OPEN ACCESS Freely available online

Journal of Geography & Natural Disasters

Research Article

Climate Change and Hydropower Development in the Eastern Himalaya: Emerging Conflicts in the Upper Tista Catchment of Sikkim, India

Navin Rai*, **Vimal Khawas**

Department of Peace and Conflict Studies and Management, Sikkim Central University, Gangtok, Sikkim, India

ABSTRACT

Hydropower development-related issues have been on the rise in the Upper Tista catchment in recent times threatening the life and livelihood of local people and environmental settings. This paper assesses the controversies and tensions being created by the target of ambitious hydropower development plans in the name of climate mitigating energy in the Upper Tista catchment of Sikkim which is a part of the Eastern Himalayan region. However, in the face of climate change, hydropower projects have become a contested developmental paradigm in the Eastern Himalayan region of Sikkim. The paper highlights potential issues and conflicts between the climate mitigation approach through hydropower projects and the anti-hydropower forces of local people. The paper critically examines pre and post-hydropower development conflict along the Upper Tista river basin. The region has witnessed that the Hydropower Project has been undermining environmental and social security over the past years. The paper also analyses the different roles of dam-affected people, local politicians, NGOs, and dam developers in advocating and protesting the hydropower dam projects in the region.

Using an environmental security framework, the paper critically analyses the environmental risks and impacts being aggravated by combined forces of climate change and hydropower development in the upper Tista catchment of Sikkim Himalaya (India).

Keywords: Climate change; Hydropower development; Upper tista basin; Environmental insecurity; Ecological zones

INTRODUCTION

The Eastern Himalayan region covers a broad spectrum of ecological zones in Eastern Nepal, Northeastern India, Bhutan, Tibetan Region, and Yunnan of China and Northern Myanmar [1]. The culturally and ecologically diverse Eastern Himalayan region is considered climatically vulnerable and is currently the target of ambitious hydropower projects [2]. While North-Eastern states of India fall under the Eastern Himalayas has been considered as a 'Power house' or 'Future power house' of the country [3]. Water stored in the high mountain in the form of snow and glaciers regulates the water supply and supports the livelihood of millions of people [4-7]. The region is therefore the source of many perennial rivers which are transboundary in nature and are the lifeline of downstream provinces and countries. Tista is a perennial river system that originates from Sikkim, a North-Eastern state of India. The literature shows that the major parts of the Eastern Himalayas are undergoing warming trends and climate change impacts are disproportionate and influence lives and livelihoods variedly [1,8,9]. It has been estimated that the temperature across the mountainous Hindu Kush Himalayan region will increase by about 1-2°C by 2050. Correspondingly, changes in temperature and precipitation will have serious and far-reaching consequences for climate-dependent sectors, such as agriculture, water resources, and health [10].

The fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) shows that the Earth's average surface temperature has risen by 0.76°C since 1850. 'Climate Change' denotes a long-term change in the statistical distribution of weather patterns e.g. temperature and precipitation over decades to millions of years [11]. However, to combat growing

Correspondence to: Navin Rai, Department of Peace and Conflict Studies and Management, Sikkim Central University, Gangtok, Sikkim, India, E-mail: navinrai101@gmail.com

Received: 02-Jan-2023, Manuscript No. JGND-23-21234; **Editor assigned:** 05-Jan-2023, PreQC No. JGND-23-21234 (PQ); **Reviewed:** 20-Jan-2023, QC No. JGND-23-21234; **Revised:** 27-Jan-2023, Manuscript No. JGND-23-21234 (R); **Published:** 03-Feb-2023, DOI: 10.35841/2167-0587.23.13.263

Citation: Rai N, Khawas V (2023) Climate Change and Hydropower Development in the Eastern Himalaya: Emerging Conflicts in the Upper Tista Catchment of Sikkim, India. J Geogr Nat Disasters. 13: 263

climate change, all the countries have committed to goals for the reduction of global greenhouse gas emissions through various international and national policies [12,13].

Since the late 1800s, scientists have noted that climate change may be progressing at an alarming or accelerated rate, and it has been believed that human beings may be contributing to this accelerated rate of climate change [11,14,15]. Furthermore, UNDP highlights that GHG emissions are more than 50 percent higher than at the 1990 level. Thus, immediate and drastic greenhouse gas emission reductions are needed to address climate change [16]. Therefore, Clean Development Mechanism (CDM) under Kyoto Protocol and subsequent climate conferences give preference to renewable sources of energy such as hydropower. Over the years, the development of hydropower, therefore, represents one of the options to mitigate climate change [17].

The concept of hydropower has been polarized by the grouping of opinions into two extremes, i.e., pro-hydropower (proponents) and anti-hydropower (opponents) of it [18]. The proponents portray large hydropower as a win-win source of water supply, renewable electricity, climate mitigation, irrigation, flood control, and revenue generation to uplift poor people but contradictorily, a hydropower dam opponent considers it as an epicenter of environmental and human insecurity through uncertainties of displacement, loss of arable land and Riverine ecology, inundation, and devastation of cultural heritage and livelihood [2,18,19]. Furthermore, the dominant pro-dam discourse celebrates hydropower as an uncomplicated, sustainable, and renewable source of energy indispensable to development objectives, such as green growth, climate change mitigation, and poverty alleviation [19]. Over the years the public debate on climate change and large hydropower dams has entered a new phase. In the face of climate change, hydropower dam construction comes with severe social, economic, and ecological impacts [20] as the contentious situation has been witnessed along the Tista basin over the past years. It has been witnessed that the traditional symbiotic and intimate human-environment relationship in the Tista Basin has increasingly been endangered by diverse undercurrents of so-called 'development' over the past two decades [21]. The present study focuses on the Upper Tista catchment of Sikkim Himalaya which falls under the Eastern Himalayan region of India. The region is considered to be a geologically young folded mountain. Rapidly expanding hydropower development in areas prone to geological and hydro-climatic hazards poses multiple environmental and technological risks [19].

MATERIALS AND METHODS

Study area

Whole Tista River basin drains a total geographical area of about 12,159 km^2, draining the Upper Tista basin in Sikkim Himalaya (6930 km^2), the middle Tista basin in West Bengal (3225 km^2), and the lower Tista basin in Bangladesh (2004 km^2) before joining the great Brahmaputra in Bangladesh [21]. The present study covers the two Gram Panchayat Units (GPUs) i.e. Rakdong-Tintek and Samdong-Kambal nearby a 510 MW Tista-V hydropower dam site of East Sikkim which is located at Upper Tista Basin. These two GPUs are dependent on agriculture and associated activities are highly affected by the 510 MW Tista-V hydropower dam project.

Tista is a lifeline of Sikkim Himalaya. It is a glacier-fed river that originates as Chhombo Chu from Khangchung Chho Lake at an elevation of 5280 m in North Sikkim. Among many, Rangit is the largest right-bank tributary of the Tista, which originates as Rangit Chu from the Talung glacier at an elevation of 4080 m in the west district of Sikkim [22]. The Tista River and its tributary have been subjected to the cascades of hydropower projects over the last three decades. 510 MW Tista-V hydropower project is a Run of the River (ROR) scheme located near Dikchu village of east Sikkim. The project comprises of 88.6 m high Concrete Gravity Dam with three penstocks of length 321 m and a 17.2 km long Head Race Tunnel housed on the left bank. The underground Power House near Sirwani with an installed capacity of 510 MW houses 3 units of 170 MW capacities each designed to operate under the net rated head of 197 m. The construction started in 2000 and the project was commissioned in 2008 as shown in Figure 1.

