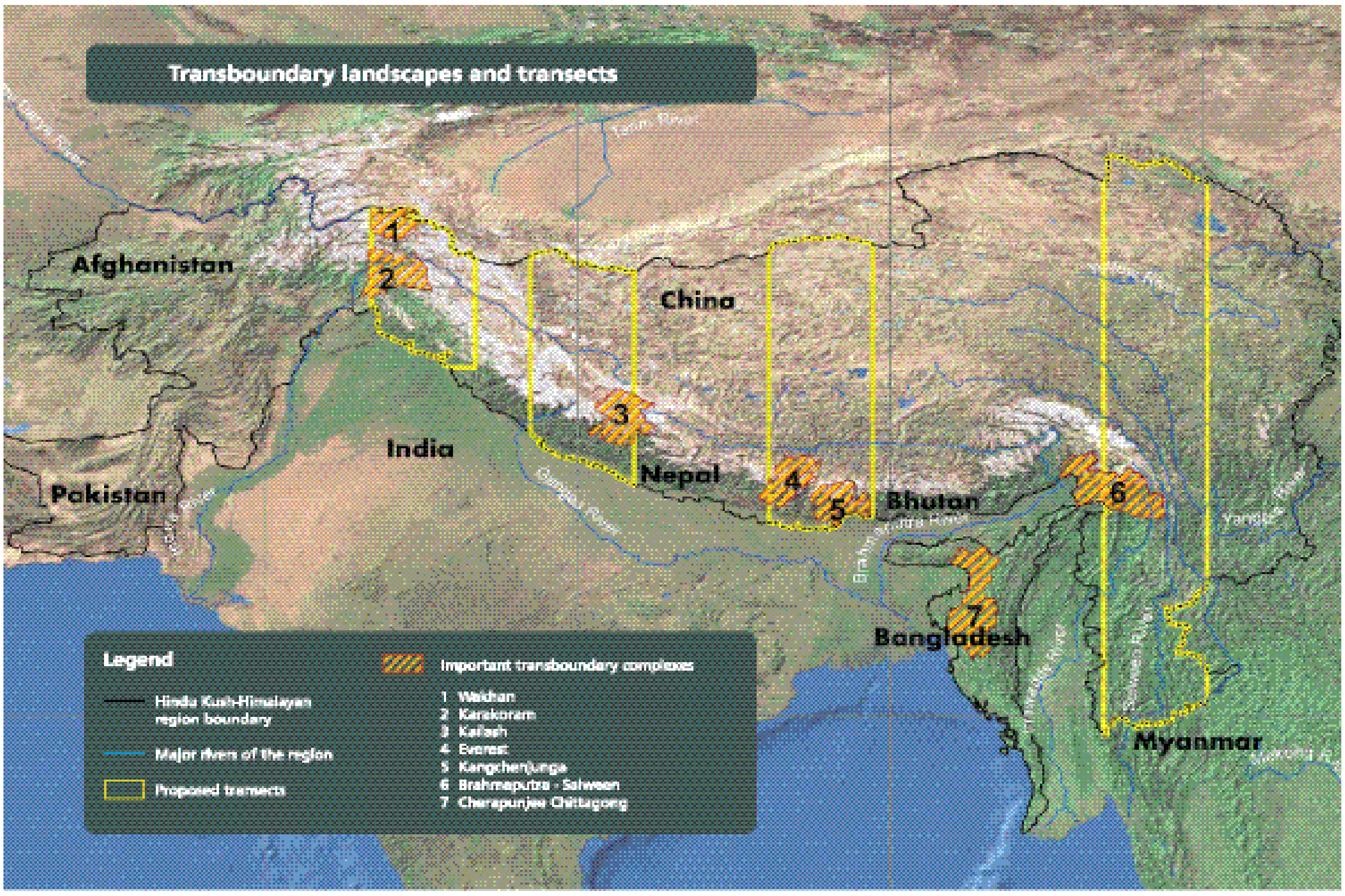
Agricultural fields in Thangu, North Sikkim. Alpine ecosystems are sensitive to the impacts of a changing climate

The maintenance of biodiversity and associated ecosystem goods and services are vital for human well-being, yet despite increase in conservation activities, the loss of biodiversity continues (Butchart et al. 2010). Although habitat degradation, fragmentation, and destruction, overexploitation, and invasive species have driven recent biodiversity loss, climate change is projected to be the major driver of extinction throughout the 21st century, impacting directly and via synergies with other stressors (Parmesan 2006). Climate change and concern over biodiversity loss has put the Himalayan region at the centre of regional and global attention, especially in terms of realising the vulnerability of diverse ecosystems in the context of changing climate, and their implications on the poor and marginalised communities who exclusively depend on the biodiversity resources for their livelihoods (Chettri et al. 2010a). Broadly, the link between climate change and biodiversity is twofold, at one hand biodiversity is threatened by climate change, and at the other, proper management of biodiversity provides significant opportunities to mitigate the impacts of climate change (Fig. 1; CBD 2009).

