

VULNERABILITY OF SIKKIM TO CLIMATE CHANGE AND STRATEGIES FOR ADAPTATION

Sumana Bhattacharya, Srinivas Krishnaswamy and C. K. Rao



Talung glacier in North Sikkim. Retreating Himalayan glaciers provide one of the clearest indications of climate change



Traditional rabi crops like mustard are being promoted to adapt to the warmer and drier winters

Over the last two years, the various stakeholders including the civil society, government departments, academic institutions and others have come together to prepare the State Action Plan on Climate Change (SAPCC) for the state of Sikkim. After several rounds of consultation, the SAPCC has been formulated with support from German Technical Cooperation (GIZ). The details of the same are provided for in this article.

The key changes predicted due to climate change in Sikkim can be described as follows:

Changes in forest vegetation type: Ravindranath et al. 2012 carried out an assessment of the impact of projected climate change on forest ecosystems in Sikkim using the HadRM3 climate model and the A1B scenario. The findings indicate that there is not going to be any impact in the short term or the long term periods. However, model limitations and uncertainties should not stop policies and interventions to reduce vulnerability of forest to climate risks and enhance the resilience to projected climate change.

Changes in geographic distribution of flora and fauna: Some birds, insects, mammals and plants are already showing changes in their geographic distribution and have moved northwards or to higher altitudes in response to the observed changes in Sikkim. There is increasing evidence that many species with the northern limit of their range currently in the tropical and subtropical regions in Sikkim are expanding further north and onto higher ground. In contrast, the southern limits of some cold-adapted species may be pushed northwards as temperatures increase and due to limited space available at such heights may vanish e.g. Snow leopard.

Limitations of shifting beyond extreme north at higher altitudes: Alpine plant species on mountain ranges with restricted habitat availability above the tree line will experience severe fragmentation, habitat loss, or even extinction as they cannot move to higher elevations. This would have adverse consequence for the *Amji* system of Tibetan medicine dependent almost exclusively on alpine herbs.

Changes in timing of seasonal events: Phenology is the study of changes in the timing of seasonal events. As temperatures have increased, spring and summer events are taking place earlier in the year. Evidence includes leafing, fungal fruiting, bird egg laying, spawning of amphibians, arrival of migrants and insect emergence. Autumn events are occurring both earlier and later in the year, and the trends are less clear.

Changes in abundance and habitat preference: Species are both increasing and decreasing in correlation with climate change. Climate change can also cause a change in habitat preference. For example, the Red Panda of Sikkim which is the state animal and according to IUCN ranking a vulnerable species, may experience change in habitat as the temperate ecosystems which is the preferred habitat has started shrinking.

Changes in species interaction: Species do not respond simultaneously to climate change, which in turn leads to changes in the species composition found in a particular habitat and in the interaction between these species. The conservation implications of interacting species becoming mismatched in space (geographical shifts) or in time (phenology shifts) are only just emerging and are likely to need increased attention as climate change progresses.

Changes in ecosystems: Changes in species composition including intrusion of invasive species and in species interaction eventually lead to ecosystem-level changes. Changes to ecosystems can affect their ability to provide essential services, such as carbon sequestration and food provision.

Threat to high altitude wetlands of Sikkim: Climate change, triggering glacier melt and erratic precipitation may likely change the amounts, duration and time of run off from glaciers, leading to altered hydrological cycle and hence altering the aquatic biota, altering physical and chemical habitat and resource availability. Further the altered physical and chemical characteristic of the wetland may lead to mineralisation and more diffusion of Oxygen (O₂) in aquatic system, and more microbial activity affecting water quality and release of Methane (CH₄). Climate change may thus be riding over and above the anthropogenic pressures leading to degradation of environment that affect the ecosystem services provided by the wetlands.

Increased frequency of disasters such as landslides and Glacial Lake Outburst Floods (GLOFs): The Sikkim Himalaya with rugged topography, ongoing seismic activity (by active tectonics) and extreme rainfall is subjected to intense landslide activities. Climate change, bringing more frequent intense rainfall may exacerbate the land slides across the mountains of Sikkim. Also rapid changes in temperature and intensive precipitation may lead to rapid melting of glacier ice and snow with or without the retreat of the glacier, with resultant lakes putting pressure on the moraines damming the snout.

