International Research Journal of Natural and Applied Sciences
ISSN: (2349-4077)
Impact Factor- 5.46, Volume 5, Issue 4, April 2018
Website- www.aarf.asia, **Email** : editor@aarf.asia , editoraarf@gmail.com

ENVIRONMENTAL IMPACT ASSESSMENT OF HYDROELECTRIC POWER PLANT

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ABSTRACT

This paper attempts to assess the environmental impacts due to Hydropower projects development in Indian Himalayan state, Uttarakhand.

Forest clearance for hydroelectricity development is the major issue for environmental degradation. Uttarakhand alone accounts for 5391.17 Ha of forest area diversion for Hydro projects since 1980 to June 2013. Beside this, land cover and land use change degrade environment of mountain region like Uttarakhand at a faster rate.

Keeping in view of the economic development of the nation and to meet the energy need, India has to increase the generation of electricity. The challenge is to produce required power in a sustainable manner.

Hydropower project has some advantages and positive impacts as it is a clean source of power with almost "no cost" of resources, improves living standards, generates employment and creation of reservoir, multifunctional in nature, can be used for irrigation, flood control, drinking water, supply sufficient electricity at the pick demand season etc.

Despite of some positive impacts, it has significant adverse impacts in many folds such as reduce forest carbon stock (above and below ground) and carbon sequestration, increasing in temperature, decrease in rainfall, alter rainfall pattern, forest fire, glacial melt, disastrous flood, decrease agricultural production, reduce water security and so on.

Hydro is renewable but electricity generation from hydropower projects might not renewable. Most of the environmental impacts are negative, long-term, irreversible or permanent in nature.

Uttarakhand has Renewable Energy (RE) potential of 16800 MW. Solar, 1708 MW. SHP and 534MW. Wind @80m hub height as on 31-03-2016. There is a scope for off-grid/on-grid and rooftop solar

with the good sunshine hour and wind power with moderate wind speed @80 m hub height in the ridge.

Research & analysis based on historical/statistical data, physical observation and communication with local household, came to a conclusion as, to meet the upcoming electricity demand and at the same time, to overcome these adverse situations or to minimize the further adverse environmental impacts, we may stop the activities related to development of hydropower project and replace it with Renewable Energy sources like solar and wind energy with no or very negligible environmental impact.

Keyword: Power scenario, Hydro energy potential, RE potential, Forest clearance and deforestation, Environmental impacts, Wildlife, Health, Alternative sources.

INTRODUCTION

ENERGY SCENARIO OF INDIA: The economic growth of a country is inextricably linked to and driven by energy either in the form of finite resources such as coal, oil and gas or from non-conventional sources such as hydropower, wind, solar and biomass. Electricity generated from energy is one of the basic constituents for the economic growth of a country.

In the country like India, our future is fully dependent upon equitable access to energy. It is mainly due to rapid growth and improved efficiencies in the agricultural sector to increase the supply of food leads to population growth, improvements in manufacturing with a rapid growth in the automobile sector, mining, road & transport, airport & port, healthcare and education with the advancement of science and technology etc.

India is accounting for 3.4% of global energy consumption and energy demand grows at an average of 3.6% per annum over the last 30 years and ranks as world's 6th. largest in terms of both an energy consumer and power generation. (http://indianpowersector.com/home/about/)

The country is presently facing energy crisis as the demand for electricity has always been more than the supply. More than 40% household that has lack of electricity and around 400 million people have zero access electricity (India's looming power crisis, Feb 19, 2016, The Economic Times, Thermal). India's power demand is likely to soar more than 300 GW if the country continues to 8% economic growth in the next10 years and by 2031- 32 (By Mc Kinsey & Co. Powering India, The Road to 2017), and needs to increase its primary energy supply by three to four times and its electricity generation by five to six times of the 2003-04 levels (India's looming power crisis, Feb 19, 2016, The Economic Times, Thermal).

To minimize supply lag or power supply deficit, the dependence on imported fuels are on the rise to increase the primary energy supply sources. Table (1) shows the import of coal, oil and petroleum and the growth rate in 2014-15 over 2013-14 are tabulated below--

Fuels Import (in MT) in India

	2005-06	2013-14	2014-15	Growth Rate in 2014-15 over 2013-14
Coal	38.59	166.86	212.10	28.05 %
Oil	99.41	189.24	189.43	0.10 %

Table: 1

Energy Potential of India: *India is presently focused on non-conventional sources (mostly on Hydro, Solar & Wind), more emphasizes on RE (Renewable Energy) to generate electricity and to become a part against GHG (Green House Gas) and Global warming.*

India uses 83% of its water withdrawal for agriculture as compared to the global average of 69%. About 5% water used for drinking and balance for industrial and ecological purpose.[1]

Hydropower Potential: India is blessed with an immense hydroelectric potential to the tune of 148 GW, which will be able to meet a demand of 84 GW at 60% power load factor (PLF)[2]

RE Potential: The total potential for renewable power generation in the country as on 31.03.16 is estimated at 1198856 MW. This includes wind power potential of 102788 MW (8.57%) at 80m hub height, wind power potential of 302235 MW (25.21%) at 100 m hub height, SHP (small-hydro power) potential of 19749 MW (1.65%), Biomass power of 17,538 MW (1.46%), 5000 MW (0.42%) from bagasse-based cogeneration in sugar mills, 2556 MW (0.21%) from waste to energy and solar power potential of 748990 MW (62.48%) assuming 3% wasteland is made available.[3]

Energy Potential of Uttarakhand: Uttarakhand has a high potential for renewable energy. Uttarakhand is going to develop as an 'energy state' and it is growing at rapid pace.

Hydropower Potential: Uttarakhand of Indian Himalaya has a hydropower potential of the order of 27,000 MW(Table:2)[4] *against which only about 3,942MW has only been able to harness (in operation)so far through 45 hydropower projects of different capacities in the central and private sector.*[5]

Potential of Hydropower: Installed Capacities Of HEPs In Uttarakhand
(Commissioned, Under Construction and Under Consideration)

Sl. No.	Project Status	Micro-Mini			Small	Medium	Large	Total MW
		≤ 1 MW	> 1 ≤ 2 MW	> 2 < 5 MW	≥ 5 < 25 MW	≥ 25 < 100 MW	≥ 100 MW	
1	Commissioned	11.96 (54)	7.15 (5)	31.3 (9)	121.6 (9)	246.15 (5)	3206 (10)	3624.16 (92)
2	Under Construction	2.78 (15)	3.5 (2)	20.4 (5)	76.5 (8)	175 (2)	3014 (6)	3292.18 (38)
3	Under Consideration	22.28 (59)	34.75 (19)	108.25 (30)	1390.05 (106)	2429.8 (66)	16138 (40)	20123.13 (320)
Total		**37.02 (128)**	**45.4 (26)**	**159.95 (44)**	**1588.1 (123)**	**2850.9 (73)**	**2235.8 (56)**	**27039.4 (450)**

Table: 2.