Fig. 1: Dzongu, North Sikkim: A well maintained ecosystem is instrumental for local adaptation

Climate change affects people's well being in two ways, directly through altering local weather conditions inviting extreme weather events and hazards, and indirectly through its effects on ecosystem goods and services that people need for their sustenance (Xu et al. 2009). Climate change also induces a new set of challenges for conventional biodiversity management of protecting biodiversity within a boundary of 'protected areas or reserves' as many of the protected areas in the region are small and isolated as conservation 'islands' (Chettri et al. 2010a). In order to understand the diverse scale and magnitude of impacts of climate change and other drivers of change on biodiversity conservation and management across the topographic complexity and diverse ecosystem structure in the Himalayas, International Centre for Integrated Mountain Development (ICIMOD) has identified seven east-west 'transboundary conservation landscapes' and 'four north-south trans-Himalayan transects (Figure 1) across the Hindu Kush-Himalayan region (HKH hereafter). The four transects envisages to provide a geographical sampling frame for long term ecological monitoring to enhance the representativeness of climatic, ecological and socio-economic data across the HKH. The seven landscapes focus on promoting the 'ecosystem approach' advocated by the Convention on Biological Diversity (CBD) at the landscape level. One among these seven landscapes is the Kangchenjunga Landscape (KL), considered as one of the most important transboundary landscape in the eastern Himalayas (Rastogi et al. 1997; WWF and ICIMOD 2001).

Figure 1: Trans-Himalayan transects and transboundary conservation landscapes in the Hindu Kush-Himalayan Region



The KL with an area of 14,432 sq km, geographically spreads over parts of western Bhutan, Darjeeling and Sikkim of India and eastern Nepal (Figure 2). The biodiversity richness of the landscape can be weighted by the presence of a network of 14 protected areas (PAs hereafter) and by the diversity of climatic zones, as well as species diversity over a short elevation gradient (Acharya et al. 2011; Chettri et al. 2001; Chettri 2010; Chettri et al. 2010b; Tambe and Rawat 2010). Within a stretch of only 100 km vertical distance, the KL possess diversity of vegetation types ranging from dry deciduous tropical forests to subtropical and temperate broadleaved forests to alpine meadows (Chettri et al. 2008). The biodiversity here comprises of a rich mixture of globally significant habitats; vegetation complexes corresponding to climatic and edaphic variations; and a diverse assemblage of endangered and endemic flora and fauna. Several of the PAs in the landscape host globally significant (rare and endangered species, endemic) mammal and bird species (Acharya and Vijayan 2010; Chanchani et al. 2010; Chettri et al. 2008; Lachungpa 2009) and economically important species (Chettri et al. 2005; Tambe and Rawat 2009); and there are also many high conservation priority zones, and unique cultural areas outside the PAs that reflect upon the diversity of microclimatic habitat or ecological niches in the landscape (Photo 2; Chettri et al. 2008).