Increase in incidences of forest fires: Fire mediates the responses of forests to climate change, either by accelerating species turnover or by selecting fire-adapted species. In the same way, changes in species composition may alter fire occurrence by changing the concentration and arrangement of flammable fuels. The strong potential for interactions and feedback between fire and its controls suggest that fire occurrence over long periods may reflect indirect (ie vegetation and human land use) as well as direct climatic controls. Additionally, increase in forest fire incidences would lead to increase in crop predation in fringe villages by species driven out of the forest like Indian Peafowl as well as genetic dilution in Red Junglefowl.

Impact on livelihoods: Climate change leading to degraded biodiversity of forests, is likely to impact the quality and quantity of forest products and hence adversely impact the associated livelihoods of communities thriving on the same. The forest products being eco-tourism, apiculture, sericulture, medicinal plants, cane, bamboo for small scale cottage industries and natural fibres.

Impact on access to fire wood from forests: With climate change it is anticipated that the decline in forest biomass may accelerate and rural communities and road transport workers staying and working in the forest fringes dependent on fire wood extraction from forests are likely to experience the energy crunch for cooking and heating purposes (development though may make them less and less dependent on forest resources for energy). A study carried out by Chhetri et al. 2006, to ascertain region wise fuel wood demand, indicates that demand increases with elevation though production decreases. The gap that exists between firewood demand and supply, is increasing due to population growth, growing tourism and depleting forest resources.

Increase in man-animal conflict: Climate change may adversely alter the production of biomass and fruits on which the wild animals thrive. As a result, the animals may come in direct conflict with man outside the forests. In Sikkim, man-animal conflict consists of direct encounters and human casualties as well as damage to crop and livestock. From crop depredation and human casualties by Himalayan black bear to crop damage by wild boar, porcupine, monkey, peafowl, deer etc. Sikkim, being a global biodiversity hotspot, has diverse fauna which live in close proximity to human beings. In the recent past, there has been a dramatic increase in direct encounter incidents involving Himalayan black bear and crop damage by wild boar.

Degradation of environment due to release of pollutants from anthropogenic activities: Enhanced fossil fuel combustion in transport sector (due to continuous increase in motorised transport), release of waste water from industries as well as homes, unsustainable methods of solid waste management, fossil fuel use in commercial and residential establishments and also the use of fire wood in rural homes for space heating, cooking and warming of water are some of the causes of emissions of greenhouse gases contributing to global warming.

STRATEGIES FOR ADAPTATION

Ensuring Water security

To ensure water security of the state of Sikkim in future, the steps that need to be taken include:

- i. Ascertaining high spatial resolution rainfall measurements, measures of evapo-transpiration and hence estimation of net water availability.



Households on scattered mountain terrain pose a challenge for provisioning of basic amenities and services

- ii. Make available high resolution climate change scenarios that can capture the micro climate variability of this mountainous region and make projections at short, medium and long term time lines.
- iii. Implement adaptation strategies such as:
 - Artificial recharging of dried springs through rain water harvesting specially in the recharge zone, 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. These measures will help in ensuring that the surface runoff of rain water in the spring shed is reduced, and more water percolates down to recharge the spring.
 - Recharging of natural lakes on hill tops to increase the percolation and recharge ground water. The geo-hydrology of the lake needs to be understood to identify the recharge and catchment zone. In some places where lakes have dried up due to breaches in the embankments, these can be repaired and restored to increase the storage and percolation capacity. In certain dried up lakes, especially those on ridge tops, which have limited catchment area, one may also consider artificial recharge using spring water harvesting techniques. Water can be piped into the dried up lake from perennial spring sources.
 - Maintenance of adequate forest cover in the upper catchment areas for them to act as recharge zones.
 - Improve the base flow of critical streams specially in the dry season which can be done by creating water harvesting structures like pits, trenches etc to supplement the natural rain water recharge in the recharge area of the streams.
 - Rejuvenate stream-shed and harness the water from perennial streams in the lower belt of Sikkim - The drought prone lower belt of Sikkim has perennial streams like Khani, Seti, Rabi, Rolu, Manpur, Barhi, Raphu, Rohtak, Reshi etc to name a few and a few perennial water falls like Omchu. The water of these streams has not been traditionally utilized since they flow through gorges and lift irrigation systems are absent in the state. While spring-shed development programs can assist in ensuring water for drinking and domestic use, rejuvenation of stream-shed and harnessing the water from these perennial streams can meet the irrigation demand of these villages and transform the rural economy.
 - Increase water storage capacity by building household, community and village level reservoirs especially in villages which are located on the top of hills where there is perennial water shortage.
 - Form Water Users Associations (WUAs) that monitor leakage and water supply, regulate use of water, and help to conserve water that is supplied through Public Health Engineering Department, Rural Management and Development Department, private supply of untreated water from springs and manual collection of water from springs.
 - Introducing pricing and regulation and water tax- Leakages of water and unregulated water use contributes to unsustainable use of water resources. Therefore water for households especially urban households, industries, and for irrigation need to be priced and regulated. The water usage may also be taxed, to avoid wastage and hence over use of water for irrigation or over extraction by private parties to supplement urban water supply. Therefore the state government might set up a water regulator authority with defined powers.
 - Adoption of innovative techniques viz. drip and sprinkler irrigation: In addition to adopting innovative techniques such as drip and sprinkler irrigation, the government could encourage multiple-