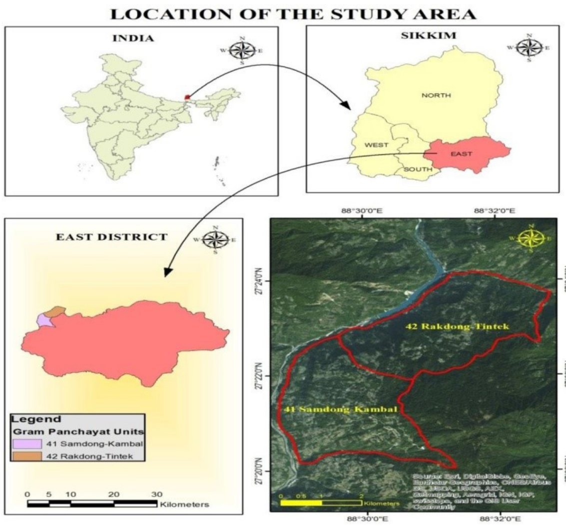

Figure 1: Map Based on Rural Management and Development Department, Govt. of Sikkim **Note:** Gram Panchayat Units ( ) 41 Samdong-Kambal, ( ) 42 Rakdong-Tintek

Tools and techniques of data collections

The study applied various tools and techniques during the field study. Participatory Rural Appraisal (PRA) techniques of the qualitative method have been used to extract ground data. This method seeks to understand the context and gather information from the field through a case study with the help of local people. This approach aims to incorporate the knowledge and opinions of rural people in the planning and management of development projects. The different tools and techniques of PRA are resource maps, weather charts, crop calendars, and social mapping. Similarly, the study extracted field data through in-depth interviews, Focus Group Discussions (FGDs), and observation. The targeted people in the in-depth interview were the community people, local politicians (Panchayats), Self Help Groups (SHGs), and Non-Governmental Organizations (NGOs). The interviews were also conducted with subject experts and local researchers. Similarly, FGDs were taken with the community members who have been impacted by both changing climatic conditions and hydropower development in the Tista river basin. The study conducted 10 FGDs and 15 In-depth Interviews, which were taken with the age group of 40 years and above.

RESULTS

Hydropower and climate change nexus: Emerging challenges

The growing emissions of greenhouse gases are a central point of concern that leads to climate change [15,23]. Despite many criticisms, the increasing greenhouse gases in the atmosphere in recent times leading to global warming are believed to be due to excessive use of fossil fuel-based energy since the industrial era [15]. The issue of climate change has been widely debated as a matter of development in the twenty-first century [24]. A report by the Joint Research Centre of the European Union (EU) has estimated that 75 percent of the global CO_2 emissions result from the combustion of fossil fuels. Correspondingly, UNDP [15] suggested that the high growth in fossil-based CO_2 emissions was due to robust growth in energy use. This indicates that fossil fuel combustion is considered the largest single contributor to the greenhouse effect. As a solution to heavily dependent on fossil-fuel-based energy, global companies and institutions for decades have pushed for building large-scale hydropower projects as an environmentally friendly solution with no carbon emissions. It was the Rio Earth Summit 1992 that led to the creation of the United Nations Framework Convention on Climate Change (UNFCCC). The massive interest and participation of nations and NGOs in the Earth Summit indicated a shift in global attitudes towards the environment [25]. The scientific evidence gathered in the second half of the twentieth century indicated that human activity was taking a toll on the environment. The scientific evidence also indicated that pollution and depletion of natural resources that occurred in one country could have a profound effect on the environment of other nations [25] as shown in Figure 2.

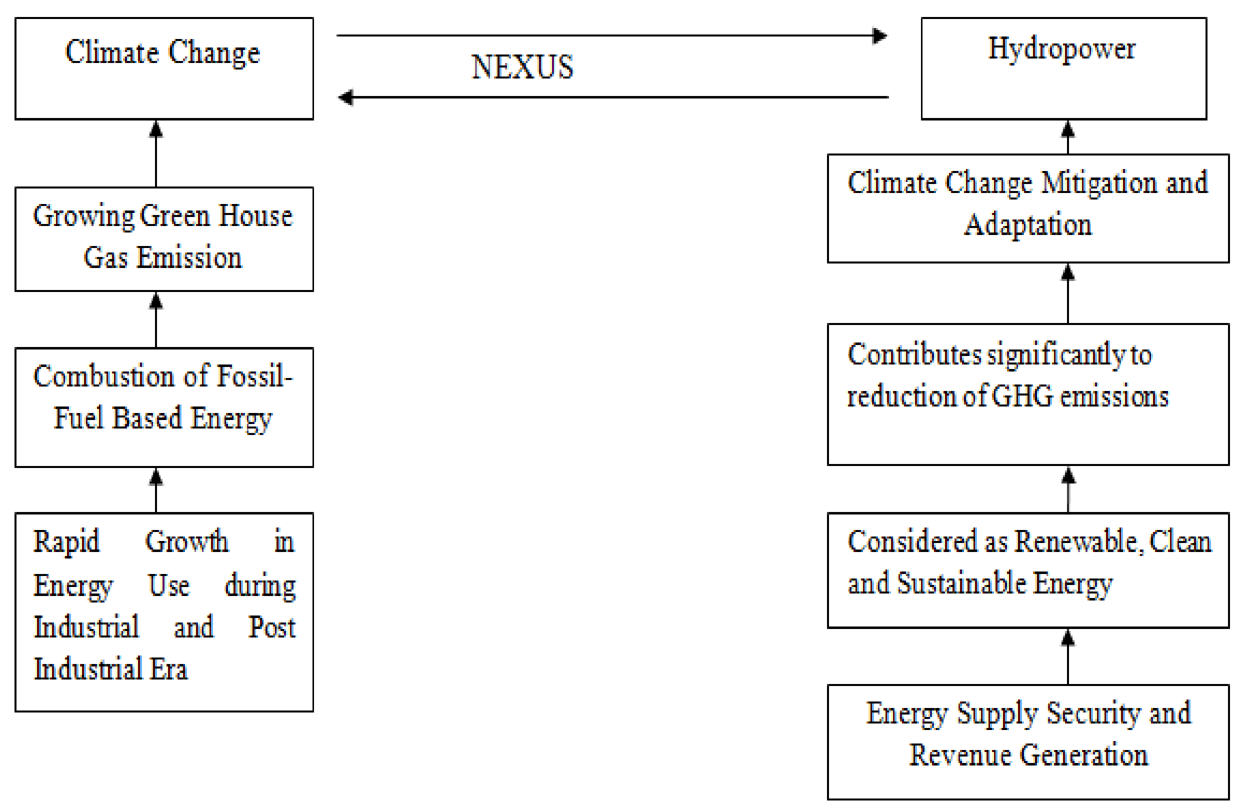

Figure 2: Hydropower and Climate Change Nexus **Note:** Based on literature Review

Increasing scientific evidence of human interference with the global climate system along with growing public concern about the environment pushed climate change onto the political agenda in the mid-1980s. Therefore, climate policy has driven the transition to clean energy. Consequently, renewable energy development has been encouraged in almost every country. At the global level, a legally binding international treaty on climate change was organized in 2015 as Paris Agreement or COP-21. Its goal is to limit global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels. Recently, in 2021, the Prime Minister of India placed five-point agenda at COP-26 conference in Glasgow to overcome from climate change. First, India will increase its non-fossil fuel energy capacity to 500 giga watt by 2030. Second, India will fulfill 50 percent of its energy requirements from renewable energy sources by 2030. Third, between now and 2030, India will reduce its total projected carbon emissions by 1 billion tones. Fourth, by 2030, India will reduce the carbon intensity of its economy by 45 percent. And Fifth, India will achieve the target of net zero by 2070. In the face of climate change, hydropower have emerged as the most renewable and sustainable source of energy globally that can contribute to mitigating the widespread potential human impacts of climate change, and it plays a vital role in national strategies for delivering affordable and clean energy [26]. The Clean Development Mechanism (CDM) under Kyoto Protocol is therefore witnessed as one of the milestones in global efforts to protect the environment from excessive greenhouse gas emission and achieve sustainable development. Since the 1997 Kyoto Protocol, the idea of hydropower development has been re-strengthened by quoting it as a climate mitigating energy. India has also pushed for renewable energy to tackle climate change, with hydropower publicized as one of the green solution [27].