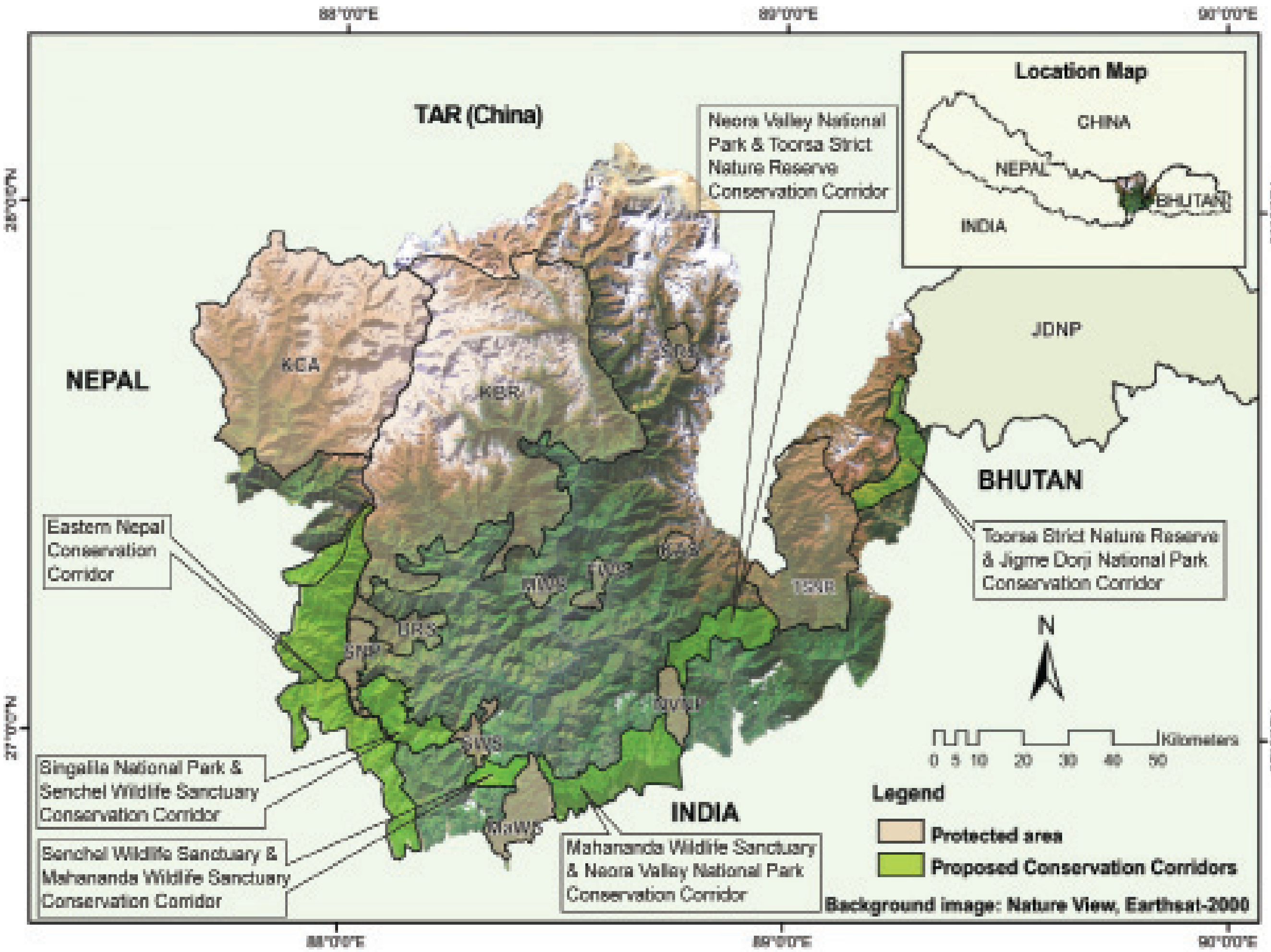


Figure 2: Kangchnejuga Landscape showing protected areas and conservation corridors

Photo 2: Kabi, a scared grove in North Sikkim plays an important role in maintaining biodiversity and sustaining life support system

However, this landscape is facing numerous threats to its biodiversity through habitat fragmentation, poverty, and associated over-exploitation and unsustainable resource extraction (Sharma et al. 1992; Sundriyal and Sharma 1996; Chettri et al. 2002; Chettri et al. 2008). Although, an integrated system of 14 PAs covering 42% of the terrestrial land areas, and conservation corridors adding 11% of additional land to the biodiversity management regime in the landscape has been established (Chettri et al. 2007), there are still challenges related to long term sustenance of ecosystem services in the context of changing climate and the rapidly changing structure and function of ecosystems (Photo 3). The report of the Intergovernmental Panel on Climate Change (IPCC) has indicated that the warming is greatest in the northern high latitudes, and that the warming in the Himalayas is likely to be well above the global mean (IPCC 2007). Given this increased magnitude of warming with elevation in the eastern Himalayas (Tse-ring et al. 2010), climate change implications in this mountain landscape with altitudinal variations over small distances is likely to become more severe.

Photo 3: Glaciers such as Zemu in North Sikkim are important indicators of climate change

Climate change in the Himalayas is already a reality, being felt through erratic and irregular rainfall and temperature patterns and extreme events, melting of Himalayan glaciers and expanding glacial lakes (Photo 4; Xu et al. 2009). Climate change is likely to alter soil and water quality; influence ecosystem productivity, change species composition, reduce population size of montane species, extirpate restricted ranged and isolated species, change species distribution often along elevational gradient; influence phenology, food web pattern, and plant-pollinator relationships and increase the frequency of forest fires and outbreak of pest and diseases (Parmesan 2006) thereby affecting the resource use and management practices, impairing the adaptive capacity and resilience of ecological and socio-economic systems (Chettri et al. 2010a).

The paper attempts to assess: i) the trends and projection of climate variability in the landscape, ii) the nature and magnitude of climate change impacts on biodiversity including people's perception, and iii) the implications of climate change on ecological and socio-economic systems in the landscape. It also briefly elaborates the critical role of biodiversity management at the landscape level being implemented in the KL to facilitate ecological and socio-economic resilience for adaptation to climate change.

Photo 4: Glacial ecosystems are most vulnerable to climate change

MATERIALS AND METHODS

Four major approaches were used while attempting the above mentioned three assessments. Firstly, the trends and projections of the climatic variables were used from climate change regional projection based on a transient HadCM3 model downscaled using HadRM2 and PRECIS (Providing Regional Climates for Impacts Studies; Hadley Centre) regional climate models (RCMs) run under two future Green House Gas (GHG) emission scenarios [A2 and B2 of the SRES (Special Report on Emissions Scenarios)] as described in Shrestha and Devkota (2010). Likewise, the nature and magnitude of impacts on biodiversity was extrapolated from Chettri et al. (2010a). More detailed analysis was carried out for people's perception based on the primary data from 200 odd questionnaires obtained during the survey conducted in 2009 by ICIMOD, from Eastern Nepal, Darjeeling, Sikkim and Bhutan. The perception studies assessed the extent of people's awareness about climate change how people perceived climate change, what they see as important causes behind climate change, what changes are evident as a result of climate change, who are most affected, how people are coping, and what could be the best means to adapt to the impact of climate change. The surveys involved participation of wide range of stakeholders from government official, business people, academics, religious teachers, farmers and other community members.

