

Climate change and adaptive strategies in Sikkim Himalaya, India.

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ABSTRACT

The 6th IPCC Report highlights the warming of the climate system unequivocally, attributed mainly to anthropogenic activities including the Indian Himalayas. Reports and studies suggest climatic variations were and are impacting biodiversity and the people of the entire Himalayan region, including Sikkim Himalaya. The indigenous people are impacted to a great extent, leading them to change their way of life vis-à-vis adapting to climate realities. Still, there is a dearth of information on the impacts or the response of the communities, who have a wealth of information in the form of indigenous local knowledge based on their observations, perceptions, experience and practices for ages. This present study would look into the primary challenges of farmers for ensuing adaptive capacity and achieving resilience for future vulnerabilities. A household survey was conducted from 2017 to 2019 of 110 respondents above 40 years of age from various pockets of Rangit Basin. It provided numerous insights into local concerns and challenges. It was found that the region is experiencing climate change, with signs of impacts on forested areas nearby, water bodies and the agricultural eco-system. The agrarian system is facing challenges of declining yield, water scarcity and climate-induced migration. They have been adapting to the change and are still in the process based on their traditional knowledge. It was found that indigenous communities had much to offer on the discourse on and actions combating climate change. It was suggested that to overcome climatic challenges and local perceptions, adaptive strategies must be documented which is inclusive of the local practices for ages along with culture and beliefs to combat climate change.

RESUMEN

El sexto informe del IPCC destaca de manera inequívoca el calentamiento del sistema climático, atribuido principalmente a actividades antropogénicas, incluido el Himalaya indio. Informes y estudios sugieren que las variaciones climáticas afectaron y están afectando la biodiversidad y a la población de toda la región del Himalaya, incluido Sikkim Himalaya. Los pueblos indígenas se ven impactados en gran medida, lo que los lleva a cambiar su forma de vida para adaptarse a las realidades climáticas. Aún así, hay escasez de información sobre los impactos o la respuesta de las comunidades, quienes tienen una gran cantidad de información en forma de conocimiento local indígena basado en sus observaciones, percepciones, experiencias y prácticas durante siglos. El presente estudio analizaría los principales desafíos de los agricultores para lograr la capacidad de adaptación y lograr resiliencia para vulnerabilidades futuras. Entre 2017 y 2019 se realizó una encuesta de hogares a 110 encuestados mayores de 40 años de varias zonas de la cuenca de Rangit. Proporcionó numerosas ideas sobre las preocupaciones y desafíos locales. Se encontró que la región está experimentando un cambio climático, con señales de impactos en las áreas boscosas cercanas, cuerpos de agua y el ecosistema agrícola. El sistema agrario enfrenta desafíos como la disminución del rendimiento, la escasez de agua y la migración inducida por el clima. Se han ido adaptando al cambio y aún están en el proceso basándose en sus conocimientos tradicionales. Se encontró que las comunidades indígenas tenían mucho que ofrecer en el discurso y las acciones para combatir el cambio climático. Se sugirió que para superar los desafíos climáticos y las percepciones locales, se deben documentar estrategias de adaptación que incluyan las prácticas locales durante siglos junto con la cultura y las creencias para combatir el cambio climático.

INTRODUCTION

The climate is the average weather at a given point and time of year over a long period of generally above 30 years (World Bank, 2021). It is a change that is attributed directly or indirectly to human activities that alter the structure and composition of the atmosphere globally (UNEP, 2021). Natural climate variability is observed over comparative periods from 1987 to 2017 (Kumar et al., 2020). Climate change is expected to have severe environmental, economic, and social impacts on South Asia, mainly where rural farmers' livelihoods depend on natural resources (Sharma et al., 2019). In Sikkim Himalayas, farmers widely depend on biodiversity for their livelihood sustainability (Rahman et al., 2012). These farmers are probable to bear the brunt of its adverse impacts because they are the most vulnerable to the harmful effects of climate change (Eriksson et al., 2009). The most susceptible population to climate change and variability have been rural communities because they mainly depend on primary activities for their livelihoods (Luitel et al., 2012). It affects agricultural productivity, and the source of farmers' income has been adversely affected over the year (Pandit et al., 2014). The Himalayas are considered the most significant example of the tragedy of commons, though it is home to several flora and fauna species (WMO, 2021). The region is an abode to several micro and macro biodiversity, endemic and exotic species, and domesticated and wild animals (Allen et al., 2020). The Himalayas are renowned as the centre of biodiversity hotspots, direct that climate change has negatively impacted the people and biodiversity of the region (Ingty & Bawa, 2012). It is the crisis of our time, and in reality, it is because animals and plants are struggling to adapt to such conditions (Chhetri & Lal, 2018). If one species is affected, it will have a domino effect on the entire global food chain (Mishra et al., 2012).