Source: iCED Jaipur-July, 2015. Under Consideration (Awaiting Clearance & Survey and Investigation stage)

RE Potential: *As per Energy Statistics 2017 (www.mospi.gov.in), Source wise, estimated the potential of Solar energy in Uttarakhand is 16800 MW followed by Small Hydro Power (SHP)1708 MW, Wind power @80m of 534MW (Fig:1), Biomass Power 24 MW and Waste to Energy of 5 MW.*

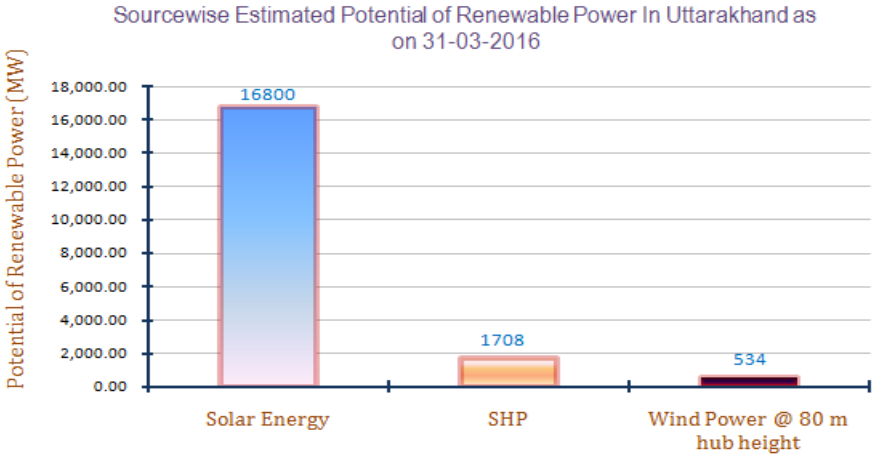


Fig: 1

***Policy (Uttarakhand)*:** Uttarakhand is richly endowed with natural renewable resources for generating electricity. Most of this could be harnessed through the environmentally clean Medium & Large Hydroelectric Projects (i.e. projects with capacity in excess of 25 MW); it is estimated that a capacity of more than 20,000 MW is yet to be tapped through these sources. In addition, the State has significant Renewable Energy (RE) Sources that includes sites for developing Micro (up to 100 KW), Mini (100KW-5 MW) & Small (5-25 MW) Hydropower projects) as well as sources for generating electricity through Biomass/Agro residue, Wind power, Solar energy, Cogeneration etc. This policy aims at expeditiously harnessing these sources of energy that are non- polluting and are useful for electrification of isolated and remote habitations in Uttarakhand. It is felt that more than 1,000 MW electrical powers could be tapped through these sources before 2020.

Policy Objective: To create conditions conducive to Private Sector/Community participation in power projects based on RE Sources in the State. In particular,

1. To harness the environment-friendly RE resources and enhance their contribution to the socio-economic development of the State.
2. To meet and supplement minimum rural energy needs through sustainable RE projects.
3. To provide decentralized energy supply to agriculture, industry, commercial and household sector.
4. To improve the quality of grid power through such projects, as a consequence of tail-end generation and feeding.
5. To enhance the use of energy sources that assist in mitigating environmental pollution.
6. To support efforts for developing, demonstrating and commercializing new and emerging technologies in the RE sector and, to this end, help establish linkages with national and international institutions for active collaboration.
7. To create conditions conducive to the involvement of private investors in RE projects.
8. To create public awareness and involve users/local community along with their capacity building in establishing, operating and managing RE projects.
9. To create direct and indirect employment opportunities in the State.[8]

***Impacts of Hydropower*:** Indian rivers carry more than 2/3rd. of their annual flow during three monsoon months. We are wasting this huge amount of water flowing continuously which can be converted to energy. Thus, Hydropower source is one of the best forms of energy security and can control flood as well as drought.

Clean & efficient Source of Power: India has the huge opportunity to optimally harness the hydropower potential towards energy security and green growth.

Hydropower is the most efficient means to convert energy into electricity. It can be developed over a wide range of scales, from kW to GW Typically 85%-95% of water energy can be converted into electricity. For others. it is 15%-20% for PV solar, 35%- 45% for wind, and 30%-45% for coal.[6]

Small hydro plants (up to 25MW) have least environmental impacts or most environments friendly. Environmental impact of SHP (small hydropower) is 300 times lower than with lignite, 250 times less than with coal, 125 times lower than with uranium and 50 times less than with natural gas for per kWh of electricity production and it is ideally suited for rural electrification especially in remote areas.[2]

Immune to the variation in the cost of fossil fuels like oil, coal and natural gas, the hydropower is most suitable and clean source for the generation of electricity.

Cost of Resources & Improvement of the Living standard: The cost of this (hydro) renewable source is almost "no cost". It does not consume resources or there is no net loss of resources (river water) in compare with power generation from other conventional sources of energy. Electricity generation by utilizing hydropower may reduce the environmental cost. The generation cost is inflation free and may reduce over time.[2]

Being located in remote regions, hydropower installation leads to develop remote and backward areas with respect to education, medical, road communication and is significant for the rural electrification especially located in difficult terrain thus improve human development index (HDI).

Employment generation: The result from the analysis (A case study by Prof. Andreas Loschel, Heidelberg University) shows the employment generation creates as Direct (including initial effect), Indirect and Induced effects.

In the construction phase, 25 % of the total employment growth is due to the initial effect. 15 % of overall job creation occurs in the directly related supply sectors, 13 % result from further indirect effects due to intermediate linkages and 47 % of the total annual increase in employment during the construction phase of the hydropower plant is induced by the additional income. The initial effect mainly creates employment in the manufacturing industry, whereas the induced income effect increases demand for consumer goods.

The study estimates that approximately 30,000 jobs per year during the six-year construction phase (Table: 3) and around 2,530 jobs during the operational phase (Table: 4) are created over the useful life of the plant.

Employment Effect Per Year During Construction Phase

	Highly Qualified	Medium-skilled worker	Un-skilled worker	TOTAL
Service Sector	1563	3132	2910	7605
Manufacturing Sector	638	3009	6321	9968
Agriculture Sector	242	2902	9443	12587
Total	2443	9043	18674	30160

Table: 3. Source: KFW Position paper, January 2013

Employment Effect Per Year Over The Useful Life Of The Plant

Initial effect	First round effect	Indirect effect	Induced effect	TOTAL
420	450	450	1210	2530

Table: 4. Source: KFW Position paper, January 2013

Creation of Reservoir and its multifunctional nature: Dams and reservoirs are designed to last over hundred years. While in contrast, another type of energy sources has no such long life. Reservoir- based hydroelectric projects are sustainable, multifunctional in nature thus economically lucrative. Large impoundment of water due to damming of the river can be used for irrigation, flood control, drinking water and can supply sufficient electricity at the pick demand season. Soil nutrients and soil quality are increased and improved adjacent to the large reservoir. With the increase of both temperature and humidity, the organic carbon turnover into the soil is more thus improve the quality of soil resulting an increase in crop yield. [7777]

OBJECTIVE

a) The objectives of this study are to assess the adverse environmental change in terms of increasing temperature, humidity and less seasonal rainfall which leads to climate change.
b) Also to guess the economic loss in terms of less agriculture, loss of asset, effects on wildlife and increase of harmful diseases which can take human lives.