cropping pattern, introduction of macro-irrigation, macro-management of agriculture and initiation of conjunctive use of water resources.

- iv. Archive and disseminate traditional knowledge on water harvesting and conservation.
- v. Undertake appropriate water pricing and regulation for judicious use of water under water scarcity conditions due to increase in droughts.

Ensuring food and livelihood security

Agriculture crops including horticulture

To ensure livelihood security of the poor relying on agriculture, focus should be on optimizing productivity with maximum profits. Research and development will play a vital role in identification of new cultivars resilient to higher temperatures, water stress and high concentration of Carbon dioxide (CO₂). Some of the strategies that might be propagated for ensuring food security can be:

- Introduce high yielding varieties of rice, best suited to the Eastern Himalayan foothill that can sustain low light intensity and water stress conditions.
- Introduce System of Rice Intensification (SRI) which helps to grow paddy in minimum water.
- Encourage cultivation of value added maize cultivars such as popcorn, baby corn and sweet corn suitable for different ecological zones as the rising temperature is beneficial to maize.
- As the area under wheat is gradually declining, encourage suitable cultivar of mustard, improved varieties of buckwheat like Himpriya for high hills, VL-7 and PBR-1 for low hills and lentil as pulses especially in lower belt for Rabi Season should be introduced especially in drier belt of Sikkim. Fruit crops like local mango, yams, colocasia etc having high resilience need to be identified and promoted.
- Initiate crop diversification through popularisation of indigenous varieties such as buckwheat, maize, paddy, soybean, rajma, rice bean and urd that are climate resilient. Futuristic DNA mapping, systematic preservation, collection of information about their morphological traits and nature of adaptability are few areas where active research is essential. Their cultivation practices need to be improvised through introduction of newer technologies and setting up fixed packages and practices of these landraces for their crop production.
- Undertake large cardamom rejuvenation programme through control of disease and pests. Involve ICAR, Spices Board etc with a special focus on identification of emerging diseases, production of quality plant material including tissue culture. Building systems in horticulture department to provide advisory services for improved management practices including shade trees. Continue the ginger disease management programme, to control pests and diseases through biological and organic interventions. Intensify Sikkim mandarin orange rejuvenation programme by providing technological and input support which may include budded plants for early fruiting, drip irrigation, mulching etc.
- Study the impacts of climate change on orchids and introduce appropriate adaptation strategies, viz. ascertaining new production centres and encourage growing of other flowers of high value by taking advantage of the new changing climate.
- Undertake integrated pest management by physical and biological means. The IPM laboratory at Gangtok to be strengthened to provide support in identification of suitable bio control agents and their production and application in the field for their efficacy.



Kishong sacred lake in Upper Dzongu, North Sikkim. Mountain lakes play a vital role in recharging ground water and need to be preserved

- Achieve self reliant in quality organic seed production by 2015, which is also moisture stress resistant through development of infrastructure for storage and seed testing in every district and train farmers to produce quality seeds that can be certified to minimise dependence on outside source.
- Improve and strengthen water management systems to overcome prolonged periods of water stress such as drip irrigation, construction of rain water harvesting structures, installation of community tanks and bench terraces. Repair of damaged channels, creating micro irrigation system and construction of water harvesting structures.
- Soil conservation measures to be extended to land cultivated without any soil conservation treatments. Bench terracing followed by reclamation of soil to conserve soil and soil moisture is to be taken up. For improving health of the soil, regular soil testing should be high on the agenda and based on test reports undertake soil amendments programmes.
- Reduce climate related risks, by introducing weather stations at high spatial resolution in the state. Collect data at micro-level for informed decision regarding time of cropping and choosing efficient crop management practices.
- Monitoring existing programmes of the government to ensure their climate proofing. All developmental works of the department related to climate change should be closely monitored from now onwards. The Monitoring and Evaluation (M&E) cell of the agriculture department needs to be strengthened to factor in climate change.
- Make crop insurance mandatory through Kisan Credit Card and/or encourage taking of crop loans to automatically insure crops.