Himalaya influences India's entire sustainability, and Sikkim is no exception to it (Kumar & Prabhu, 2012). It represents two contrasting sides of the region; extreme hunger and charismatic beauty side by side (Tiwari, 2012). The economic and population growth of the area resulted in increased demand for natural resources from the Himalayas (Datta, 2020). The extensive demand for raw materials has led to over-exploitation of natural resources, demographic change, deforestation, topsoil, and water erosion are major environmental challenges (Chandy et al., 2012). Apart from these, the region faces chronic effects as the rapid melting of glaciers is a vital indicator of climate change and variability (Tambe et al., 2012). Climate change, ecosystem services, livelihood and biodiversity are closely interconnected in the Himalayas (Behera et al., 2018). It has become critical to understand day-to-day living and how climate change affects farmers' livelihoods directly or indirectly (Sen & Kansal, 2019). It impacts every aspect of their life in the current scenario (Sarkar, 2017).

Research Objective

Identify and analyze the linkages between climate change and livelihood sources and impact and adaptive strategies for farmers' livelihood.

Database and Methodology

The study is based on both primary and secondary databases. Secondary data sources like IMD, IPCC reports on policy and planning, programs and activities regarding climate-related risk management, and

adaptation practices were consulted for the analysis. Studies on perceptions, responses and local knowledge of climate variability, impact on farming, and adaptive strategies at the household and community levels were gathered through field observations. Personal interviews, key informants' interviews, and consultation with institutions and community-based organizations like the forest protection committee were done. A primary survey was conducted in 2015, where purposive random sampling was used to select the interviewee. The interviewee chosen for the interview were all above the age of 35 years or above because they have experienced the impact of climate change over the past three decades. Both qualitative and quantitative techniques were applied to analyze the outcome of the study. A semi-structured questionnaire was used to ask farmers about long-term changes in mean temperature, mean precipitation and extreme climatic events. What kind of changes they have seen in natural resources over the past 30 years, and how are they coping with such changes over the years? The data collected during the interview were later compiled with and quantified before the analysis. Different statistical tools like Ms-Excel (bar and pie diagram) were used to represent research findings in the best possible way.

Study Area

The study was conducted in Boom village, a single panchayat ward under Samdong Gram Panchayat Unit (GPU) situated about three km. from Kaluk bazaar. Kaluk is one of the GPUs under Reshi Kola Watershed of West Sikkim districts, Sikkim Himalaya. It is a village with about 132 households, with about 680 people. The climatic condition ranges from sub-tropical to alpine during winters (Koppen Climate Classification). Major crops of the region are maize, orange, ginger and millet. Essential non-timber forest products are broom-grass, bamboo and mushroom. Reshi and Rangit are major rivers in the region (Table 1). The major Community of the area includes Nepali and Lepcha. In terms of religion, primarily Nepali villagers are Hindu, and Lepcha is Buddhist. All people speak Nepali, and the respective Community speaks the Lepcha language, making Sikkim Himalaya culturally rich.

Table 1 Socio-Demographic and Economic Profile of Study Area

Category	Items/Elements	Percentage
Gender	Male	64
	Female	36
Age	Below 35	20
	Above 35	80
Education	Illiterate	30
	Primary	50
	Middle and Above	20
No. of Family Member	Below 3	20
	3-5	55
	5 and above	25
First Source of Income	Agriculture	66
	Off-farm	16
	Others	18

Source Primary Survey, 2015 *(NTPF: Non-Timber Forest Products)