At the global and local level climate change awareness has increased the popularity of hydropower, now presented as renewable and clean energy that can replace fossil fuels as well as fulfill growing energy demands in Asia and elsewhere [28]. Therefore, in the 21st-century climate change is a key driver for hydropower. But in contrast, hydropower dams and associated infrastructure appeared the most controversial and debating which are believed to be not necessarily the source of clean energy because they produce Greenhouse Gas Emissions (GHG) to the atmosphere that can be substantial during the process of construction and subsequent land-use change [29-32]. Additionally, the literatures show that greenhouse gas especially methane is produced from the decomposition of submerged vegetation in a newly submerged area behind dams. Yet, repackaging hydropower infrastructure as clean energy is confusing the resource with the instrument: water resource is renewable, yet dams are not [33]. Therefore, Clean Development Mechanism (CDM), United Nations Framework Convention on Climate Change (UNFCCC), and IPCC have recognized emission from the reservoir as important issues both at the national as well as the international level [34].

As per the report of the World Commission on Dam (WCD) in 2000 explored that large dam reservoirs could contribute between 1% and 28% of the global warming potential of GHG emissions [35]. For instance, in the recent past, the total annual methane emission has been assessed from major hydropower dams in Malaysia are estimated as 387.34 Gg of CH_4 per year. Most of the literature revealed that tropical and subtropical hydropower reservoirs are more significant sources of GHG compared to boreal or temperate ones [34,36]. The emission factor and net GHG emission of Koteshwar reservoir in Uttarakhand, India are respectively, estimated as 13.87 g CO_2 eq./kWh and 167.70 Gg C/year, which are less than other global reservoirs located in the same eco-region [36]. Similarly, Kumar and Sharma [29] attempt to predict the vulnerability of Tehri reservoir (India) to GHG emissions using the GHG Risk Assessment Tool (GRAT). They analyzed annual mean CO_2 and CH_4 fluxes from diffusion, bubbling, and degassing during 2011-12. The study found that Tehri reservoir emitted higher CO_2 and CH_4 (i.e. 790 mg $m^{-2}d^{-1}$ and 64 mg $m^{-2}d^{-1}$ respectively) in 2011, causing more climate change impact [29].

Furthermore, it has been estimated that nearly 90% of Indian Himalayan valleys would be affected by dam building and 27% of these dams would affect dense forest [37]. In Himachal Pradesh (India), the associated construction activities for hydropower projects have not only impacted livelihoods, existing land-use, disturbed forest biodiversity and fragmented the forest landscape, but the related compensatory afforestation plantations are also ridden with problems [27]. The dam-building activities are known to trigger adverse impacts on terrestrial and aquatic ecosystems and their biological diversity but the most conspicuous impacts are anticipated on the Riverine ecosystem and its functions [22 ,38].

Nonetheless, healthy rivers are necessary for supporting life on earth. They help to maintain a healthy ecosystem and balanced climate but most of the world's free-flowing rivers have been sacrificed for the big hydropower projects. In the recent past, Southeast Europe (SEE) has been witnessing a boom in Hydropower Plant (HPP) construction while as SEE includes global hotspots of aquatic biodiversity, it is expected that this boom will result in a more severe impact on biodiversity than that of other regions [17]. Furthermore, Zarfl et al. [20] expressed that hydropower development will disproportionately impact areas of high freshwater megafauna richness in South America, South and East Asia, and the Balkan region. More recently in 2018, due to faulty construction, operation, and the failure of authority to observe early warning signs, under-construction southern Laos's dam collapsed, killing at least 40 people, leaving hundreds missing and homes washed away [19,39]. In fact, over the years, the sustainability and win-win nature of big hydropower dam project has been questioned by researchers, environmentalists, and social activists. Large dams, long viewed as sustainable, renewable, beneficial in climate mitigation, flood, and drought control, and essential to development, have become sites of major social and environmental conflicts [18]. In a highly complex geological, ecological, cultural, and political context, the Eastern Himalayan region is widely regarded to be especially vulnerable to the effects of climate change, while hydropower as a development strategy makes for a toxic combination [28].

In recent pasts, climate change has been a key driver for hydropower development in India in general and the Upper Tista basin of Sikkim in particular [40]. It has been witnessed that since the last century, an increase in average global temperature has been observed, and it is expected to increase further in the future [41,42]. The intensity and frequency of precipitation are also expected to change, despite the trend differing with the season and the region [40]. The last five year climate variability assessment (2006-2010) has shown table 1 that there is a marked decrease in rainfall in almost all the seasons and warmer nights and cooler days with increase in minimum temperature and decrease in maximum temperature respectively [43]. In Sikkim Himalaya, the problem of dying springs is being increasingly felt across the region because of impacts caused by changing climatic conditions manifested in the form of rising temperature, rise in rainfall intensity in summer, reduction in its temporal spread with a marked decline in winter rain [44]. Climate projections for 2030s in Sikkim indicate decrease in winter rainfall by 12 mm and an overall decrease of precipitation by about 30%. Rainfall has become variable in Sikkim, with late monsoons and torrential rainfall replacing the characteristic monsoon drizzle [40].

Table 1: Observed trends in climate during the Five Years Period (2006-2010)

Months	% Change in precipitation	Change in maximum temperature (In °C)	Change in minimum temperature (In °C)
January	-79	0.4	2.2
February	-30	0.5	2
March	-7	-0.1	1.8
April	-18	-0.3	1.6
May	-24	0.2	1.4
June	-7	-0.3	1.3
July	-7	-0.2	1.3
August	0	-0.4	1.1
September	-9	0	1.2
October	-24	-0.3	1.7
November	-41	-0.9	1.8
December	-44	-0.7	1.8
Annual	-9	-0.2	1.6

Note: Information and Public Relations Department, Govt. of Sikkim, 2012

Seetharam [43] in a report of Information and Public Relations Department (Govt. of Sikkim) has calculated the variation in rainfall, variation in minimum temperature, and variation in maximum temperature from 1957 to 2005. The observed trends in climate during the five years period (2006-2010) was based on the long period averages calculated in study and the projected figures in trend per decades as indicated in Table 2 i.e. "Variation in rainfall (mm) over Gangtok (1951-2005).

Table 2: Variation in rainfall (mm) over Gangtok (1951-2005)

Months	1951-1980	1961-1990	1957-2005	Change in rainfall from 1951-80 to 1961-90	Change in rainfall from 1961-90 to 1957-2005	Change in rainfall from 1951-80 to 1957-2005	Projected figures based on 1957-2005
January	40.4	25.5	32.6	-14.9	7.1	-7.8	-2.7
February	50.2	58.6	62.6	8.4	4	12.4	6.5
March	127.1	107.4	135.5	-19.7	28.1	8.4	-12.7
April	270.5	308.7	270.3	38.2	-38.4	-0.2	44.6
May	534.7	533	523.9	-1.7	-9.1	-10.8	50.7
June	650.4	590.9	630.9	-59.5	40	-19.5	-56
July	666.4	662	658	-4.4	-4	-8.4	67.9
August	578.2	552.2	578.9	-26	26.9	0.7	62.3
September	429.3	481.5	464.6	52.2	-16.9	35.3	-41.7
October	180.3	160.7	175.6	-19.6	14.9	-4.7	20.8
November	35.8	36.8	40	1.0	3.2	4.2	-2
December	17.2	21.6	21.2	4.4	-0.4	4	1.8
Annual	3580.5	3538.9	3611.7	-42	73	31	49.6

Note: Information and Public Relations Department, Govt. of Sikkim, 2012

The climate change issue in Sikkim Himalaya has become more pronounced over the past years. In Sikkim, long term and reliable meteorological data is available only for two stations-Gangtok and Tadong (east Sikkim) since 1957 till present. It has been witnessed that monthly, seasonal, and annual analysis of data based on Gangtok meteorological station for the period of 1957 to 2005 indicates a trend towards warmer nights and cooler days, with increased rainfall except in winter [43]. The temperature in Gangtok has been rising at the rate of 0.2-0.3°C per decade and the annual rainfall is increasing at the rate of nearly 50 mm per decade. It has been estimated that the temperature in Gangtok has risen by 1 to 1.5°C since 1957 [40]. As per the record of two decades i.e. 1991-2010, the number of rainy days, as well as the annual rainfall, has decreased at the rate of 0.72 days/year and 17.77 mm/year respectively [11]. The warming is more pronounced in winter even though considerable warming has been observed in other seasons too. The more cooling of days has been observed in the months of November and December [45]. During the year 2008 and 2009, the state witnessed one of the driest winters in living memory. In Sikkim Himalaya, it has been projected that by the 2030s, the average annual temperatures are likely to rise by 1.8 to 2.1°C in 2030s with respect to the 1970s. According to Meteorological Department, Government of India, Sikkim Division, the year 2009 was the warmest year in the century of Sikkim [40].