The paper also referred to the vulnerability assessment in the eastern Himalayas by Tse-ring et al. (2010) and the results were extrapolated for the KL. The vulnerability assessments for ecoregions, administrative units and protected areas (PAs) were based on the climatic exposure, sensitivity of their component ecosystems, habitat and species, and dependencies of human population on goods and services for 89 administrative units, following IPCC (2007). In addition, the sensitive ecosystems, topographic and geomorphological features, isolation and habitat connectivity, human induced fragmentation and the rankings have also been considered for 91 PAs and 25 Ecoregions (Tse-ring et al. 2010). For the purpose of this paper, ecosystem and species vulnerability have been further weighted against the three criteria of vulnerability namely exposure (reduced snowfall, decreased or increased rainfall, warmer and drier winters, autumn heat, less winter rain etc) sensitivity (threatened species, rarity, endemism, net productivity, area of managed land) and adaptive capacity (geographic dominance, morphological features and plasticity, population dynamics) following Dawson et al. (2011). For socio-economic implications of climate change, the report by Jing and Ludec (2010) was followed, together with some additional general observations made from the literature on the subject.

RESULTS

Trends and projections of climate variability

In the landscape, the annual and seasonal temperature trends indicate an increase at the rate 0.01 – 0.015^0 C/year, with higher warming rate in winter (December – February) of around 0.20- 0.30^{0}C/year. Similarly, with regard to temperature trend by elevation, areas >4000m are experiencing the highest warming rate (Table 1). The projections for 2020s and 2050s (HadCM3) and 2080s (PRECIS) showed that by the 2080s, the mean annual temperature change of the Eastern Himalayas would to be in the range of +2.9 to +4.3°C and the mean annual precipitation change in the range of 13 to 34%. However, the segregated data from the KL projects rise in mean temperature from 0.58°C during 2020 to +4.5°C in 2080s, and there is higher rise in temperature in the trans-Himalayan region with distinct variations along the altitude zones (see Tse-ring et al. 2010, page 18, Fig 5). Though there is no clear trend for precipitations in the KL, there is tendency of decreasing rainfall in the high altitude region (see Tse-ring et al. 2010, page 19, Fig 6).

Table 1. Temperature trends by elevation zone for the period 1977–2000 (°C/year). Source: Shrestha and Devkota 2010

Elevation zone	Annual	DJF	MAM	JJA	SON
Level 1: (<1000 m)	0.01	0.03	0.00	-0.01	0.02
Level 2: (1000-4000 m)	0.02	0.03	0.02	-0.01	0.02
Level 3: (> 4000 m)	0.04	0.06	0.04	0.02	0.03

Nature and magnitude of climate change impacts and threats to biodiversity

The cumulative vulnerability index in the KL with regard to biodiversity, water, ecosystems and human wellbeing is milder (0.4-0.56) compared to other vulnerable areas in the Eastern Himalayas (0.7-0.9) such as lower Gangetic plain, Brahmaputra valley and Terai-Duar tract from south east Nepal to eastern Bhutan (see Tse-ring et al. 2010; page 96, Annex 3). According to Tse-ring et al. (2010; page 94 Annex 2), among the ecoregions within the KL, the vulnerability indices of majority of ecosystems fell within higher vulnerability index range of 0.60 - 0.75, the most vulnerable ecoregion being the Terai-Duar Savanna and Grassland and the eastern Himalayan broadleaved forests.

Likewise, the extrapolated data of vulnerability for the seven administrative units in the KL, showed higher vulnerability ranking for Darjeeling, followed by Sikkim and eastern Nepal (Table 2). The least vulnerable areas, as per the analysis, were the administrative units of Bhutan. With regard to PAs vulnerability in the KL, the Mahananda Wildlife Sanctuary is determined as having the highest vulnerability ranking, while the Toorsa Strict Nature Reserve is the least vulnerable (Table 3). The vulnerability indices of four other protected areas in the KL, namely Singhba Rhododendron Sanctuary, Pangolakha Wildlife Sanctuary, Jorepokhari Salamander Sanctuary, and Senchel Wildlife Sanctuary could not be determined due to data unavailability. Considering, the vulnerability framework of Dawson et al. (2011), there are several vulnerable ecosystems and species identified from the landscape (Figure 3). Some of the microclimatic habitats in the landscape such as alpine meadows, alpine scrub slopes, alpine dry and moist scrub, old growth fir forest, birch-rhododendron forests, Juniper forests, bamboo undergrowth, cloud forests, Juniper-rhododendron scrub, hemlock-spruce, larch forest, willow scrub have high sensitivity to climate related stress; and several of the native species in the temperate zone have high exposure risk due to impacts from invasive lowland species, insects and diseases.