(a) Improved water management system for agriculture



(b) Inspection for seed selection for ginger



(c) Flowers of high commercial value being grown in greenhouse

- Increase productivity through farm mechanisation such as use of micro size power tillers with better efficiency in manoeuvring in small size terraces with zero tillage operation, weeding capacity, seed drill is essential. The agri-engineering college for Post Harvest Technology, Ranipool can work closely with the department of Agriculture in formulation of agri-engineering activities and implementation of appropriate tools and machinery to adapt to climate change in the state.

Livestock and livestock products

Considering the dependence of small and marginal farmers on ruminants, it is imperative that concrete strategies be put in place to climate proof livestock health, dairy products and other livestock products. Some of the strategies suggested are as follows:

- Strengthen disease investigation system through study of causes of prevalent diseases that are escalating and the emerging diseases as well, and devise methods to arrest the same.
- Undertake preventive health measures to control and contain the existing epidemic diseases. The department needs to prepare a long term strategy where by entire livestock population gets regularly vaccinated to prevent various diseases. Beside this, animal health camps need to be set up on various occasions to make people aware of adopting different control measures.
- Improve cattle sheds and feed management practices at farmers level to maintain better hygiene, prevent the animals from getting exposed to heat and avoid excess methane emission.
- Conserve threatened indigenous livestock species by undertaking appropriate programmes and create infrastructure for establishing embryo transfer technology for these breeds.
- Encourage production of leguminous fodder crops that require less management and are produced through mixed crop system.
- Establish farmer centered fodder banks to combat winter fodder shortage. Undertake mineral mapping in different regions to assess mineral status and accordingly supply specific mineral mixture to farmers.
- Improve quality of milk by establishing milk cooling facilities at strategic locations. Improve facilities at Jorethang and Gangtok dairy plants for conducting bacteriological tests.
- To sustain the income of the farmers through mixed farming system, encourage poultry farming and pig rearing in a sustainable manner.

Box: Indigenous livestock of Sikkim

Species	Corresponding local breed
Caprine	Singhari
Ovine	Gharpala, Banpala
Bovine	Siri
Avian	Dumshi, Basti, Nangay
Procine	Harrey
Canine	Tibetan Mastiff, Apso
Yak	Gargu

- Encouraging the farmers to acquire Kisan Credit Card in order to insure all. This is being announced in every gram sabha.
- Capacities within the department required to be developed to gain knowledge on climate change and advice farmers on right adaptation practices. The training centres need to be strengthened with all facilities to train farmers and field staff
- Introduce M&E for climate proofing of ongoing programmes of the department of animal husbandry

Protecting Forests, Biodiversity, Wildlife and Environment

Based on the concerns in Sikkim, a set of nine strategies are proposed which are also in line with the initiatives of the State Government. The strategies thus proposed are:

- Undertake spring recharge and enhancing ground water recharge in forest areas which could be done by climate proofing of the existing programmes of Integrated Watershed Management Project (IWMP), Catchment Area Treatment (CAT) plans and Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) through appropriate management of water sheds.
- Enhance the quality of moderately dense forest, open forests and degraded forests to improve the health of these type of forests, improve the ecosystem services and enhance the carbon sequestration potential through regulation and monitoring of invasive species and identification of non-native species that can survive climate change and be beneficial to the ecosystem, management of insects and other pathogens, adoption of short rotation species, preventing forest fragmentation by conserving contiguous forest patches, eco restoration of degraded open forests and restoration of grass lands. Sustainable management of these forests would lead to increase in soil moisture content of the forests, increase in biomass density, along with increase in the flow of forest goods like Non Timber Forest Products (NTFPs), fuel wood, hydrological services, improvement in biodiversity and enhancement in carbon sequestration.
- Secure corridors to facilitate species migration of both flora and fauna to enable them to adapt to climate change, especially for species with limited dispersal ability. It can be done through connecting fragmented forests with ‘Canopy Corridors’ and ‘Flyways’ to assist species migration. Corridors will be prioritized and maintained by local stakeholders. As for people living in these corridor areas, rapid agency responses to crop-raiding, man-animal conflict, crop-insurance and hassle-free compensation would be some of the key interventions. Special studies may be launched to understand the feasibility of establishing such corridors and their effectiveness vis a vis natural dispersion and assisted migration in the context of climate change. The Important Bird Areas (IBAs) concept could be used to identify and conserve such potential corridors with peoples’ participation