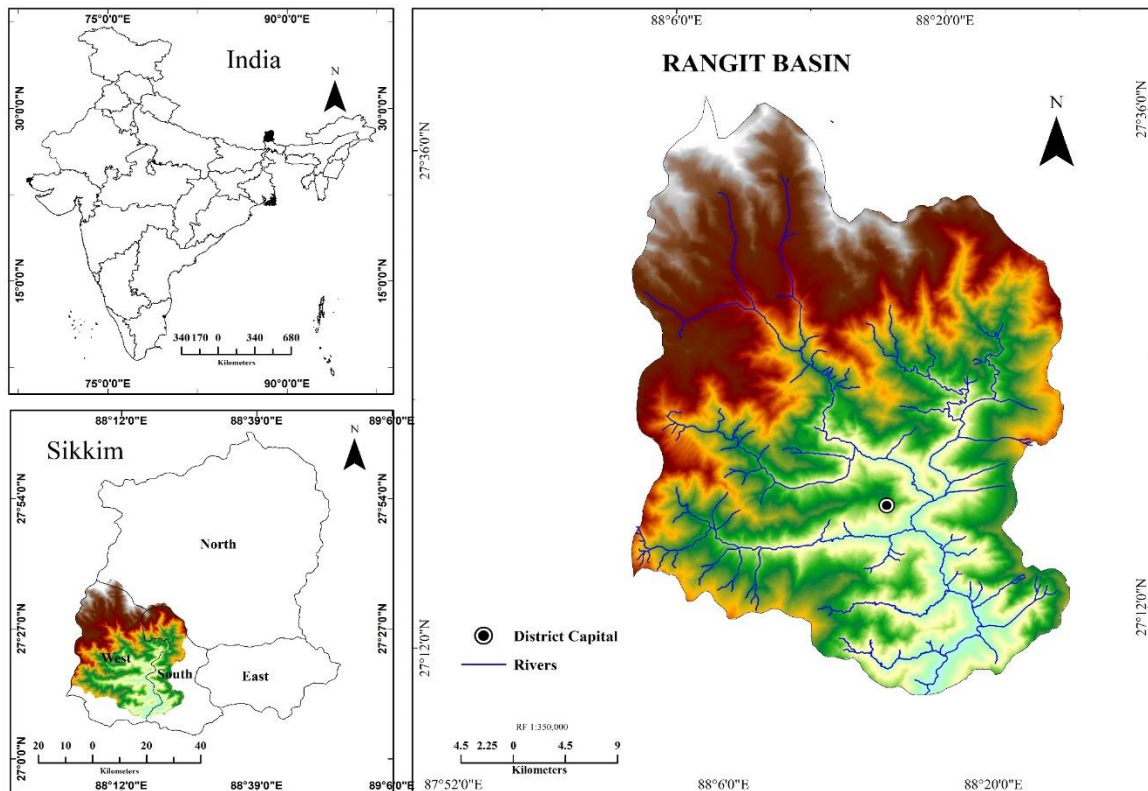


Fig. 1 Location of Study Area .

Major Findings and Discussion

People perceive that there is climate change is affecting them. Almost 70% of the people had heard about climate change, and 80% think that climate change is real. Nearly 100% said that climatic anomalies lead to an increase in average temperature. In this regard, they have their assessment citing shifting agricultural zones, frequent pest attacks on crops, and reducing precipitation as significant indicators. They complained of water shortage for farming activities, and locals streams and springs like jhoras and kholchas are drying up as evidence. They raised concerns that extreme events have multiplied over the past few years, citing frequent landslides and the Sikkim-Mangan earthquake of 2011

a. Declining Water Availability

Formerly, the village received snow of around 2-3 feet on the ground, which was their primary water source in the Himalayas, but now, the intensity of snowfall has reduced over the past 30 years. Prior, the village was not only self-sustainable in water resources but also supplied water to nearby towns. Presently, the entire village faces the challenge of water scarcity, and they solely depend on rain for water. Erratic rainfall pattern is another cause of concern for villagers, which began in the mid-1980s and has continued so far. Non-availability of water has restricted the cultivation of water prone crops like paddy. Existing spring is disappearing, resulting in a shift in the agriculture zone, reduction in annual crop yield and productivity and extinction of several plant species (Table 2). The water crisis has intensified clashes among people during lean seasons as their sources are drying despite their constant efforts.