Hence, the State Action Plan on Climate Change (SAPCC) has been formulated by the Department of Science and Technology (DST) and Climate Change under the state government in 2011 to help communities' adaptation and mitigation to changing climate and its consequences. But, Joshi et al. [2] critically analyzed the State Action Plan on Climate Change (SAPCC) of Sikkim. They highlighted that the focus of the report is not on how large dams might exacerbate climate change impacts; rather it is on how climate change impacts might threaten the viability and sustainability of hydropower projects. The term 'Climate' is conspicuously absent in the development of hydropower in Sikkim, even though hydropower development is otherwise at global and national levels positioned explicitly as a climate change mitigating strategy (ibid). Therefore, the climate policy framing is an exclusionary process, and climate mitigating interventions that are engineered essentially to address neoliberal economic concerns rather than environmental challenges are often the source of multiple new conflicts [2]. In the face of climate change, hydropower as a developmental pathway in the climatically vulnerable Upper Tista catchment is predominant with controversies over the socio-cultural and environmental impacts being aggravated by power projects [46-50].

Hydropower development in the face of climate change: People's perception in upper tista basin

The Government of Sikkim has taken steps to exploit abundant hydroelectric power potential for revenue generation, and electricity generation as well as harnessing climate mitigating clean energy. The construction of hydropower projects is a part of the central government's mater vision of the North-eastern region as 'India's future power house'. According to the Government of Sikkim, "The River Tista has tremendous potential for promoting power generation, as the river descends from an elevation of about 3600 m to about 300 m over a distance of 175 km [21]. Hence, Sikkim welcomes private developers for developing and exploiting its hydropower potential, which has been assessed as 8,000 MW seasonally and 3000 MW power during winter month [40] and it is one of the key high revenue-generating sectors for the state can be through possible sale of electricity generated from its vast hydroelectricity generation potential to the national grid. Hydropower development is therefore considered desirable or rather necessary for its potential contribution to the Indian economy.

Apart from the development of various small, mini, and micro hydropower projects, several mega projects have been awarded to the NHPC, NTPC, and private developers in the last one and half decades [21]. There are various private developers making an investment in Upper Tista Catchment of Sikkim-Darjeeling Himalaya such as Gati Infrastructure Ltd, Tista Urja Ltd, Sneha Kinetic Power Project Ltd, and Shiga Energy Pvt. Ltd etc. These private developers' gives 12 percent of their output which will go to the host state Sikkim as royalty; the rest will be taken to the national power field. There is tremendous scope to export and sell power generated through hydropower projects over Tista and other tributaries and streams. As per the Vision Document of the Energy and Power Department, Government of Sikkim (2010), the total annual revenue generation from the hydropower projects expected to be commissioned by 2015 is around Rs.1,292 crore, which is now being revised to Rs.1,500 crore according to the latest vision document of the same department published in 2014 [51] as shown in Table 3, Table 4 and Table 5.

Table 3: List of Projects Commissioned

Sl. No.	Name of Project	Capacity	Location	Implementing Agency/ Project Developers	Remarks
1	Teesta-III	1200 MW	North Sikkim	Teesta Urja Ltd.	Project commissioned in 28/02/2017 and is operational
2	Dikchu HEP	96 MW	Dikchu, North Sikkim	Sneha Kinetic Power Project Ltd.	Commissioned in 31/04/2017 and is operational
3	Rangit-III	60 MW	Hingdam, South Sikkim	NHPC Ltd.	Commissioned in 15/02/2000 and is operational
4	Teesta-V	510 MW	Balutar, East Sikkim	NHPC Ltd.	Commissioned in 2008 and is operational
5	Chuzachen HEP	110 MW	Chuzachen, East Sikkim	Gati Infrastructure Ltd.	Commissioned in 18/06/2013and is operational. Now project is under NCLT.

6	Jorethang Loop	96 MW	Majitar, South Sikkim	DANS Energy Pvt. Ltd.	Commissioned in 25/09/2015 and is operational
7	Tashiding HEP	97 MW	Tashiding, West Sikkim	Shiga Energy Pvt.Ltd.	Commissioned in 18/10/2017 and is operational

Note: Energy and Power Department, GOS (As of June 2021).

Table 4: Status of Under Construction Projects with 25 MW Capacities and above

Sl. No.	Name of Project	Capacity	Location	Project Developers	Remarks
1	Teesta-IV	520 MW	North Sikkim	NHPC Ltd.	Only preliminary works are under progress. First stage environment clearance is obtained.Process for public hearing has been initiated.
2	Teesta-VI	500 MW	South Sikkim	Lanco Energy Pvt. Ltd.	NHPC has acquired the project through NCLT and preliminary works at site has commenced.
3	Panan HEP	300 MW	Dzongu, North Sikkim	Himagiri Hydro Energy Pvt.Ltd.	Only preliminary construction works started due to conditional availability of Wild life Board Clearance and due to damage of approach road to dam site at upper Dzongu. CoD extended till Sept. 2025.
4	Rongnichu HEP	96 MW	Kumrek, East Sikkim	Madhya Bharat Power Corporation	Project is almost complete. Due to the impact of Covid-19 CoD was extended till June 2021
5	Rangit-II	66 MW	West Sikkim	Sikkim Hydro Ventures Ltd.	Stalled due to fund constraints. Corporate Insolvency Resolution process initiated in NCLT, Delhi Branch.
6	Bhasmey HEP	51 MW	East Sikkim	Gati Infrastructure Ltd.	Project works suspended due to funding issues. Developer has been directed to commence the construction works immediately failing which the IA is liable to be cancelled.
7	Rangit-IV	120 MW	Rothak, West Sikkim	Jal Power Corporation Ltd.	Project works suspended due to funding issues. NHPC acquired the project through NCLT.
8	RahiKhong	25 MW	Dzongu, North Sikkim	Sikkim Engineering Pvt. Ltd.	Project under survey and investigation. DPR is under preparation. Public hearing has been concluded by SPCB.

Note: Energy and Power Department, GOS (As of June 2021)

Table 5: List of scrapped project

Sl. No	Name of project	Capacity	Location	Project Developer	Reason
1	Teesta-II Revised Capacity 150 MW	330 MW	North Sikkim	HimUrja Infra Pvt. Ltd.	Due to non-performance project is terminated
2	Upper Rolep (Nathangchu)	30 MW	Rolep, East Sikkim	Cosmic Infra Powergen Pvt. Ltd.	MoU/IA terminated on 24.09.2016 due to non-performance of the developer
3	KalezKhola-I	27.5 MW	West Sikkim	Cosmic Infra Powergen Pvt. Ltd.	MoU/IA terminated on 24.09.2016 due to non-performance of the developer.
4	KalezKhola-II	54 MW	West Sikkim	Pentacle Power Pvt. Ltd.	MoU/IA terminated on 20.02.2017 due to non-performance of the developer.
5	Upper Rolep (Changuchu)	30 MW	Rolep, East Sikkim	Cosmic Infra Powergen Pvt. Ltd.	MoU/IA terminated on 24.09.2016 due to non-performance of the developer.
6	SadaMangder	71 MW	South & West Districts	Gati Infrastructure Ltd.	MoU/IA terminated on 26.02.2017 due to non-performance of the developer.
7	Lethang	96 MW	West Sikkim	KHC-LethangHydroprojectPvt. Ltd.	Implementation agreement terminated as National Wild Life Board, Ministry of Environment & Forest, govt. of Sikkim India did not grant clearance.
8	Suntaleytar	40 MW	Suntaleytar, East Sikkim	Moses Baer Electric Power Limited	Due to non-performance of the developer the LoI has been terminated on 20.02.2017.