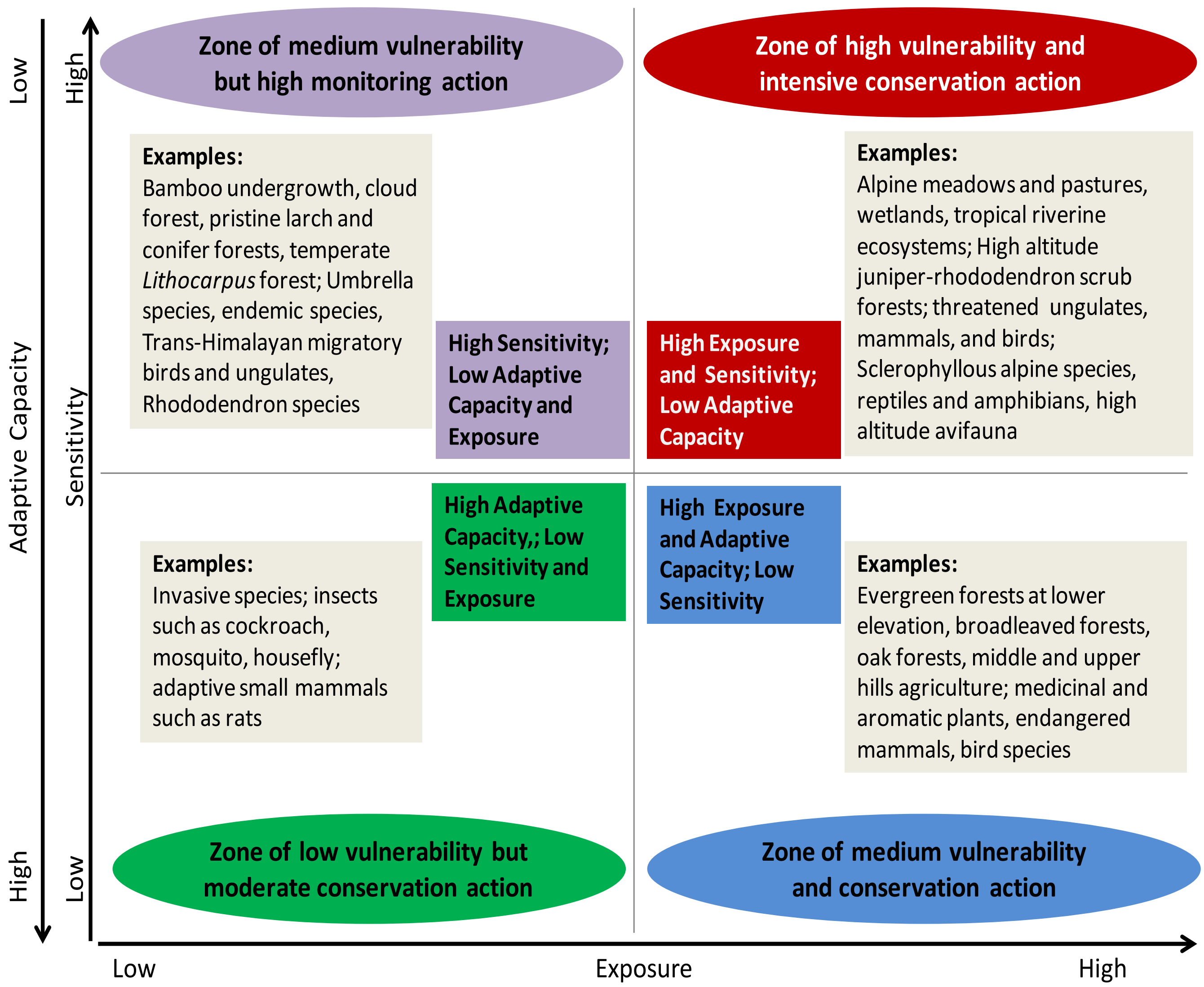
Table 2. Administrative units of the KL with indicators of vulnerability and vulnerability ranking (Source Tse-ring et al. 2010)

KL Countries	Countries Administrative Units within KL	Vulnerability ranking within KL	Vulnerability ranking within EH	Adaptive capacity index	Exposure index	Sensitivity index	Vul-ner-ability
India	Darjeeling	1	14	0.334	0.486	0.449	0.534
India	Sikkim	2	51	0.441	0.434	0.304	0.452
Nepal	Taplejung	3	55	0.454	0.49	0.299	0.445
Nepal	Ilam	4	59	0.525	0.474	0.36	0.436
Nepal	Panchthar	5	61	0.511	0.452	0.337	0.426
Bhutan	Paro	6	81	0.562	0.472	0.295	0.401
Bhutan	Haa	7	89	0.693	0.463	0.303	0.358

Table 3. Protected areas in the KL with indicators of vulnerability and vulnerability ranking (Source Tse-ring et al. 2010)