ENVIRONMENTAL IMPACT ASSESSMENT

RESEARCH METHODOLOGY

Study Area: Tehri Dam Region and Dehradun.

Study Period: November 2016 and October 2017.

Method of Data collection: The methodology of this study initially based on the adverse environmental impact and risk for HEP development through extensive literature review and field visit for confirmation of those risk factors and impact assessment.

Primary data collected during numerous field visit and through some personal interviews in random sampling basis (which includes the people either some way related to hydro projects or among the affected due to the projects) with the help of some pre-selected, semi-structured questioner (which covers the time frame right from pre construction phase to post commissioning of hydropower projects) was used as a tool for further confirmation of these adverse impacts and gathering information on climate change and environmental aspects like weather change (temperature, rainfall etc), forest cut and tree felling, land slide, agriculture, wildlife, pollution, health, economic development etc.

During the study, a number of individuals from government and private sources which include- Hydro Power Project construction companies like THDC Ltd. etc, Meteorological department, State Electricity Authority, State Pollution Control Board etc. were contacted for their inputs and views.

The secondary data collected through extensive literature/article and document reviews, historical and statistical data.

Analysis: Compiled all the key information from collected primary and secondary data, then analyzed the acquired data and interpreted to conclude as a simplified presentation.

LITERATURE SURVEY

The article '*Energy and Employment: Case Study Hydropower in India by Dr Henrike Koschel, January 2013*'describes and evaluates the methodology and results of the induced (gross) employment effects created by the construction and operation phase, but not the long-term effects of an improved electricity supply taking into account all direct, indirect and in-come-induced effects.

Article "OCEANS AND AQUATIC ECOSYSTEM, Vol. I- Environmental and Social Impacts of Reservoirs: Issues and Mitigation" by J.Manatunge. et all", -- aim this paper to discuss environmental and social impacts of dam construction and how mistake from the past can be rectified for better implementation of HE projects. Acknowledging the benefits, the author(s) discussed details of the negative impacts too, in order that these adversities are lessened and

dam construction can be utilized as a positive development objective without hampering the well-being of the society, environment, and their interrelations.

"Environmental hazards of dams and reservoir" by Walter et. all Wildi Institute and University of Geneva, CP 416, CH-1290Versoix, Switzerland" --This chapter briefly reviews a large range of potential impacts and hazards linked to the exploitation of dams and reservoir.

The Paper "Uttarakhand Disaster and Land Use Policy Changes by Genta Nakano et. all, Chapter 13,December 2017, DOI: 10.1007/978-4-431-56442-3_13" emphasizes on unplanned constructions, encroachments, and blockade of surface drainage that are observed to pose a serious threat to the stability of the hill slopes and suggests, Land use/land cover change studies can help in better developmental planning and in keeping identified vulnerable areas, particularly in the proximity of rivers and in the recharge zone of water bodies, free from human intervention.

The article "Damming rivers in the tectonically resurgent Uttarakhand Himalaya ***b****y K. S. Valdiya (Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore 560 064, India) CURRENT SCIENCE, VOL.106, NO. 1658 12, 25 JUNE 2014"---describes as*--A very large number of big and small dams are being constructed and planned in Uttarakhand at seismically and tectonically active belts which recurrently ravaged by excessive rains and resultant landslides. The author suggests that, if the idea is to have environment-friendly power projects, then the planners and dam builders must not ignore the geological reality of the geodynamical sensitive region. Better sites for dams can be explored far upstream of the Main Central Thrust Zone and The well-being and socio-economic security of the people should be the overriding consideration, not the cost.

"RESEARCH ARTICLE: MICROBIAL BIODIVERSITY OF TRIBUTARIES OF RIVER GANGA IN UTTARAKHAND by Nidhi Singh et. all, Department of Microbiology, Himalayan University, Naharlagun, Itanagar, Arunachal Pradesh. International Journal of Recent Scientific Research Vol. 6, Issue, 10, pp. 6888-6891, October 2015."-- During the study through bacteriological analysis of six bacteria, they observed that the average values showed that three species i.e. Escherichia coli, Enterobacteraerogenes, Staphylococcus were found to be dominating in river Alaknanda than the river Bhagirathi at Devprayag. All samples were positive for E. coli, which indicates faecal pollution of water and exceeding the standard limit.

A leading scholar Harsh K.Gupta on his topic *"Earthquakes Caused by Dams: 'Reservoir-Triggered/Induced Seismicity' 2002"*defines the earthquakes occurring in the vicinity of artificial water reservoirs as a consequence of impoundment. The author describes the consequences related to impoundment in detail.

"Land Use / Land cover change detection in Doon valley (Dehradun Tehsil),Uttarakhand: Using GIS & Remote Sensing technique by Tiwari Kuldeep , Khanduri Kamlesh"--The aims of this study are to detect land use changes between 2000 to 2009 using satellite images and to produce a land use/land cover map of Dehradun valley in order to detect the changes that have taken place particularly in the built up land and forest areas and finally to predict the changes in urban habitats and land use/land cover changes occurred.

"Slow onset events, Technical paper, United Nation, FCCC/TP/2012/7, 26 November 2012". The objective of this technical paper is to generate a knowledge base on approaches to address loss and damage associated with slow onset events in developing countries that are particularly vulnerable to the adverse effects of climate change due to hydropower development.

*In the paper "Dams, Rivers & People VOL 10 ISSUE 3-4-5, APRIL MAY JUNE 2012"---the s*tudy focused on several impacts on environment and livelihood in connection with dam building on river and like to emphasize the need for understanding and protecting and restoring the Systems using existing govt schemes can be made to restore the invaluable traditional systems with low-cost.

*"Thermal Pollution Caused by Hydropower Plants. Chapter 2, By Alaeddin Bobat. Springer International Publishing Switzerland 2015 A.N. Bilge et al. (eds.), Energy Systems and Management, Springer Proceedings in Energy, DOI 10.1007/978-3-319-16024-5_2"—the study shows that the t*hermal pollution is the change in the water temperatures of lakes, rivers, and oceans caused by man-made structures. These temperature changes may adversely affect aquatic ecosystems especially by contributing to the decline of wildlife populations and habitat destruction. Any practice that affects the equilibrium of an aquatic environment may alter the temperature of that environment and subsequently cause thermal pollution. This paper aimed to reveal the causes and results of thermal pollution and measures to be taken in HPPs.

In this article "Hydropower Generation and River Water Pollution in India by Shweta Agrawal 2Swati Singh Sikarwar. INTERNATIONAL JOURNAL OF APPLIED RESEARCH AND TECHNOLOGY. ISSN 2519-5115 IJART-Vol-1, Issue-2, December 2016" the author discussed as Hydropower dam operations are responsible for the extinction and near-extinction of a number of species, and are a major contributor to the significant loss of aquatic biodiversity. Hydropower dams are a significant source of water pollution caused by altering the temperature and harming the biological integrity of river ecosystems. The cumulative impacts of multiple hydropower dams are often much greater than the simple sum of their direct impacts.