Table 2 Farmer’s Perception on Climatic Factors and associated challenges

Attributes	Challenges	Response (%)
Climatic anomalies	The temperature has been Increasing	80.00
	Erratic/Unpredicted Rainfall	78.67
	Seasons Changing	74.33
Ecosystem Services and Functions	Reduction in annual Yield & Productivity	73.67
	A shift in agricultural Zone	70.33
	A shift in Plant Species/Extinction of Plants	74.67
	A decline in the availability of Water	66.67
	Heavy Hailstorms and Damages	73.33
	Incidents of Floods and Droughts	71.33
	Disappearing Springs	65.33
Biological System	Change In fruit ripening timing/ early ripening	73.67
	Change in flowering and Fruiting time	64.33
	New Disease and Problem of Pest	86.67
	New Species of Plants	31.67

Source Primary Survey, 2017-19

Water is one of the most precious natural resources available on the earth, but watershed across the region is declining due to anthropogenic activities. The village population has increased over the past few years, which leads to adverse impacts on water resources resulting in their gradual extinction. Snow and glaciers are two significant freshwater sources in both upstream and downstream dwellers. The increased population is putting immense pressure on the available water bodies. Villagers' primary source of income is agriculture, followed by off-farm and other activities constituting 66%, 16% and 18%, respectively (Table 3). It has affected farmers' livelihood as many depend on water like selling water to households.

C. Crisis in Farm Sector

Erstwhile, irrigation was done regularly, but it has been reduced and contained to a few patches due to climate change. Irrigation was impossible in Sikkim Himalaya due to less rainfall in April, while heavy downpours in March damaged farmers' crops. The land is drying due to untimely rain, with declining winter days with no rain and heavy downpours in March, resulting in frequent drought-like conditions in the region. Complete washout of their crop has become a common phenomenon via-a-vis water bodies in the village are drying rapidly, and hummus is a prerequisite for smooth farming. Though, farming on the hill slope is another challenge as it requires more hardship and is quite different from plain area farming. Mechanization is impossible in Sikkim Himalaya, and intensive labour is suited to the region, whether ploughing, harvesting or thrashing. There is a

minimal mode of transportation available to collect the finished crops from hills as very narrow lanes. The existing transportation facility is costly and beyond their budget. It is manually done wherein they carry merely 2-3 kg of agricultural products on their shoulders, which is a hectic and prolonged process. On the way, many crops are damaged due to mishandling. Intermediaries buy their products at a very cheap rate and sell them over twice or thrice higher than they buy from farmers in the market. Farmers don't have the facility to sell their products directly in the market; hence, they sell to intermediaries. If they take up direct sales to market, they must travel to the market in the early hours and return the same day, where they temporarily acquire a particular space and sell their products till evening. If the products go unsold, they sell them to nearby shopkeepers at a meagre rate, say ₹5/kg for a product priced at ₹10/kg. Here, they bear the double loss impacting the sustainability of such farmers, and marketing is a growing concern. The region's economy is based on the farm sector, which depends on its natural resources. Around 20% of farmers are living below the poverty line.

d. Climate Change and associated challenges

Global warming has resulted in the melting of glaciers and the formation of several high altitude lakes. The increased volume of water is beyond the land's carrying capacity to retain for a longer time, which might discharge a rapid and colossal amount of water, causing a threat to the local Community. It leads to glacial outbursts of floods that have become frequent, and dwellers are worried about such incidences in the region. The spread of these small glacial lakes threatens dwellers' residential areas. The traditional spring is drying due to rising temperatures, causing women and children to trek around 2-3 km for water. The daily hardship of water collection is heaviest on the marginalized one. It puts immense pressure on children's education because most of their time is wasted fetching water. Increased temperature in terms of the ecosystem's health is causing heat stress in the Himalayas. Global warming will lead to acute water shortage and negatively affect water sources used for different purposes like irrigation, ecological balance, and hydropower generation in time to come. The increase in temperature has forced several faunas to migrate to safer places for their habitat, including higher altitude movement. Massive alien species and diseases are flooded into the landscape, jeopardizing native biodiversity. Any negative impact on the Himalayas' biodiversity puts the well-being of locals at significant risk. The effects of climate change in the region have increased over a few decades. Climate change harms both people and the environment in the region. It has affected the ecology of both upstream and downstream areas. Its effect is apparent in several unusual phenomena, including increased temperature, erratic and uneven rainfall, heavy short showers, seasonal changes, flowering and ripening times etc. (Fig. 2). It leads to flash floods, landslides, topsoil erosion, deposition of silts and other eroded materials that eventually damage the downstream landscape in terms of livelihood crisis and human habitat destruction.