Ranking among KL PAs	Rank among EH PAs	Name of PAs	Country	Area (Sq km)	IUCN Cat-egory	Vulner-ability index	Adaptive capacity Index	Expo-sure Index	Sensi-tivity Index
1	11	Mahananda Wild-life Sanctuary	Darjeeling, India	127	IV	0.556	0.294	0.495	0.466
2	27	Neora Valley Na-tional Park	Darjeeling, India	88	II	0.512	0.346	0.486	0.396
3	44	Kangchenjunga Conservation Area	Taplejung, Nepal	2,035	VI	0.467	0.414	0.511	0.303
4	49	Singhalila National Park	Darjeeling, India	79	II	0.458	0.437	0.452	0.36
5	50	Khangchendzonga Biosphere Reserve	Sikkim, India	2,620	II	0.458	0.421	0.501	0.294
6	52	Barsey Rhododen-dron Sanctuary	Sikkim, India	104	IV	0.451	0.443	0.466	0.331
7	57	Mainam Wildlife Sanctuary	Sikkim, India	35	IV	0.438	0.481	0.479	0.315
8	61	Kyongnosla Alpine Sanctuary	Sikkim, India	31	IV	0.433	0.434	0.443	0.29
9	62	Fambong Lho Wildlife Sanctuary	Sikkim, India	52	IV	0.433	0.48	0.48	0.299
10	83	Toorsa Strict Na-ture Reserve	Bhutan	651	Ia	0.356	0.699	0.461	0.307

Figure 3. Some of the vulnerable biodiversity entities in the Kangchenjunga Landscape varranged with respect to vulnerability management framework after Dawson (2011)



People's Perception

The questionnaire survey provided an insight on how local people perceive climate change in the KL (Figure 4). About half of the respondents regarded deforestation as one of the major factors contributing to climate change (Figure 4a). Most believed that deforestation, together with rapid and haphazard urbanization have added to the air and water pollution, and hence have caused climate change. Human population increase and the consequent unsustainable resource use and rapid industrialisation have also been regarded as important causes leading to environmental pollution and climate change (Photo 5). Majority of respondents have related climate change with the changes in the weather patterns over the years indicating erratic rainfall patterns, advancing monsoon, advancing summer and spring, shorter and warmer winter, drier and hotter summer especially in hilly areas (Figure 4b). About one-third of the village communities related climate change with the increasing shortage of water for drinking and irrigation. They mentioned of water resources gradually drying up and that the amount of water available is hardly adequate to support the annual crop production. About 32% indicated changes in biodiversity around them, especially pointing out to changes in the flowering and fruiting time of local trees; early arrival of migratory birds; and changes in the breeding season of livestock.

Photo 5: *Rheum nobile* - high value resource of alpine areas

As far as perception of climate change impact is concerned, more than 50% mentioned that climate change has the most impact on the farming and pastoral communities including those who are agricultural labourers, since their very source of livelihood is affected (Figure 4c). People have related this vulnerability with decreasing crop productivity in the earlier productive and fertile areas, and with the loss of certain cash crops. Farmers have witnessed decreased productivity of millet, paddy, and maize, but increased production of crops such as potato and wheat. Farmers also opined that the changing temperature, erratic rainfall pattern and frost conditions are important reasons behind losing their important cash crops such as the large cardamom and ginger to new diseases. People also pointed out that climate change has affected tourism and the sectors dependent on this industry.

The local people, while expressing their views on probable adaptation strategies (Figure 4d), mentioned awareness, education and preparedness to climate change as being the most fundamental adaptation strategy. People expressed that natural resources management with regard to forest protection, wise use of water and biodiversity resources is going to be essential to adapt to climate change. The afforestation and forest protection programmes being implemented by the government agencies in the KL are supporting biodiversity management. The respondents were also conscious about exploring and assessing indigenous knowledge and technology base in relation to coping strategies, and mentioned that there are already several farming innovations being practiced locally and that the traditional framing systems need technical farming innovations in order to cope with the long term changes.