Govt. initiation/intervention through regulation, execution, monitoring and awareness is an essential part to control the pollution and to protect the natural environment.

ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT PLAN FOR JELAM TAMAK H.E.PROJECT UTTARAKHAND. Prepared for: THDC India Limited. CENTRE FOR INTER-DISCIPLINARY STUDIES OF MOUNTAIN & HILL ENVIRONMENT UNIVERSITY OF DELHI, DELHI. EXECUTIVE SUMMARY, JUNE, 2012" –Jhelam Tamak H.E. Project is proposed to tap hydropower potential of Dhauliganga between Jhelam and Tamak villages. The main objective of the present study is to carry out the Comprehensive Environmental Impact Assessment (EIA) for the proposed Jhelam Tamak HE project and based on the impacts, to prepare various mitigative plans and also to meet the Environmental clearance criteria of Ministry of Environment and Forests (MoEF), Government of India.

"Article Re-Linking Governance of Energy with Livelihoods and Irrigation in Uttarakhand, India Stephanie Buechler, Debashish Sen, Neha et. all, 2016, 8, 437; DOI: 10.3390/w8100437. www.mdpi.com/journal/water" –The author(s) on the Bhilangana river basin, where water dependent livelihoods differentiated by gender include farming, fishing, livestock rearing and fodder collection. We examine the contradictions inherent in hydropower governance based on the interests of local residents and other stakeholders including hydropower developers, urban and other regional electricity users, and state-level policymakers. We use a social justice approach applied to hydropower projects to examine some of the negative impacts, especially by location and gender, of these projects on local communities and then identify strategies that can safeguard or enhance livelihoods of women, youth, and men in areas with hydropower projects, while also maintaining critical ecosystem services. By assessing the Bhilangana basin case, we also offer hydropower–livelihoods–irrigation nexus lessons for headwater regions across the Himalayas and globally.

PHYSIOGRAPHIC

Uttaranchal, presently known as Uttarakhand came into existence on 9th November 2000 as an Indian Himalayan state, which was carved out of a mountainous north-west region of Uttar Pradesh. The state lies between Longitude 77°34′ 27″ to 81°02′ 22″ E and Latitude 28°53′ 24″ to 31° 27′ 50″ N. It stretches across an area of 53,485 km^2 with 13 districts and it is bordered by the Indian state of Himachal Pradesh to the north-west, Tibet Autonomous Region of China to the north-east, Nepal to the south-east, the Indian state of Uttar Pradesh to the south & south-west and a tiny segment of the Indian state of Haryana to the west. Out of 13 districts, 9 districts are mountainous and the substantial portions of remaining 4 southern districts are plain. There are two administrative divisions: The Kumaon and The Garhwal regions. The total population of the state is 10,116,752(Census of India, 2011). Primarily, it is a rural state with 69.5% of the people living in around 15, 761 villages located mostly in the mountain districts.[9]

Major peaks- Nanda Devi (25,646 ft. asl) the highest peak of Uttarakhand, Mount Kamet (25,446 ft. asl) the 2nd. Highest peak of India, Abi Gamen, Mukut Parvat, Chaukhamba, Trishul, Kedarnath, Neelkanth, Shivling, Nilgiri and Bandarpoonch etc.

Major Rivers- Ganga, Yamuna, Bhagirathi, Alakananda, Kosi, Mandakini, Pindar and Saryu

Major Glacier- Maiktoli Glacier, Kaphini Glacier, Ralam Glacier,, Sunderdhunga Glacier, Chorabali Glacier, Gangotri Glacier, Khatling Glacier and Nandadevi Glacier.

The mountains, rivers and forests also provide a habitat for rare and threatened species of both plants and animals.

Uttarakhand is a part of Western Himalayan physiographic division and the state divided into five transverse zones:

i) The Trans Himalaya: To the north of the snow- clad ridges.

ii) *The Inner (Great) Himalaya:* The north zone of the MCT including permanently snow-clad Peaks at

height ranging up to just below 8000 m.

iii) *The Middle (lesser) Himalaya:* Between the MBF and MCT (Main Central Thrust) with Ridges at high as about 3000 m.
iv) *The Doons:* Between the Main Boundary Fault (MBF) and the Shivalik (Outer Himalaya)
v) *The Terai:* South of the Himalayan Frontal Fault.
Uttarakhand is the birthplace of two major rivers the Ganges and the Yamuna, These Rivers and their tributaries provide the vast opportunities for hydropower generation.[12]

SOIL

In Uttarakhand, the northern hills support forests and southern faces are generally naked. Thus the soil in this state is mountainous forest soil and is divided into five types. These are a) Quartzite soil. b) Volcanic soil. c) Brown or grey soil. d) Alluvial soil and e) Tertiary soil.
But, the above soil quality gets negatively affected in various ways due to hydropower development in the hilly terrain. There are two main impacts of dams and reservoirs on soil quality.
Firstly, salinisation may occur in arid conditions in relation to irrigation, mainly due to the maintenance of a high groundwater level when evaporation and evapotranspiration are strong. *Secondly*, contamination of soil in the floodplain by reworked contaminated reservoir sediments during floods may be expected. This mechanism is linked to the accumulation of contaminants in reservoirs.[11]
Development of multiple hydro projects and damming on river within a short river stretch are one of the major responsible factors of climate change which alters rainfall pattern during monsoon, contributes to increased run-off resulting into soil and river bank erosion in hilly terrain of Uttarakhand and increase of sediments in the river bed turning the river shallow and reducing their water carrying capacities[10] and it may further enhance the soil erosion in the catchment area.[12]
Shrubs are suitable for soil conservation and it acts as a resistance to high wind velocity and can be used for bio-fencing. Some shrubs, by fixing nitrogen, increase soil fertility. Massive deforestation for Hydropower project development and afforestation by pine trees destroys the shrub's growth which further initiates soil erosion, reduces soil fertility and increases the intensity of forest fire to some extent which further initiates soil erosion.
The reservoirs are the causes of the suspended particles to settle into it thus it limits the flow of sediments downstream, which hampers agricultural activities on floodplains due to limited nutrient-rich sediments. [9]

SEISMICITY

Uttarakhand is known as a multi-hazard-prone state. The Indian plate is moving toward the northeast with the convergence rate of 55 mm per year.[13] The region is under seismically and tectonically active belts and recurrently ravaged by excessive rains, resultant landslides[14]. As per earthquake zoning map of India, the entire State can be divided into two zones, Zone V and Zone IV. The State has experienced many earthquakes of small and large scale with their epicentres located within the Himalayan region

There are four districts (Pithoragarh, Chamoli, Bageshwar and Rudraprayag) of the thirteen of the state fall completely in Zone V, Five other districts (Uttarkashi, Tehri-Garhwal, Pauri, Almora and Champawat) fall partially in Zone V and partially in Zone IV and the rest four districts (Dehradun, Hardwar, Nainital and Udham Singh Nagar) fall totally in Zone IV of the seismic risk map of India.[10]