Climate change has impacted all the segments of ecology such as agriculture, forest, vegetation, human health, food security, livelihood, poverty, and the entire local economy. Agrarian based regional economy is one of the most fragile parts to climate change and variability. Marginalized people living there for generations, dependent on climate-sensitive natural resources for their livelihood, are the primary victims of climate change-induced impacts. The centuries-old water spring is dried up due to climate change and causing hardship in local's routine life. The spring's catchment area and volume decrease due to anthropogenic activities like increased

deforestation and heat stress. The uncertainties associated with climate variability are enormous, and we have to find some innovative solutions with limited available resources.

e. People's Response and Coping Mechanism

As per respondents, some of the major impacts of climate change were reducing agricultural productivity of crops like ginger, elaichi and paddy. Farmers are slowly giving up the cultivation of traditional crops like pulses due to meagre yield. Their primary concerns were pest infection in crops, falling of fruits before ripening, and paddy burning due to overheating. Around all respondents believed that the condition for the cultivation of ginger, elaichi and orange has changed. Widescale mosquito breeding is leading to malaria and other chronic diseases. The sudden death of livestock and cattle herds due to thunderstorms is also becoming a common phenomenon.

Way Forward

Growing alternative crops in the winter season will be a better option which people were not growing. Although, snowfall and extreme freezing stop farmers from growing any crop on their land. Growing plantation crops like cardamom and Badi elaichi with hybrid methods as these products have good market value. Instead of conventional crops with a traditional way like potato, maize, millets, ginger, orange, banana and paddy. The change in method of production will be helpful in their livelihood sustainability. A hybrid method for plantation crops has increased production and prevented the spread of disease in crops.

1) Indigenous Local Practices

The indigenous Community of Sikkim Himalaya includes Lepcha, Chhetri, Bhaun, Gurung, Rai, Thatal and Limboo, and they speak Lepcha, Limboo and Nepali languages from generation. Although they are not highly literate, their indigenous knowledge is beyond the imagination, from the Himalayas to their home. Agricultural practices in the region are known for indigenous and local knowledge (ILK). It helps develop different types of local water and soil management systems and practices that are considered adaptive and tailored to the local situation. climate change poses a threat to local people's adaptive capacities. It becomes essential to document local practices to promote and protect valuable knowledge and practices to ensure local people's water, food, and energy security. Indigenous and local practices (ILP) result from applying the culture, context, and location-specific knowledge to solve local problems. In many cases, it has been found that farmer-managed irrigation and local drinking water systems adapt better than capital and technology-intensive government-built systems. Fertility management of agricultural fields with natural manuring and crop rotation is applied regularly. In crop rotation, several techniques, including cowshed in farmland, which is locally called goth, burning dried leaves, and mulching of ginger, enhance soil fertility. The mulching process is referred to as covering soil that conserves its moisture for a longer duration. When there is no mulching, the existing water in the field will evaporate rapidly. Cattle sheds improvement for regular animal product collection like animal urine to prepare biofertilizers. Improved compost and maintaining soil moisture will yield a better result during the sowing season.

Sikkim Himalaya's water or moisture control measures include terraces or bench terraces and water harvesting pits like tanks, as water won't retain inland due to higher slopes. Agroforestry of cardamom, construction of waterways, scientific irrigation practices like drip irrigation and development of Kholchas are

concrete control measures. Preparation of small plastic ponds at specifically designated locations for wastewater collection is used for agriculture-related activities like irrigation purposes. Single pond stores around 20k to 22k litres of water, which is enough to fulfil water demand for agriculture activities during dry spells or during one winter season. The stored water can irrigate around 2 hectares of land to grow rabi crops and vegetables during the winter season.

2. Implementation of Mixed Farming technique

Multiple farming or mixed farming can be seen from farming activities of planting banana, orange, ginger and millet plants, broom grass, bamboo, mushroom, simal tarul and maize in the same field. Groom grass, tarul and bananas are planted at the edges of fields for multiple uses like economic values and fodder for cattle, and it is helpful to check soil erosion and velocity of water during monsoon. They practice crop rotation and keep some patches fallow to regain their fertility over the years. They still practice the concept of tying cattle on the field for natural fertilization from their dung. They rear poultry, cow, goat and fish and grow cabbage, coriander, methi, dhania and other green crops to support their livelihood. This practice has multiple advantages like natural fertility remains, timely ripening of fruits and flowers, protection against the spread of disease and labour involved in the fertilization process are saved (Fig. 3). Additionally, pests' problems, growth of new invasive species, change in livestock's behaviour and reduction in life below water can be addressed timely. They keep practising from time to time to burn their fallow field, which they think retains soil fertility. Apart from all these, they maintain their seasonal agricultural calendar; based on their experience and traditional knowledge. They allow adequate time for sowing crops, reaping timing, and adjusting accordingly. Most of these local farmers were practising vegetable farming instead of cereal crops as crop diversification and livelihood diversification to earn more income than cereal crops.