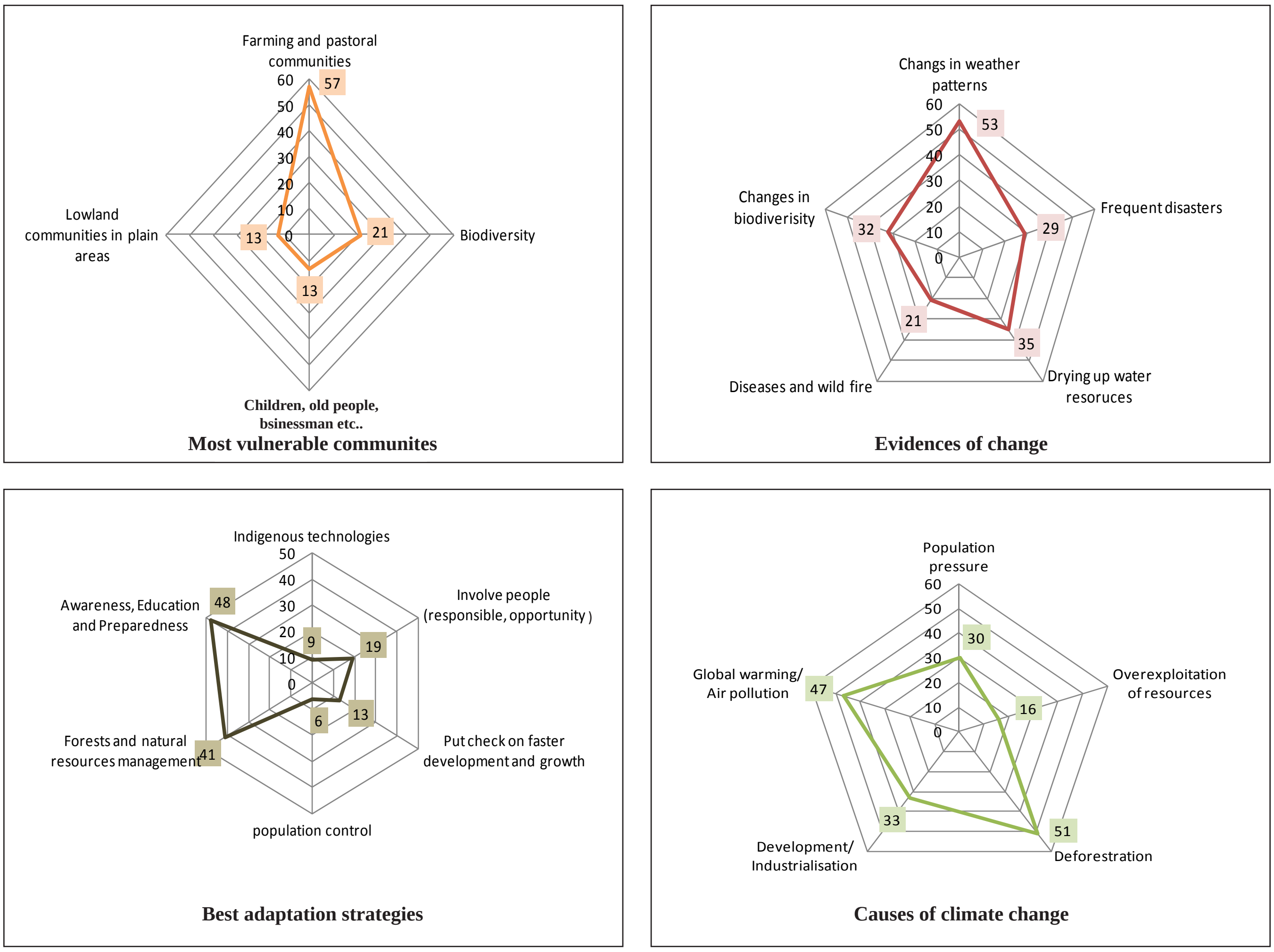


Fig 4: Perception of climate change by local community in the Khangchendzonga landscape

Climate Change and its implications on socio-economic systems

Rising prosperity and climate security are not conflicting objectives. Climate change is a reminder of the symbiotic relationship between human culture and ecological systems. This relationship is very evident in the Himalayas, where some of the world's most fragile ecosystems are being affected by rapid warming. The livelihoods of subsistence farmers and pastoral people, who make up a large portion of the rural population are negatively affected by such changes. Though the magnitude of impact of climate change on different ecosystems and its implications on socio-economic system in the Himalayas is difficult to assess because of the lack of proper inventory on dependency, production system and values of the goods and services derived from the different ecosystems, some of the recent studies on climate change science from the Himalayas and elsewhere have already added knowledge on the linkages. The results from the Eastern Himalayas revealed that not all ecosystems provide the same ecosystem services and not all will be affected to the same extent by climate change (Tse-ring et al. 2010). Agriculture in the KL is highly sensitive to climate change and is expected to have differential impact with some places projected to lose potentially good agricultural land, while others will benefit from substantial increase in suitable areas and production potential (Tambe et al. 2011). In addition, several studies in the past have shown that the production of rice, corn, and wheat has declined due to increasing water stress arising partly from increasing temperature and a reduction in the number of rainy days (Agarwal et al. 2000). Climatic changes are predicted to reduce the livelihood assets of poor people, alter the path and rate of national economic growth, and undermine regional food security due to changes in natural systems and infrastructure impacts.

Recreation is one of the cultural ecosystem services practiced in the KL. In socioeconomic context, mountain areas in the KL have attracted large numbers of people for recreation and tourism. However, the environmental stress imposed by growing numbers of tourists have increasingly burdened biodiversity and local communities who are not part of this entrepreneurship and faces competition for resources use (Photo 6). Tourism is, thus, both a significant economic driver for many mountain communities, but also an industry capable of adversely affecting the environmental quality of mountains (Chettri 2011). Likewise, climate change has strong linkages to greater incidence of infectious disease and severity of epidemics through the expansion of the geographic extent. However, data on health surveillance in the KL are not readily available, making predictions and comparisons difficult. Based on the anecdotal information reviewed by Jing and Leduc (2010), climate change is set to adversely impacted human wellbeing such as nutrition, security and health, unless policies, legislation, and institutions are put in place to make development sectors more resilient to climatic perturbations. With regard to building socio-economic resilience, climate change needs to be considered as a security concern rather than simply an environmental or economic issue, because adverse impacts of climate change will place additional stress on both socioeconomic and physical systems that people are bound with, and that altogether induce changes in demographic processes. Demographic changes directly influence human health, human settlements, food security and the viability of natural resource-based economy.