Between the period July 1720 to January 2009, there are around 3052 earthquake occurred in and around Alaknanda and Bhagirathi Basin within the magnitude 1.1 to 8.0.[16](Fig: 2)

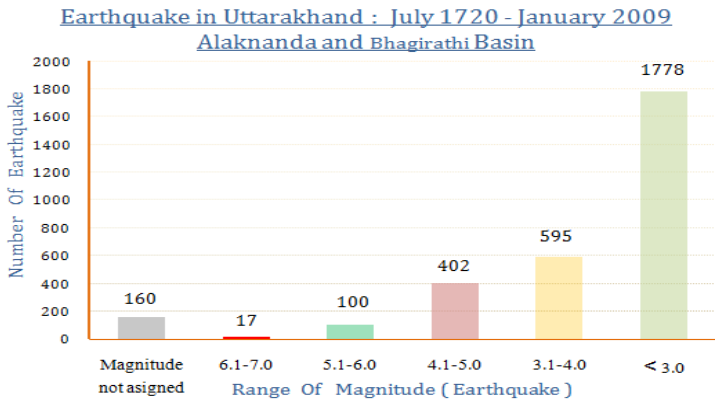


Fig: 2

Damming on Himalayan River and Seismicity:

Alaknanda and Bhagirathi river valley are affected by several tectonic features and has a potential of high/moderate magnitude of earthquake. It has been observed that around the hydro power project sites in those valleys that are highly earthquakes prone ($M \geq 6$) which generates from the potential Seismo-genic sources.[16] (Table: 5)

Hydro power Project	Projects On the River	Location District/Village Or Town	Seismicity		
			Seismic Zone	Seismo-genic Source	Observed $M_{max.}$ (M=Magnitude)
Kotlibhil IA	Bhagirathi	Tehri Garhwal/Muneth	IV	MBT & NAT	7.0 *
Bowala Nandprayag	Alaknanda	Chamoli/Bowala	IV	MCT, MBT & Martoli Thrust.	7.0 *
Bhairon-Ghati	Bhagirathi	Uttarkashi/Bhatwari	IV	MCT & Kaurik Fault System	8.0
Pala Maneri	Bhagirathi	Uttarkashi/Maneri	IV	MCT.	7.5 *
Tapovan-Vishnugad	Dhauliganga	Chamoli/Tapovan	V	MCT, MBT, Alaknanda Fault & Indus Suture Zone.	7.5
Koteshwar	Bhagirathi	Tehri Garhwal/Tehri	IV	MBT & NAT.	7.0 *
Tehri	Bhagirathi	Tehri Garhwal/Tehri	IV	MBT & NAT. Lies between MBF & MCT	7.0

Table: 5

Reservoir triggered seismicity (RTS): Artificial water reservoir triggered earthquake has grouped into two categories: a) Rapid Response category and b) Delayed Response category. The tectonic loading on the active fault due to local seismicity coupled with the reservoir loading and unloading may generate earthquake and cause additional seismic risk in this

critically stressed region.[20] It has been seen, around Tehri, in the year 1995 there were 229 local events which are maximum during this period and the year 2005 shows minimum around 76 local events which were significant. (Fig: 3)[17]

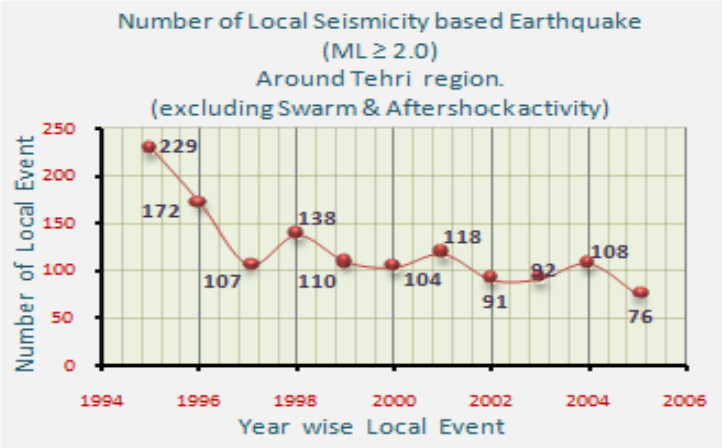


Fig: 3

Reservoirs can increase the frequency of earthquakes in areas with a previously low occurrence of the seismic activity.[18] In recent past, during the period 2012 to April 2017(< 6 years period), it has been observed that there are 74 earthquakes occurred in the Uttarakhand region with the magnitude ranges $2.5 \leq M \leq 5.8$ as per record of Indian Meteorological Department (IMD). Table: 6

UTTARAKHAND Districts & India(Uttarakhand)-Nepal Border	2012	2013	2014	2015	2016	2017 (Till 10 th April)	**TOTAL**	Magnitude (Range) ≤ M ≤
Chamoli	3		1	6	2	2	14	3.2 ≤ M ≤ 5.1
Uttarkashi	2	5	1		5	2	15	2.5 ≤ M ≤ 4.8
Bageshwar	1	1	1				3	2.6 ≤ M ≤ 4.1
Pauri	1						1	M = 3.6
Pithoragarh		2	3	3	5		13	2.7 ≤ M ≤ 4.8
Rudraprayag		2	2		1	6	11	3.2 ≤ M ≤ 5.8
Dehradun		1			4		5	3.0 ≤ M ≤ 3.9
India-Nepal Border	1	2	1	1	2		7	2.8 ≤ M ≤ 5.2
Almora-Pithoragarh Border					1		1	M = 3.2
DNS(Districts not specified)		1		3			4	3.2 ≤ M ≤ 4.3
TOTAL	8	14	9	13	20	10	74	

Table: 6

The seismicity is likely to be more widespread and deeper for a large reservoir than for a smaller one. The depth of the water column and the reservoir volume are two important factors that control the triggered earthquakes.[19]

LAND USE & LAND COVER CHANGE

The main drivers of the land use/cover change are economic development, population dynamics and climate change resulting of environmental changes which further change the livelihoods of the mountain people and increases environmental vulnerabilities.

Hydro project development – Land Use, Land Cover Change and Its Implications: The Union Ministry of Environment and Forests (MoEF) estimates that almost 45,000 ha of forestland have been diverted to non-forest uses in Uttarakhand since 1980 (www.downtoearth.org). Around 40% of this forest area has been converted to HEPs, transmission lines and for road construction (Fig: 4). It is around 30,000 ha of forests have been diverted to non-forest use in Uttarakhand since the formation of the state. [13, 21].