3. Livelihood Sustainability

Ecosystem-based adaptation focuses on existing natural resources and their monetization to improve rural livelihood sustainability. The focus area is to identify where there is demand for livelihood as of now versus vulnerability in the region, considering the safety of people. If people are unsafe, make special provisions for their protection, which is the utmost concern. The area is an agriculture-based economy dependent on rainwater for agriculture. However, irregular rainfall in summers (March) impacts their farming livelihoods, such as crop damage and food security. Water harvesting throughout the year will help utilize it for better harvest and agriculture purposes during lean seasons. It is imperative that eco-friendly, accessible, and affordable methods be adopted for the sustainable utilization of locally available resources.

4. Community Participation

There is no discrimination based on religion because there is no majority of any single religion, whether Hindu, Buddhist or Christian. They lived in a harmonious environment and helped each other with their needs. Female-led Community-based organizations are creating a sense of ownership among farmers and developing a positive atmosphere for their livelihood sustainability during unprecedented climate change conditions. Resource pulling, joining together many fragmented and scattered farming and terrace farming to grow cash crops at a broader scale to support the local economy. If their incomes are improved, it will help the capacity of

households to quality of households to a certain extent. Community-level analysis towards drip irrigation, mulching and wastewater collection pond with locals' involvement. The grain mill, locally called gharat, has been used to grind grains in the Himalayas for five hundred years. Strengthen their capacities and institutionalize rural livelihood sustainability with practical training to be organized frequently to reduce the impact of climate change. Building harmonized relationships among all stakeholders like farmers and local administration and taking it forward to the need of the hour. Also, Community collaboration with local administration identified the dry spring and made everyone accountable for rejuvenating them scientifically. The water catchment area slowly began collecting rainwater and recharging underground lost springs. These restored water springs have become lifelines for the rejuvenation of the local economy. Implementation of a state action plan is indeed needed to solve environmental problems like climate change.

5. Revival of Spring

Around 80% of the population in Sikkim Himalaya depends on spring water to support their livelihood, but spring recharge is relatively slow due to steep terrain. People are reviving the lost springs under Mahatma Gandhi National Rural Livelihood Guarantee Act (MGNREGA). They prepare smaller digs that are prepared on soil ground in a proportion of 6:4:2 length, breadth and depth, respectively, to retain running water for a longer duration. Further, stored water helps revive springs as it percolates to permeable ground. The stored water improves forests' greenery on a large scale besides spring's recharge. Institutions such as Self-Help Groups (SHGs), North-East Rural Livelihoods Projects (NERLP) and Capital Development Groups (CDGs) are playing a significant role in Sikkim Himalaya. These are Community based institutions. They are crucial in abating socio-economic stress and environmental challenges in climate change and variability. Important government institutions include the Development of North Eastern Region (DoNER), the agriculture department, soil and water conservation department. Apart from these, local institutions such as community radio and awareness campaigns contribute significantly to making rural livelihood sustainable.

CONCLUSION

Local people's response was based on their past experiences that warming days, erratic rainfall patterns, ecological variability and their adverse effects on human beings have increased. More than 80% of respondents replied that warmer days rise, rainfall patterns become more unpredictable, and seasons frequently change. The frequency of drought has increased, warmer wind flows these days, and natural water resources have decreased. People have perceived that climate change is real and affects them to a more significant extent. Some respondents blamed extreme events like earthquakes and landslides on changing natural cycles, while others replied that it was God's will. Some incidents of bees, insects, mahautsab, dasai bolouney kira, fish extinction and water in pipes were the basis of perception and findings. Apart from indigenous knowledge, effective implementation of suggestions could combat climate change and prepare locally-based climate change resilient solutions. The only way we can solve the problem of climate variability and rural livelihood sustainability is through human efforts.

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