9	Rechu-Meyongchu	26 MW	Rechu, North Sikkim	Planet Infra Projects Pvt. Ltd.	MoU/IA terminated on 20.09.2016 due to non-performance of the developer.
10	Rangyong	117 MW	North Sikkim	BSC(P)L SCL JV Engineers and contractors	Public claimed that tunneling leads to landslides which breaks water channels frequently
11	Chakung Chu	50 MW	North Sikkim	ATIL	Social and cultural reason
12	Ralong	40 MW	South Sikkim	ATIL	Technical reason
13	Thankgchi	40 MW	North Sikkim	Lachung power Pvt. Ltd.	Public Opposition
14	Ratheychu	40 MW	North Sikkim	Coastal Pvt. Ltd.	Cancelled due to public resistance
15	Bakchachu	40 MW	North Sikkim	Coastal project Pvt. Ltd.	Cancelled due to public resistance
16	Teesta stage-I	280 MW	North Sikkim	Himalayan green Energy Pvt. Ltd.	Cancelled due to environmental issue and public resistance
17	Lachen	210 MW	North Sikkim	NHPC	Social and cultural issues
18	Bimkyong	99 MW	North Sikkim	Teesta power Pvt. ltd.	Social and cultural issues
19	Bop	99 MW	North Sikkim	Chungthang power Pvt. Ltd.	Land feasibility
20	Lachung	99 MW	North Sikkim	Lachung power Pvt. Ltd.	Social and cultural reason
21	Ting-Ting	99 MW	West Sikkim	T.T energy Pvt. Ltd.	Submergence area, susceptible to erosion

Note: ATIL (Amalgamated trans-power India Limited) as cited in Chhetri (2015 pp 20). Energy and Power Department, GOS (As of June 2021).

"Since last many years the weather patterns have been changing in the region, sometimes erratic rainfall and sometimes drought-like condition. We are experiencing increasingly warmer conditions nowadays. But additionally, during the last 10 years, our village is in critical condition because of hydropower dam and its impacts on natural springs and agriculture"- (64 years old man, farmer of Lower Samdong village near Tista Stage-V dam).

The basic understanding of people's perception of changing climatic conditions in the Tista river basin will provide strategic directions for government policy, adaptation strategies, and the development of community-based guidelines. The people's perception of weather patterns of Upper Tista Catchment are extracted with the help of 'weather chart' Table 1 based on Participatory Rural Appraisal (PRA) and Focus Group Discussion (FGD) at Samdong-Kambal and Rakdong-Tintek Gram Panchayat Units (GPUs) near 510 MW Tista-V dam. The affected people of these GPUs were interviewed mostly those who are engaged in agricultural and associated activities. The various climatic indicators have been taken such as rainfall, hailstorm, warm and cold temperature, dry period, and landslide to extract detailed ground insights regarding the changing climatic conditions. The changing climatic conditions of a region are drawn by comparing the people's perception of the past and the present experiences as shown in Table 6.

The overall rainfall has reduced drastically in comparison to the past years. As per the people's perception, the overall temperature (hotness) has increased around the year since last 10-15 years. The agricultural productivity has also decreased as compared to earlier years due to an increase in temperature. The villager reports that the region is a source of a large number of organic vegetables, large cardamom, pulses, and cereal crops. With the increasing trends of dryness due to an increase in temperature, the production of these vegetables has gone down by one-fourth. In fact, the livelihoods of the local people are agrarian, where around 80% of the villagers are dependent upon agriculture and allied activities. It has been witnessed that some people of the villages left water-intensive cultivation such as paddy because of untimely rainfall and water scarcity during the summer months. The high levels of impacts from climate change were recorded for paddy, maize, wheat, oilseeds, cardamom, ginger, spring water, and fodder trees [52]. The region experiences extreme water scarcity during the months of November-March. As per the local residents, the onset of monsoon is observed to be delayed for the last 11-12 years. Over the years, people have been witnessing fluctuation in rainfall patterns. They claimed that the natural spring is being further accentuated and degraded by the tunneling process of the Tista-V Hydroelectric Project.

Similarly, as per the local people intensity of rainfall remains high during three months i.e. June, July, and August. But it has been witnessed that during the last two decades average rainfall has decreased both in terms of the number of rainy days (14.40 days) and total rainfall (355 mm) [53]. It has been reported that the high-intensity rainfall in the monsoon time leads to landslides and soil erosion. Additionally, it is said that aggressive landslides in the region are further aggravated by hydropower dams, tunneling, and road constructions. The local people has been witnessing a severe cold (or chilling weather) in the month of December, January, and February. However, the warm temperatures are more pronounced in the rest of the months as shown in Table 7.

Table 6: Climatic Hazards and Events (based on people's perception)

Indicators	Time	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Rainfall	Past	**	***	***	***	***	***	***	***	***	**	*	*
	Present	*	*	*	**	**	***	***	***	**	**	*	*
Warm Temperature	Past	*	*	*	**	**	**	**	**	**	*	*	*
	Present	*	*	**	***	***	***	***	***	***	**	*	*
Cold Temperature	Past	**	**	**	**	*	*	*	*	*	**	***	***
	Present	***	***	**	*	*	*	*	*	*	*	**	***
Dry Period	Past	*	*	*	*	*	*	*	*	*	**	**	**
	Present	***	***	**	*	*	*	*	*	*	**	***	***
Hail Storm	Past			*	**	*							
	Present			*	**	*							
Landslides	Past						*	**	**	**	*		
	Present						**	***	***	**	*		

Note: 'Weather Chart' based on FGDs *Low, **Medium, ***High

Table 7: People's Perception of Extreme Events and Changing Climate in Upper Tista Catchment

Climatic Parameter	Experienced changes	Experienced impacts
Temperature	-Increased overall temperature (Increased warmer days). -Intensity of hot days increased. -Not so extreme cold at winter.	-Insects and pests (diseases) are appearing in crops. -Erratic landslide in rainy season and drought like condition in winter season. -Natural springs are drying and water scarcity due to less rainfall. -Decreased in agricultural production.
Precipitation	-Uneven rainfall. -Shortening rainfall season. -Less rainfall during winter. -Rainfall intensity during summer increased.	-Water scarcity -Drying up of natural springs from the original aquifers. -Reduced agricultural production.
Coldness/Hotness	-Duration of overall coldness decreased. -Increased overall hotness	-Production of fruits and vegetables decreased (Orange, cardamom, and green vegetables).
Landslides	-Facing aggressive landslides due to erratic rainfall in monsoon months.	-Blockage of road and village footpaths.
Water scarcity	-Almost 80% of natural springs dried up or became seasonal.	-Declined food productivity (Production level of rice, orange and Large Cardamom reduced). -Food shortages.
Drought	-Longer dry period	-Increased dry land

Note: Based on Focus Group Discussion at Field Sites

The various climatic parameters shown in the table above reflect the changing climatic condition of a region. Because of these changing trends of climatic conditions, the region has been witnessing several impacts on agriculture and associated sectors, which directly or indirectly worsen the situation of lives and livelihoods of a local people and the environment.

People's perception around hydropower development: Insights from the field

In the face of changing climatic conditions, the hydropower project has explicitly accentuated the region and the environment. The mindset of the people has been critical towards the environmental impact being aggravated by hydropower projects in Sikkim Himalaya during the last two decades (2000-2020). In fact, the Tista basin provides significant human and environmental security to the geographic milieu of the region [21]. The people's perceptions particularly on hydropower in the upper Tista catchment bring out the grounded insights of public repulsion to the hydropower projects. Wherein, the people conceptualized the dam as a 'deteriorating agent of the environment and culture of a place'.

Natural spring is the only source of water in the study area is highly susceptible to changing climatic condition. Furthermore, locales witnessed that the drying up of natural spring is an important associated consequence of tunneling and blasting in the region. In fact, agricultural production has gone down by one-fourth due to inappropriate climatic conditions which is further been accentuated by tunneling and road construction. Agriculture is the major source of income. Consequently, the agricultural-based livelihood in the River Tista basin faces two alarming environmental challenges in the form of hydropower development and changing climatic conditions. There are two contradictorily conflicting perspectives in Upper Tista Basin in the context of hydropower projects i.e. the developmentalists perspectives who prefer hydropower development as a 'bridge to attain socio-economic enhancement' and the environmentalists' perspectives who critically voice against the cascading hydropower dams. The environmentalists and affected people believed that the environment, society, and livelihood have been deteriorated alarmingly due to unsustainable way of water resource development. There is a contestation that none of the power projects that are constructed in the mountain areas in northeast India including Sikkim are based on the geo-hydrological assessment [54]. The people's perception of hydropower varies with time i.e. pre-construction, during construction, and post-construction period. Therefore, people's perceptions of the hydropower project and their impacts upon the villages and adjoining areas at different stages of the Tista-V project are briefly summarized below.