Fig: 4

LCLUC for the development of hydro projects leads to several environmental problems such as deforestation, soil erosion, water pollution etc. Water pollution is increased due to increased use of fertilizer in agriculture to meet the upcoming demand as well as the decrease in cultivable land, municipal solid waste and sewage etc. More intensive agricultural practices are vulnerable to soil erosion/loss of soil. Soil erosion and water run-off reduce soil nutrients/fertility, destabilizing mountain slopes and contributing to more intense and frequent landslides and floods. [23]

Massive hydroelectricity generation plants installation and other related development further accelerate natural phenomena which in turn drive changes that would impact the natural ecosystem. Increasing density of build-up area is found in Uttarkashi Tehri, Hardwar, Dehradun (Fig: 5) etc. with the considerable increase in settlements. One of the major reasons for the increase in built-up area in Hardwar and Dehradun is rehabilitation for hydro projects.[22]

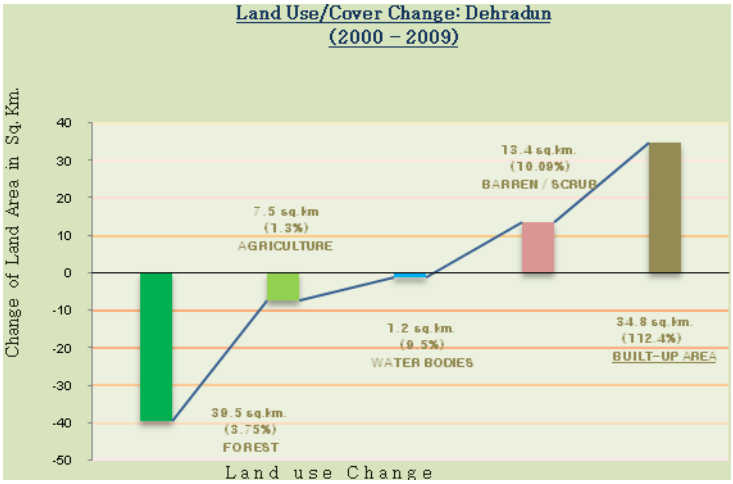


Fig: 5

These environmental impacts are irreversible or which is beyond mitigation.

FLORISTICS & FOREST TYPES

The recorded forest area of Uttarakhand is 34,520 km.^{2} which are 64.54% of the state's geographical area. The total forest area is divided into three parts (by status) namely, the Reserved Forests (71.1%), Protected Forests (28.5%) and Un-classed Forests (0.4%). Most villages also have smaller forests within their boundaries.

There are four major forest types are observed in the state Uttarakhand:

a) *Tropical Moist Deciduous Forest:* Mainly found in the sub-Himalaya terai-bhabar belt.

b) *Subtropical Pine Forests:* These forests are found at lower elevations of the lesser Himalayan belt.

c) *Moist Himalayan Temperate Forests:* They occur at elevations between1600m and 2900m.

d) *Sub-Alpine and Alpine Forests:* Exist at altitudes of 2900 to 3500 m. The tree line is about 3200m.Temperate and tropical grasslands exist inside forest areas.

The dominant species in this region are Sal (*Shorea robusta),* Khair *(Acacia catechu),* Sheesham *(Dalbergia sissoo,*. chir pine *(Pinus roxburghii),* Oak (banj, *Quercus leucotricophora),* Rhododendron *(*burans, *Rhododendron arboreum),* Cedars (deodars, *Cedrusdeodara*), Blue pine *(*kail, *Pinus wallichiana),* Fir(*Abies spectabilis),* silver fir*(Abies pindrow),* junipers *(Juniperus squamata, Juniperus indica) etc.*

Consequences of deforestation due to development of Hydropower projects: Forest clearance or forest area diversion in the Himalayas to develop hydro projects has increased the severity of floods during the rainy season and reduced stream flows and dried up springs during dry seasons and responsible for local climate change.

Increases Temperature: It disrupts watershed processes, including the infiltration of precipitation into soils. Intensify the hydrologic cycle, causing dry regions to become drier and wet regions to become wetter. The temperature variation[10] changes the microclimate increases the intensity of snow avalanches and accelerates melting of the snow and glaciers at high altitudes at a faster rate which impacts on water security.

Alter Rainfall pattern: During periods of limited rainfall, soil gets dried and heavier rainfall results in greater and more rapid runoff, thereby increasing flooding and nutrient loss, resulting in reduced food production. [24] Change in rainfall pattern reduced stream flows and dried up springs during dry seasons.

Decreasing Carbon stock & Carbon sequestration rate: Massive deforestation and fragmentation of forest decrease above ground, below ground & soil carbon stock and carbon sequestration rate decreases due to a reduced number of trees due to nation's development like the development of hydro projects.

WATER ENVIRONMENT: AQUATIC ECOLOGY & FISHERIES

Impacts of HEP on River Water Environment: One of the main reasons of pollution, started from upper reaches of the rivers in Uttarakhand is the development of hydroelectric projects[27]resulting disturbance of ecosystem and loss of marine life.

Variation in discharge (or velocity) from the reservoir decrease DO (Dissolved Oxygen), may affect water quality by altering the self-purification capacity of the river[28] which is indifferent, permanent and irreversible in nature.

Turbidity increases due to suspended solids from construction and Eutrophication by sediment, nutrient leaching and fertilizer residues [29] which affect the river water quality and river ecology.

Construction of reservoir and tunnels changes the hydrological balance due to evaporation loss from the reservoir and drying or low flow through entire stretches from reservoir/ tank to powerhouse. [29]

Disappearance or dry up of original flows are visible over the entire stretch due to one after other projects are building upon the same river.[30]

A different set of dynamics begin impacting species that traditionally grow, nest, feed, or spawn in these areas due to inundation of the dam.[31]

Changing water levels and a lack of streamside vegetation can also lead to increased erosion. Increases in erosion can also increase the amount of sedimentation behind a dam. [31]

Impacts of HEP on Aquatic biodiversity & Fisheries: Hydro Electric Projects often have major effects on fish and other aquatic life. The net impacts are often negative because the dam blocks upriver fish migrations and the downriver passage through turbines or over Spillways is often unsuccessful. Alteration of river flow hampers critical life events like phenology of reproduction, spawning behaviour, larval survival, growth patterns, affects aquatic food chain and impacts on the structure, distribution and composition of fish communities in the region.

Change in environmental flow is one of the major causes of habitat fragmentation. There are three kinds of adverse impacts on the aquatic biodiversity are expected because of changes in

the natural flow due to HEPs in the Alaknanda and Bhagirathi Basin: (a) Stagnated water in the submersible zones of HEPs which are not conducive for snow trout and Himalayan loaches, (b) Less or no water flow in the dry zones of HEPs affects adversely on the aquatic biodiversity. (c) Changes in the natural flow impair the aquatic biodiversity to breed or maintain annual life histories.

Submergence of rivers would act as nutrient traps. Changes in the nutrient flow would adversely affect the downstream fishes and would affect the overall composition of the fish community.

Dam or any construction across rivers is always a barrier especially for the migratory fishes and affects the breeding cycle leads to disappearance or decline of major migratory fish species.