Rhododendron campanulatum is found near the tree line of sub-alpine silver fir forests



(a) Siri breed –bull



(c) Yak herd



(d) Fodder collection system

- Prevent Disasters due to climate change. In Sikkim, disasters which are likely to be more frequent with projected increase in intensity of extreme events such as extreme heat, droughts, and extreme precipitation include incidences of forest fires, landslides, increase Glacial Lake Outburst Floods (GLOFs), and land erosion. Property and life can be saved through an integrated early warning systems that does climate monitoring on a real time basis; hazard mapping of key watershed areas; maintaining a database on landslide prone areas and intensity of landslides to assess the risk of landslides; undertaking reforestation of catchment areas and slope stabilization of landslide and Flash flood prone areas; undertaking river bank protection and Re-location/ resettlement of villages and people in risk prone areas. An effective fire prevention and fire management in forests can be done through early detection and management through community participation and by planting species in forests that promote regeneration of forest ground flora and fauna in the next monsoon season just after fire. Further, awareness generation amongst general public is an essential part of disaster preparedness.
- Help wildlife to thrive within the limits of the forests with changing climate. An erratic cycle of weather patterns is being experienced in Sikkim in the last few years and it appears that there is an intricate ecological linkage between the food habits of the wild animals, the phenology of edible wild fruit bearing trees especially the oak trees and fruit production and weather patterns and the forest denizens straying into human habitations. The changing climate could have affected the natural cycle of edible wild food production. Short term strategies to address this concern could include community initiatives and identification of conflict areas and seasons. Extensive patrolling, co-ordination with local community and administration etc. can be taken up by the Department of Forest, Environment and Wildlife Management (DFEWM). Medium term initiative could include capacity building, strengthening communication and sensitization of policy makers. Long term strategies could be population estimation of key species, study on agriculture practices and phenological studies of wild edibles.
- Conserve High Altitude Wetlands (HAWs) to secure the services provided by the wetland ecosystem even in the context of the likely adverse impacts of climate change. Identify critical wetlands for undertaking long term scientific studies on flora and fauna, hydrology and limnology etc.; Identification and inclusion of more wetlands and marshes for effective management; Strengthening capacities of the stakeholders to manage the wetlands; Acceleration of the efforts to include more wetland sites under Ramsar convention and conservation and security of these HAWs through active involvement of the border protection agencies.
- Limit pollutant load in the atmosphere at sustainable levels and understand the changing climate pattern and its impact on Sikkim. The actions that need to be included in this would be to monitor, the water,



The age old practice of agro-pastoralism where herders managed cattle sheds inside reserve forests, resulted in large scale fragmentation of temperate forests. Over the last ten years, these cattle sheds have been phased off giving a new lease of life to these biodiversity rich forests

air and land environment and create paradigms by way of which cleaner environment can trade its clean quota which is over and above the permissible limits and earn credits. Also climate monitoring at high resolution within Sikkim is also an important aspect of understanding the likely impacts of climate change on various systems, which needs to be introduced with setting up of automatic weather stations, transferring data remotely to a centre which does on line processing and disseminating to all stakeholders, along with seven day forecast and has the capacity to undertake climate modeling for future long term projections of climate and its impact on various systems and sectors.

- Develop renewable energy technologies for domestic use to prevent forests from getting degraded due to over extraction of fuel wood and biomass for fodder.

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Weak geology, heavy rainfall and steep terrain make the state specially prone to frequent landslides resulting in enhanced vulnerability during the monsoon season

however, it is recognised that they were from the Department of Science and Technology and Climate Change, Rural Management and Development Department, Water Security and Public Health Engineering (PHE) Department, Irrigation and Flood Control Department, Food Security and Agriculture Department, Animal Husbandry Livestock and Fisheries & Veterinary Service Department, Horticulture and Cash Crop Department, Forest Department, Energy and Power Department and WWF Sikkim.

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AUTHORS

Sumana Bhattacharya

Independent Consultant,

Email: sumana_bhattacharya@yahoo.coM

Srinivas Krishnaswamy

Vasudha Foundation

Email: srinivas@vasudhaindia.org

C K Rao

Independent Consultant

Email: raoveni@gmail.com



Sungmoteng Tsho (Samiti lake) in West Sikkim. Conservation of high altitude wetlands is vital to secure the services provided by the wetland ecosystem