Pre-construction Period (before 2000): Hydropower project in the locale is being promoted by the government as clean and sustainable energy and inclusive development imperatives such as revenue generators or economic growth and free energy suppliers. In fact, hydropower is advocated initially as a means of mass employment generation and poverty eradication of society. The pre-construction perception of a hydropower dam in the locality was pro-development centric and pro-environment protection. When the idea of dam construction was first incepted during 1999-2000, the villagers had very little knowledge about the pros and cons of a hydropower project. The stakeholders had painted a beautiful story of a happy ending wherein each member of a household would secure a regular job and the medical issues will be fulfilled with the establishment of a hospital in their village. Correspondingly, the slogan of 100% job creation and provision of free electricity attracted educated unemployed and underemployed youths. Politicians and hydropower developers influenced the local people by citing hydropower projects as holistic communities and village developers.

It has witnessed that no or very less public level participation in the decision making process in pre-construction period wherein the project affected were not well informed and called for the public hearing. There seemed in fact polarized bi-party decision-making process between higher authorities' i.e. state government and the project developers National Hydroelectric Power Corporation (NHPC) rather than including public and stakeholder participation.

Villagers highlighted that the natural environmental setting of the river and locale area was perfect and not interfered with by any water resource development projects (like R-o-R hydropower dams). The villagers had surplus water availability as a natural perennial spring emanating from the aquifers. The water-intensive crops such as paddy and large cardamom were the most prominent crops they produced. Villagers did not have any ideas about the cracks which would appear in the lands and houses because of hydropower and associated activities such as hazardous tunneling, blasting, road construction, and quarrying. In fact, the villagers were not informed about the 17.2 km long stretch of underground tunneling from the dam site to the powerhouse site. Later on, the consequences of this tunneling during the construction and post-construction period brought cracks in the houses and landforms. The road construction and blasting transform the morphology of land due to land vibration which resulted in uncertain landslides, rock falls and debris falls.

During construction period (2000-2008): At the initial stage of construction, the stakeholders of the dam construction site tried to barricade the road to neutralize the interference of unknown people in their locality but in front of authority their effort became futile. They staged strong opposition collectively to resist the dam but the result was not effective in front of police. Police as active members of the authority came to the place and evacuated the people through harsh methods. Administrative pressures on land donors were immense during the construction period. Many times, villagers have approached the District Collector (DC) to stop the environmentally unsustainable and unnatural destruction of dam construction. Initially, the Member of Legislative Assembly (MLA), Panchayats, and District Collector (DC) convinced local people for the consent by showing innumerable socioeconomic facilities and opportunities from the company. Despite severe criticism, the construction phase of the project started in the year 2000 and was commissioned in 2008.

It was considered to be the most destructive phase of the project. Around 55 households (families) were displaced and resettled in a colony in the year 2007 by the project but the recent past condition of the resettlement and rehabilitation colony seemed dreadful condition due to arousing infrastructural problems. Respondents countered- the 510 MW Tista-V project which was designed and promoted in the 2000, which in fact sidelines local development and sustainability concerns for the sake of rapid economic growth. The promises that had been made during the time of public hearing were totally overlooked by the developer and the government.

Villager perceives the tunnel beneath their village as very much fragile and as being constructed haphazardly. Project-affected people were worried about the acute water problem and changing the behavior of the environment that aggravated by hydropower dams in the region. The real victims whose houses and lands were being taken away by the company were politically inactive. It was discussed during FGDs that the positive image of the Hydro Electric Project (HEP) was first imposed and introduced by the government by force in the region despite the public's resistance to the dam. The positive image of the big hydropower project as a sustainable form of development for the people and the region were inculcated by the politician to maintain social harmony between different social groups and politicians. Therefore, under such circumstances, villagers perceived hydropower dams as a sustainable form of water resources development despite being much public condemnation. Many people were employed as daily wage casual workers or laborers during the construction phase but removed almost all of them after construction was completed in 2008. In fact, the local people are employed on a contractual basis in clerical posts and as what the villagers quote it as casual labor or third-grade job. Therefore, the policies of a 100% regular employment facility to the villagers in the projected area were misinterpreted. The project-affected people countered the NHPC (developer) and the government for not being allocated satisfactory compensation. The Resettlement and Rehabilitation (R and R) plan which envisages incentives for the displaced families but is yet to be fully implemented and monitored [51].

At the initial stage of tunneling and damming of the river, the peripheral areas started getting impacted. Most of the respondents emphasized the declining trend of agricultural production not merely from changing climatic conditions but by tunneling as well. In fact, tunneling significantly led to drying up of perennial spring. The villagers report, due to the fragile landscape, the region feared landslides during the rainy season but the fragility of the landscape is further being accentuated by the hydropower dam and the underground tunneling. Sharma et al [54] further found in their research that the use of dynamites in road construction, underground tunneling, and cementation work has a terrible impact on springs which alters their occurrence and reduces their discharge. 64 years old man reports that-"We have been experiencing drying up of our natural spring at the fast rate since the construction of dam and tunneling started. Most of the perennial spring became seasonal and most of them have dried up. Nowadays we are experiencing uncertain landslides in the places where we had not expected to be occurred". Similarly, the people were worried due to constructional activities which accentuated the region through 'unnatural land vibration'. They faced unnatural uncertainties due to these vibrations which aggravated socio-economic vulnerabilities through the appearance of house cracks and water scarcity due to tunneling.

Post constructional period (after 2008): The Tista Stage-V project was commissioned in 2008. Subsequently, the project-affected areas have been facing extreme forms of hydropower-induced environmental impacts. In fact, environmental insecurities are a major concern. The villagers argued that the region is an environmentally vulnerable condition because of its fractured landform created by the dam-building and associated activities during the construction phase (2000-2008). People and the environment of the project-affected area are extremely impacted by tunneling and damming. Consequently, almost 80% of the natural springs dried up and faced acute water problems for household, livestock, and agricultural purposes during the winter season. Water insufficiency is the major problem in the villages. To tackle water scarcity, the government of Sikkim (irrigation department) has facilitated metalled piped for water but villagers have critical views that merely water pipe does not have any meaning until there is water in the spring. The government has built many water tanks within the village but they remained dry throughout the year. They report hydropower development accelerated the water in the spring to dry. Till now the government has not yet facilitated the water to individual stakeholders from perennial and sustained sources. Extensive landslides have become a common disaster in the region during the rainy season. Some of the houses are tilted and fractured because of unstable land due to underground tunnels. Project-affected people have been compensated with a certain amount during the pre-constructional period but the damages are still experienced after the dam has been commissioned. In this context, the villagers have common complaints that- 'who will compensate us if in case of our houses and land property gets damaged now'. Water availability in the dry season has become a serious problem in the region which led to food insecurity. A 30 years old lady responded during FGD as- "The vegetables are not grown efficiently as before, because of water shortages and further aggravated by pests, now most of us are depending upon the vegetables coming from Siliguri, state of West Bengal". In fact, the region is exclusively dependent on rainfall and natural springs for agriculture and livestock. The long stretch of tunneling just below the villages led to the drying up of natural spring and has badly impacted the productivity of traditional food crops, fruits, and vegetables.

The region is renowned for cardamom cultivation has turned into scarce cardamom cultivated land due to water scarcity. Cardamom is a water-intensive crop and has severely been affected by tunneling and water shortages, which negatively impact the economy of the region [55]. Paddy is cultivated in the rainy summer season has comparatively good production in the region but over the years climatic uncertainty or untimely rainfall has affected the production level. The village development programs as promised during public hearings such as free electricity, water facility, and house repair to project-affected people during pre-construction and construction period are yet to be fulfilled. As part of the local area development program, hydropower companies had to undertake community development projects such as such as road, school repair, and footpath construction, electrification and water supply for villages, and livelihood skill development in project affected areas [56]. These community development programs are also yet to be fulfilled.