Deforestation increases siltation of the river and increased turbidity thus deteriorates water quality. Even a few centimetres of sediment layer over the natural substrate is enough to affect the foraging and spawning fishes negatively.[32]

Hydropower development may alter the temperature of water environment and subsequently cause thermal pollution. It changes its ambient temperature. As the temperature of water increases, dissolved oxygen contenting in water decreases. If the water temperature rises by 1–2°C, some species may be eliminated entirely since the metabolism requires oxygen (O_2). It also affects the feeding and spawning of fish, increase Algae growth and kills plants thereby disrupting the web of life dependent on the aquatic food chain. [33, 34]

FLORA & FAUNA

Many of the hydropower projects in Bhagirathi and Alaknanda basins are entirely or partially inside Gangotri National Park, Kedarnath Wildlife Sanctuary and Nandadevi wildlife Sanctuary, Valley of Flowers, National Park (both UNESCO World Heritage sites of Outstanding Universal Values). They will threaten 16 globally threatened fish species, 5 rare and endangered mammals (including Snow Leopard, Brown Bear, and Mouse Deer), 5 rare and endangered bird species, and 55 rare and endangered plant species, over 300 medicinal plants and hundreds of plants which are used by locals in varied ways. These are among the known damages. There are likely to be other unknown collateral damages.[30]

HEPs are usually located in the presence of a range of ecosystems including mountains, grasslands, subtropical and temperate broadleaf forests, mixed coniferous forests and alpine meadows.[29] Riverine system changes the biological and ecological conditions of rivers and alteration occurs in the floral and faunal characteristics near the dammed site. [37]

The hydro project construction would require the acquisition of forestland. All the vegetation on the land of the large area to be cleared off for construction of project component. In addition, there is a potential impact of tree cutting by the migratory labour force that would have fuelwood requirement and timber requirement for heating, furniture etc. [38]

AIR POLLUTION

During hydro project development, air pollution occurs mainly due to excavation activities, massive vehicular movement and operation of project machinery and equipment in the construction phase.

Construction works of roads, burning of fuel woods and increased vehicular movement are main agents of air pollution levels of SPM, NO_x and SO_2.

The process of excavation, tunnelling, quarrying, dumping and transportation of muck and road construction would increase the level of SPM in many folds and it might increase to 400 – 500 $\mu g/m^3$ during the construction phase. The significant increase in the vehicular movement and operation of a large number of types of equipment and machine would increase the level of NO_x, SO_x and CO in the surrounding area. The main sources of SO_2, CO are burning of fuels such as oils, coal and fuelwood used by the construction labour.

Hydropower projects associated with large reservoir/dam in the tropical region have been implicated in large greenhouse gas (CO_2 and CH_4) emissions largely from decaying organic matter due to impoundment of large forest area leads to air pollution along with other major environmental impacts.[38,29,41,42,43]

WATER POLLUTION

The spillage of muck generated from construction work is mostly disposed off along the river bank which will lead to water pollution. Sewage from workers colony/construction camp during peak construction period can lead to serious water pollution.

The intermediate river length between barrage and powerhouse become dry or running with low flow throughout the year which impacts on the water quality adversely thus alter the aquatic ecology and change the fish habitat altogether.

Enrichment of impounded water with organic and inorganic nutrients with the decomposition of vegetative matter and phytoplankton productivity will be the main water quality problem immediately upon commencement of the operation. [38]

NOISE POLLUTION

Majority of the environmental impacts attributed to construction works of hydro projects and it extends into several years. Even though the impacts due to construction are temporary in nature, they could be significant due to the nature and intensity of the impacts.

Increasing movement of heavy vehicles (trucks, dumpers etc.) to transport construction material along with vehicles (jeeps etc.) for the movement of manpower in that area, operation of construction machinery and equipment, operation of DG (Diesel Generator) set for electricity requirement, blasting operations for tunnelling and quarrying through explosive and crushing to have small aggregate during construction phase and high noise & vibration for the running of turbine during operation phase generates noise pollution and pose a significant impacts on population nearby, workers inside the power house and wildlife in the area.[38]

IMPACTS ON AGRICULTURE & HORTICULTURE

Hydropower development is occurring on rivers where irrigation, livestock rearing, and other natural resource-based activities are already stretched in their ability to meet local resident's livelihood needs as 89% of the state is mountainous and 53% is severe to very severe erosion prone zone. Deforestation and heavy felling of trees for construction dams in this region extending the situation resulting further loss of agricultural land and irrigation water and restricts agricultural productivity.

The damming on river changes the hydrological balance. The up-stream elevates the surrounding groundwater level leading to salinisation and marshland and at the same time reduces the source of groundwater recharge in the lower reaches of the dam base, affecting gravity condition, which makes the adverse effects on irrigation.

Blasting on slop to divert river water through tunnel, quarrying, road construction are the cause of the disappearance of an irrigated channel as many of the springs are become dried. Indiscriminate muck disposal disrupts irrigation channel and irrigated land along the riverbank downstream become barren due to the diversion of river water. All these affect agriculture thus reduce agricultural production.

Hydropower projects require deforestation which affects horticulture by accentuating flood and drought events and destabilizing soil. It also attributes air pollution, decreased precipitation, water percolation and lack of moisture in the soil and fugitive dust from blasting operation impairs photosynthesis process which affects rich horticulture, reduce agricultural crop and fodder production in entire area due to non-availability of horticultural & agricultural essential imputes. [43,46,47]

IMPACTS ON HEALTH

The vectors of various diseases breed in shallow areas thus, there would be an increase in the potential breeding sites for various disease especially mosquitoes who can fly up to 1 to 2km from the breeding site, transmit malaria to the major habitat reside within 2 km from the dam site up to an elevation of 2000m asl.[42]

Water-related Diseases arises mainly due to changes in water quality, eutrophication, weed growth and the increase in areas of stagnant water on the proliferation of insects or other vectors of water-related human and livestock diseases. There is a risk of introduction of new pathogens and disease vectors which may transmit from local carriers to immigrant labour and staff and vice-versa.[29]

Wastewater generation from natural activities of human and other hydro project construction activities increases pathogens such as bacteria, viruses and parasites, reduce self-purifying capacity significantly, the cause of different infectious diseases like diarrhoea etc.[50]

Fugitive emission and dust from loose muck due to crushing operation and muck disposal increases SPM level which creates serious health hazards and photo-retardation among the local population.[49]

Psychological trauma to people and animals has been observed due to the repeated blasts and for other noise pollution during construction of the projects. Older persons and children are mostly affected.

FOREST FIRE

Fire is a common feature in the forests of Uttarakhand especially in between 1000 m to 1800 m mostly covered by Chir-Pine forest.

In recent past, on Feb. 2016, around 1890.79 hectares of green cover in this region have been destroyed by forest fire. The worst- affected districts were Chamoli, Pauri, Rudraprayag, Tehri, Uttarkashi, Pithoragarh, Almora and Nainital. Generally, the frequency of forest fires is 2-5 years, while 11% of forests of the region experience fire every year.

Implications of the forest fire: Almost all the fires are man caused. Development of multi hydropower projects and other related infrastructure are one of the major causes of the forest fire. The contributing factors are:

A) Massive deforestation reduces the soil moisture, alters the normal rainfall pattern, reduce rainfall and excessive water withdrawal cause draught. Alteration of seasonal rainfall pattern and significantly increased temperature may further aggravate forest fire events in the region.