Photo 6: Plants such as *Saussurea spp* are sensitive to climate and are endangered by changing climate

DISCUSSION AND CONCLUSION

The climatic variability in the KL in terms of temperature has shown a clear trend of rise and variability along the altitudinal range has been distinct. This trend is in line with past analysis from Nepal Himalaya (Shrestha et al. 1999) and the Eastern Himalaya (Shrestha and Devkota, 2010; Tse-ring et al. 2010). Tambe et al. (2011) also reported extreme variations on temperature and precipitation across the state of Sikkim and with reference to altitudes. Though the extrapolated information from the Eastern Himalaya did not show a clear trend in precipitation for the KL, the temporal spread of rainfall across the Sikkim Himalayas indicate reduction in precipitation where rainfall months have decreased but rainfall intensity has increased; also there is a marked decline in winter rain, causing winter to be more warmer and drier (Tambe et al. 2011).

In the landscape, while high intensity rainfall, heavy snowfall and low temperature play an important role in the evolution of unique alpine flora and fauna, intense climate variability can destabilize the ecosystems through frequent land erosion and slides, and topographic changes; the high variations in the indicators related to exposure, sensitivity and adaptive capacity, climate change will have a range of direct and indirect impacts on biodiversity as well as in the economic and social security of the rural population in parts of the landscape where there are a number of globally significant floral and faunal diversities, and ironically majority of the local human population are economically underprivileged and largely dependent on biodiversity as their primary income source (Chettri et al. 2010a; Tambe et al. 2011).

In the KL, climate change has brought a strong concern for disappearance of high altitude alpine species which have low adaptive capacity and highest exposure and could become trapped on mountain summits (Chettri et al. 2010a). Similarly, the trans-Himalayan ungulates thriving along the northernmost boundary of the landscape, mainly along the rocky or grassy slopes in the transition zone, are the most vulnerable group whose population dynamics might get affected by climate change (Chanchani et al. 2010). Likewise, the threats to Tibetan gazelle (*Procapra picticaudata*) and southern kiang (*Equus kiang polydon*) in northern Sikkim are higher due to increasing trends in temperature. Climate factors, especially temperature variability across the elevation gradient also affects most reptiles and amphibians (Chettri et al. 2010b) that are narrowly distributed along the low elevation tropical forests and riverine ecosystems in the landscape and have high sensitivity and exposure.

With regard to species response to climatic variations, some phenological changes have been observed in *Rhododendron arboreum* from the landscape which shows advancement in the timing of bud-burst with increasing temperature, and shift in flowering activity with change in reproduction time and lengthening of growing season (Badola 2010; Ranjitkar 2010). The geographic range extension from around 1950 m to 3600 m has been reported in one of the globally threatened and little known Asian bird species from the landscape - the Rusty bellied shortwing (*Brachypteryx hyperythra*), whose earlier recorded range was till 2900m (Acharya and Vijayan 2007). Further, the ability to disperse and migrate across the fragmented landscape is also going to be crucial in determining species capacity to respond to shifting climatic zones. Supporting the climate change science, even local people have observed advancements in flowering and fruiting time and crop ripening period of variety of species and of earlier arrival and later departure of migratory birds as also reported by Chaudhary and Bawa (2011) and Chaudhary et al. (2011). The interesting point to be noted here is the consistency of the perceptions on climate change across the society in the Landscape (Chaudhary et al. 2011).

Further, the KL has a substantial proportion of its area under PAs, however, in the context of climate change, PAs alone will not be adequate to enhance the adaptive capacity of species and ecosystems since climate change could alter the relationship between a species range and reserve boundaries (Hole et al. 2011). Therefore, several tiers of biodiversity management interventions will be required that looks into relationships between ecological principles relevant to environmental change and current management principles for conservation (Mawdsley et al. 2009). Assessing the consequences of climate change in the landscape is still a challenge mainly due to limited availability of climatic data, uncertainties associated with the climate scenarios, and the existence of non-linear feedback between impacts (Sharma et al. 2010). Nevertheless, review of secondary literature and consultative processes provide us with several indicators such as land-use and land-cover change, critical habitats and ecoregions, bioclimatic zones and phenology, agrobiodiversity, and threatened and endemic species that help us determine the potential impacts and extent of vulnerabilities of biodiversity with respect to climate change (Chettri at al. 2010a). In future, statistical downscaling of the regional climate models will be useful and necessary to overcome the uncertainty associated with the climate change scenario projections. But accurate predictions and effective biodiversity management solutions are possible only when evidences of impacts are drawn from multiple sources based on integrated assessment of exposure, sensitivity and adaptive capacity (Dawson et al. 2011). People have also expressed their opinion about involving a wide range of stakeholders in decision making processes, particularly when developing community based climate change awareness programmes, capacity building programmes on conservation linked alternative livelihood options and community based natural resources management. Mainstreaming climate change adaptation into national policies and development activities has also been recommended. Many believe that forest managers and policy makers have an important role to play in addressing the need of people to combat the impacts of climate change. In addition, ICIMOD has been promoting large scale conservation planning in the KL promoting habitat connectivity through corridors development, together with building community capacity for economic interventions based on conservation linked livelihood options (Sharma et al. 2007; Chettri et al. 2008). It is now time to regionally translate this strategic thinking into practice by all the three countries, sharing the KL (Photo 7).

Photo 7: Mt Siniolchu as seen from Zemu Glacier is the pride of Sikkim

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