DISCUSSION

In the face of climate change hydropower is considered a clean, renewable, and environmentally friendly source of energy at the global label. The rapid and responsible deployment of clean and renewable energy is crucial to meet the goals of the landmark Paris Agreement 2015 (COP-21), which is to limit the global average temperature so that the worst impact of climate change can be avoided. To achieve this goal, countries are aiming to reach net zero-emission. Similarly, in 2021, the UN COP-26 conference on climate change offers the chance for world leaders to take action and make urgent and meaningful commitments to reducing emissions and limit global temperatures to 1.5C above pre-industrial levels by 2050 [57]. It was the Kyoto Protocol's Clean Development Mechanism, which has been facilitating financial support for large hydropower dams, with the main goal being to reduce greenhouse gas [58]. CDM projects have a two-fold objective (a) reducing greenhouse gas emissions and (b) contributing to sustainable development. At present, hydropower has been a major part of energy supply security which produces an average of 3930 (TW.h).a-1 and yields 16 percent of the world's generated electricity, representing 78 percent of renewable electricity generation in 2015. Therefore, hydropower contributes significantly to the avoidance of Greenhouse Gas (GHG) emissions and the mitigation of global warming [59]. However, over the past years, the hydropower dams and associated infrastructure appeared the most debating which are believed to be not necessarily the source of clean energy because they produce Greenhouse Gas Emissions (GHG) to the atmosphere that can be substantial during the process of construction and subsequent land-use change [29,31,32,60]. Furthermore, the assumption of hydropower as a source of clean energy is increasingly being challenged by recent findings that a large amount of methane and other GHG are emitted during reservoir creation, turbine operation, and dam decommissioning [60]. The greenhouse gas especially methane is also produced from the decomposition of submerged vegetation in a newly submerged area behind dams.

Recently, India again committed to combating climate change at the Glasgow COP-26 summit 2021 with a bold announcement that it will achieve the target of net zero emissions by the year 2070, achieving 500-gigawatt non-fossil energy capacities by 2030, and fulfilling 50 percent of its energy requirements from renewable energy source by 2030 [61]. India also pushed the issue of emission reduction to combat climate change at the 16th G20 Summit held in Naples in 2021, where it urged the G20 countries to bring down per capita emissions to the global average by 2030 in view of the "fast-depleting available carbon space" [61]. Soon after India ratified the Kyoto Protocol it constituted the Designated National Authority to host clean development projects. India holds the second position after China in hosting CDM projects in the world [62]. In fact, the national drive for energy security (electricity) along with the climate mitigation initiative has promoted a rapid expansion of hydropower development into isolated parts of the Himalayan states. Therefore, one of the major national and state drivers for hydropower development in Sikkim Himalaya is climate change.

Significant numbers of the hydropower dams are planned in the Tista river basin of Sikkim and Darjeeling Himalaya. Therefore, the Tista river basin in Eastern Himalaya is being subjected to cascades of hydropower development and if all dams are constructed as proposed, the Indian Himalaya in general and Sikkim Himalaya, in particular, would have been one of the highest average dam densities in the world [22,37,63]. Over the years, the study area has been witnessing changing climatic variability in the form of rising temperature and decreasing rainfall patterns but the hydropower dam construction and water diversification through tunnels add to the severity of the condition and worsen the livelihood of local people. In the face of changing climatic conditions, the hydropower projects appeared a most contested developmental pathway across the Sikkim Himalaya witnessing anti-dam movements [64-66]. Hydropower is considered renewable energy but it creates a lot of socio-cultural and environmental insecurities during construction and post-construction periods. It has been witnessed that the construction of hydropower and associated infrastructure such as tunneling, road construction, building colonies, powerhouse constructions, high-voltage power transmission lines, and towers in the Tista River Basin would result in displacement of local people, river water diversion, felling of the trees, degradation of agricultural production, unnatural vibrations, landslides, river bank erosion, river water pollution, drying up of natural springs, unplanned muck disposal etc. To date, the Upper Tista Basin of Sikkim Himalaya witnessed around 21 projects that have been scrapped (Table 5) on various grounds such as socio-cultural grounds, environmental issues, technical reasons, public opposition, and non-performance of the developers [67].

CONCLUSION

In Rakdong-Tintek and Samdong-Kambal GPUs of the Tista-V project, a majority of the villagers are politically inactive and those who are active are victimized. In fact, the political victimization has suppressed the real voices that emerge against the negative impacts of the hydropower project. Initially, hydropower projects were seen and advocated as a symbol of progress, prosperity, source of revenue, and national prestige in these GPUs. The state government and dam developers attracted the local people by quoting hydropower dams as a renewable, climate mitigating, or win-win energy but on the contrary local people became vocal against socio-cultural and environmental destruction of it during the last two decades.

At the local level, these GPUs witnessed adverse social and environmental insecurity during the construction time of the Tista-V such as displacement of local people, river water diversion through tunneling, felling of the trees, unnatural vibrations, landslides, river bank erosion, water pollution, degradation of natural springs, and unplanned muck disposal etc. The post-construction impact seems to be high in the region recently. However, the post-construction impacts of the hydropower dam and associated infrastructures in the villages have not yet been addressed properly. The project-affected people have been witnessing an adverse socio-environmental impact of the dam since the project was commissioned in 2008. Severe cracks in houses and land have appeared rampantly over the last 2-3 years. River bank erosion, landslides, rock fall, and land sinking are the major point of concern for the local people. A natural spring is the only water source for drinking and other household purposes. Around 40 percent of natural springs are getting dried due to dam building and associated tunneling activities. The post-construction issues and challenges have not yet been seriously addressed either by the state government or the company. Participatory approaches from different social groups (villagers, environmentalists, NGOs), political leaders, and policymakers become vital to achieving secure and sustainable development which is lacking in the region. In fact, the project-affected place witnessed lacking village-level participation despite the growing emphasis on public participation or real participation by the affected people.

REFERENCES

1. Devkota LP, Zhang F. Climate change in the Eastern Himalayas: Observed trends and model projections. AGU. 2010: A33A-0099.
2. Joshi D, Platteeuw J, Singh J, Teoh J. Watered down? Civil society organizations and hydropower development in the Darjeeling and Sikkim regions, Eastern Himalaya: A comparative study. Clim Policy. 2018;19(1):63-77.
3. Das PK. North-East,'the power house of India': Prospects and problems. IOSR-JHSS. 2013;18(3):36-48.
4. Biemans H, Siderius C, Lutz AF, Nepal S, Ahmad B, Hassan T, et al. Importance of snow and glacier meltwater for agriculture on the Indo-Gangetic Plain. Nat Sustain. 2019;2(7):594-601.
5. Immerzeel WW, Lutz AF, Andrade M, Bahl A, Biemans H, Bolch T, et al. Importance and vulnerability of the world's water towers. Nature. 2020;577(7790):364-369.
6. Pritchard HD. Asia's shrinking glaciers protect large populations from drought stress. Nature. 2019; 569(7758):649-654.
7. Mishra SK, Veselka TD, Prusevich AA, Grogan DS, Lammers RB, Rounce DR, et al. Differential impact of climate change on the hydropower economics of two river basins in high mountain Asia. Front Environ Sci. 2020;8:26.
8. Vaidya RA, Sharma E. Research insights on climate and water in the Hindu Kush Himalayas. ICIMOD. 2014.
9. Bhadwal S, Sharma G, Gorti G, Sen SM. Livelihoods, gender and climate change in the Eastern himalayas. Environ Dev. 2019;31:68-77.
10. Shrestha AB, Agrawal NK, Alfthan B, Bajracharya SR, Maréchal J, Oort BV. The Himalayan Climate and Water Atlas: impact of climate change on water resources in five of Asia's major river basins. 2015.
11. Rahman H, Karuppaiyan R, Senapati PC, Ngachan SV, Kumar A. An analysis of past three decade weather phenomenon in the mid-hills of Sikkim and strategies for mitigating possible impact of climate change on agriculture. Climate Change in Sikkim: Patterns, Impacts and Initiatives. 2012:1-8.
12. Moser SC, Dilling L. Communicating Change Science:-Closing Action Climate. Oxford Handbooks. 2011:161.
13. Financing Climate Change Action: Policy Perspectives. OECD. 2014
14. Bhandari MP. Climate change science: a historical outline. Adv Agr Environ Sci. 2018;1(1):5-12.
15. Goal 13: Climate Action, Sustainable Development Goals. United Nations Development Programme. 2019
16. Sovacool BK, Walter G. Internationalizing the political economy of hydroelectricity: security, development and sustainability in hydropower states. Rev Int Polit Econ. 2019;26(1):49-79.
17. Hudek H, Zganec K, Pusch MT. A review of hydropower dams in Southeast Europe–distribution, trends and availability of monitoring data using the example of a multinational Danube catchment subarea. Renewable Sustainable Energy Rev. 2020;117:109434.
18. Rai N. Politics and Economics of Hydropower: Emerging Conflicts. Springer Nature Switzerland AG. 2020.
19. Huber A. Hydropower in the Himalayan hazardscape: strategic ignorance and the production of unequal risk. Water. 2019;11(3):414.
20. Zarfl C, Berlekamp J, He F, Jähnig SC, Darwall W, Tockner K. Future large hydropower dams impact global freshwater megafauna. Sci Rep. 2019;9(1):1-10.
21. Khawas V. Environment and development in the upper tista basin, sikkim himalaya. 2021.
22. Bhatt JP, Tiwari S, Pandit MK. Environmental impact assessment of river valley projects in upper Teesta basin of Eastern Himalaya with special reference to fish conservation: a review. Impact Assess Proj Apprais. 2017;35(4):340-350.
23. Parry ML, Canziani O, Palutikof J, van der Linden P, Hanson C. Climate change 2007-impacts, adaptation and vulnerability: Working group II contribution to the fourth assessment report of the IPCC. Cambridge University Press. 2007.
24. Vlassopoulos CA. Competing definition of climate change and the post-Kyoto negotiations. Int J Clim Chang. 2012.
25. "Earth Summit 1992". Encyclopedia. 2019
26. Hydropower status report: sector trends and insights, Chancy House, Sutton. IHA. 2019
27. Aggarwal M. "Hydropower not a very 'green' solution in Himachal Pradesh, finds study". Mongabay. 2020
28. Ahlers R, Budds J, Joshi D, Merme V, Zwarteveen M. Framing hydropower as green energy: assessing drivers, risks and tensions in the Eastern Himalayas. Earth Syst Dyn. 2015;6(1):195-204.
29. Kumar A, Sharma MP. Assessment of risk of GHG emissions from Tehri hydropower reservoir, India. Hum Ecol Risk Assess. 2015;22(1):71-85.
30. Fearnside PM. Greenhouse gas emissions from Brazil's Amazonian hydroelectric dams. Environ Res Lett. 2016;11(1):011002.
31. Fearnside PM. Impacts of Brazil's Madeira River dams: Unlearned lessons for hydroelectric development in Amazonia. Environ Sci Policy. 2014;38:164-172.
32. Edenhofer O, Pichs-Madruga R, Sokona Y, Seyboth K, Matschoss P, Kadner S, et al. IPCC special report on renewable energy sources and climate change mitigation. Cambridge University Press. 2011.
33. McCully P. A Critique of" The World Bank's Experience with Large Dams: A Preliminary Review of Impacts. IRN. 1997.
34. Kumar A, Sharma MP. Green house gas emissions from hydropower reservoirs: policy and challenges. Int J Renew Energy Res. 2016;6(2):472-476.
35. Dams and Development. WCD. 2000
36. Kumar A, Sharma MP, Yang T. Estimation of carbon stock for greenhouse gas emissions from hydropower reservoirs. Stoch Environ Res Risk Assess. 2018;32(11):3183-3193.
37. "Indian Himalayas moving towards highest Dam Densities in the World,"South Asian Network on Dams, Rivers and People. SANDRP. 2012
38. Pandit MK, Grumbine RE. Potential effects of ongoing and proposed hydropower development on terrestrial biological diversity in the Indian Himalaya. Biol Conserv. 2012;26(6):1061-1071.
39. Ives M. A day before Laos dam failed, builders saw trouble. New York Times. 2018:1.
40. Sikkim Action Plan on Climate Change (2012–2030). SAPCCS. 2011.

41. Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, et al. Climate change 2013: the physical science basis. IPCC A. 2013;1535.

42. Ranzani A, Bonato M, Patro ER, Gaudard L, De Michele C. Hydropower future: between climate change, renewable deployment, carbon and fuel prices. Water. 2018;10(9):1197.

43. Seetharam K. Climate change synthetic scenario over Gangtok. 2012.

44. Tambe S, Kharel G, Arrawatia ML, Kulkarni H, Mahamuni K, Ganeriwala AK. Reviving dying springs: climate change adaptation experiments from the Sikkim Himalaya. Mt Res Dev. 2012;32(1):62-72.

45. Mahamuni K, Kulkarni H. Groundwater resources and spring hydrogeology in South Sikkim, with special reference to climate change. Climate change in Sikkim-Patterns, impacts and initiatives. 2012:261-274.

46. Menon M. Saved! the story of rathong chu. Ecologist Asia. 2003;11:33.

47. Arora V. Unheard voices of protest in Sikkim. Econ Polit Wkly. 2007; 42(34):3451-3454.

48. Arora V. "Gandhigiri in Sikkim". Econ Polit Wkly. 2008; 43(38):27-28.

49. Arora V. 'They are all set to dam (n) our future': Contested development through hydel power in democratic Sikkim. Sociol Bull . 2009; 58(1):94-114.

50. Khawas V. Hydro-fever in the Upper Tista Basin and issues of regional environmental security. J Politics Gov. 2016;5(3):49-56.

51. Sharma G, Pandey T. Water Resource Based Developments in Sikkim: Exploration of Conflicts in the East and West Districts. 2013.

52. Sharma G, Rai LK. Climate change and sustainability of agrodiversity in traditional farming of the Sikkim Himalaya. 2012:193-218.

53. Bawa KS, Ingty T. Climate change in Sikkim: a synthesis. 2012:413-424.

54. Sharma G, Durga PS and Dahal DR. Water conflicts and benefits related to hydropower projects: A Case study from Sikkim, Abhilasha, Development Area, Gangtok Sikkim-737101, India. 2019

55. Lepcha T. Hydropower projects on the Teesta River: Movement against mega dams in Sikkim. InWater Conflicts in Northeast India. 2017:242-261.

56. Chandy T, Keenan RJ, Petheram RJ, Shepherd P. Impacts of hydropower development on rural livelihood sustainability in Sikkim, India: community perceptions. Mt Res Dev. 2012;32(2):117-125.

57. Dwivedi YK, Hughes L, Kar AK, Baabdullah AM, Grover P, Abbas R, et al. Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action. Int J Inf Manage. 2022;63:102456.

58. Baird IG, Green WN. The Clean Development Mechanism and large dam development: contradictions associated with climate financing in Cambodia. Clim Change. 2020;161(2):365-383.

59. Berga L. The role of hydropower in climate change mitigation and adaptation: a review. engrg. 2016; 2(3):313-318.

60. Song C, Gardner KH, Klein SJ, Souza SP, Mo W. Cradle-to-grave greenhouse gas emissions from dams in the United States of America. Renewable Sustainable Energy Rev. 2018;90:945-956.

61. India put climate change at the centre of its environmental policies in 2021. The Economic Times 2021

62. Osmani AR. Clean Development Mechanism: Concept and Governance in India. CEPMLP Annual Review. 2013;16.

63. Grumbine RE, Pandit MK. Threats from India's Himalaya dams. Science. 2013;339(6115):36-37.

64. Cherry JE, Knapp C, Trainor S, Ray AJ, Tedesche M, Walker S. Planning for climate change impacts on hydropower in the Far North. Hydrol Earth Syst Sci. 2017;21(1):133-151.

65. Cronin J, Anandarajah G, Dessens O. Climate change impacts on the energy system: a review of trends and gaps. Clim Change. 2018;151(2):79-93.

66. Rathore LS, Attri SD, Jaswal AK. State level climate change trends in India. India Meteorological Department. 2013;25.

67. Singh RL. India; a regional geography. India; a regional geography. 1971.