B) Blasting for tunnelling, road building etc. leads to drying of water sources, depleting topsoil moisture and reduced the living grasses and shrubs (which resists and control the wind flow) in the forests resulting dryness and provides an ideal ground to develop more intense fire.

C) Choice of pine tree species instead of broadleaf or broadleaf mixed forest for afforestation or plantation increases the intensity of forest fire as the pine trees and pine needles are highly fired prone.

D) The indirect effect of forest fires are the loss of soil fertility, soil erosion, loss of employment, drying up of water resources and loss of biodiversity. These fires forms black carbon shoot after burning, spread over the extended area, increase warming by absorbing heat and restricting reflection and finally changes microclimate of that region significantly in the form of soil moisture balance, increased evaporation, increased probabilities of snow/glacial melt.[39, 40, 22 35, 20]

NON BIODEGRADABLE WASTE

Solid waste disposal: Littering of solid waste like biodegradable as well as non-biodegradable on hill slopes generated by hundreds of workers, officers and technical staff during construction of HEPs, creates serious land and groundwater pollution.

Hazardous and biomedical waste disposal: Hazardous wastes are generating during construction phase from machinery and equipment using fuel, lubricating oil, batteries, etc. Empty oil drums, used oil, maintenance/cleaning clothes, used batteries, transformer oil etc. Biomedical Waste are generating from the dispensaries set up to take care of workers medical needs.[38]

After commissioning of HEP, the site becoming a tourist spot. Trekkers and tourist population at these locations becoming more and more. A huge amount of non-bio-

degradable waste like plastic cups, plates bottle and glasses, juice can, wafer wrapper and polythene bags etc. are disposed of at the surrounding mountain area at an alarming rate and wreaking havoc with and is posing a big threat to the fragile ecosystem.

Plastic and other non-bio-degradable waste absorb heat, which along with global warming, raises the overall temperature in the local mountain region, melting glaciers and creating glacial lakes thus posing the threat of glacial lake outburst flood in the future. [36]

WATER CONSERVATION

Though some of India's most important rivers originate here, the water conservation remains a burning issue in Uttarakhand. A large number of natural springs that dotted the hillside have been damaged and dried up due to the cutting and bursting of slopes for road construction, tunnelling for dam construction, Quarrying operation for aggregate acquisition or other unplanned activities. These have adversely affected the underground water table at many places and pose an adverse impact on water security.[25]

IMPACTS ON PAs & WILDLIFE

As per Ministry of Environment & Forests, Lucknow, 80,826.91 ha of forests have been diverted to non-forest use in Uttarakhand since 1980. The diversion for hydropower production is 5312.11 ha. Most of the diversion for roads and hydropower projects development. Additional forest land is lost for transmission lines.

As per record, we observed that most of the commissioned and proposed HEPs are either located inside the protected area (PAs) or in the buffer zone of the Nanda Devi Biosphere, Askot Musk Deer Sanctuary, Kedarnath Musk Deer Sanctuary etc. and many others are in or around the protected area.

The areas are the home for a large number of rare, endangered and endemic plant, bird and animal species including snow leopard, musk deer, Asiatic black bear, cheer pheasant and the blue sheep and so on. The loss of plants will disrupt the food chain for birds, small animals, deer and bear among other animals. The habitats of the larger animals will be fragmented while birds and small animals may lose their nests and holes.

The life cycle of HEPs has significant impacts on forests and terrestrial biodiversity. During pre-construction phase land required for quarrying, construction of access roads, housing colonies, project offices, stores and equipment warehouses and disposal of debris and muck leads to deforestation. Reserved forests and village forests are both affected by cutting thousands of trees during road construction and to meet the fuelwood needs of the labourers which are far beyond the officially sanctioned limit. Additionally, more trees are damaged or destroyed by rolling down the large boulders and debris through the mountain slopes during road construction. The overburden of muck disposal affects Shrubs and undergrowth. Air pollution from various operations and dust blown from the dumping grounds reduces photosynthesis activity of vegetation in the surrounding areas and hence decreases the biomass productivity thus affects biodiversity value. Hydropower project development in these protected areas can fragment and destroy wildlife habitats significantly.[26]

As per WII assessment, 2012, Out of 70 HEPs, 17 are commissioned, 14 are under construction and remaining 39 HEPs have been proposed in Bhagirathi and Alaknanda basins. It includes loss of large area of forest land and submergence due to the creation of the reservoir. (Table: 7)

HEPs Status with No.	Total Loss of Land (ha)	Loss of Forest Land (ha)	Land Under Submergence (ha)
Commissioned: 17	7126.46	2705.04	4421.42
Under construction : 14	539.59	442.36	97.23
Proposed: 39	1828.64	467.86	1360.78

Table: 7

Loss or Extinction of Wildlife species: Deforestation in connection with HEP development creates a negative impact on wildlife and wildlife habitat. It leads to the direct elimination of crucial habitats for terrestrial species. It also adversely affects the faunal species residing in these areas and which are dependent on the floral species of these regions which were lost due to project development.

Due to impoundment to create a reservoir, all terrestrial animals disappear from the submerged areas and populations decrease within a few years in proportion to the habitat area that is lost. Drying of long river stretches due to the creation of dam and diversion of the river also has negative impacts on terrestrial biodiversity and might affect the occupancy of the nearby areas by the terrestrial species due to water scarcity leading to degradation of habitat quality and affects as migration.[27] By building dams on rivers may permanently alter river systems and wildlife habitats [44]

Corridor effect: Deforestation or loss of forest land leads to a destruction of vital animal/plant corridors which ultimately effects migration and gene dispersal. Dam acts as a barrier to terrestrial animal movement and plant dispersal, particularly reduction of the riparian zone as a migration corridor. Large reservoirs may also disrupt natural migration corridors. The Dhauli Ganga sub-basin encompasses critical habitats and corridors for large mammals such as snow leopard, brown bear and Tibetan wolf.

Corridors, connecting Protecting Areas (PAs), upper reaches of the Dhauliganga sub-basin mainly Mallari and Tamak form an extremely rugged, wind-swept and frost-bitten cold desert habitat presenting a unique ecosystem. Snow leopard and Himalayan brown bear are heavily reliant on such marginal habitats making these as critical habitats. Additionally, the brown bear's easternmost distribution ends in this region.

Impact of Proposed HEPs: Out of 39 proposed HEPs, 16 would to loss of forest land either for land intake or will be under submergence. Of the 16 HEPs, 7 are located in areas that are >2.500m which are the home of wildlife habitats for many RET species and also includes critically important areas for these species. These seven HEPs that have been proposed would result in a loss of about 172.48 ha of land that includes 146.34 ha as forest land take and 26.14 ha under submergence.[32]

As the proposed barrage site and upstream area have been identified as corridors of wildlife. The project activities may affect them adversely especially breeding activities. Thus the likely impacts on the wildlife are negative, permanent, local and irreversible.

Disturbance of Wildlife: The operation of various construction equipment and blasting is likely to generate noise and the increased human interference may disturb wild animal population and may lead to marginal adverse impact.

Illegal Wildlife Trade: Many Hydropower projects are located either within 10 km from wildlife park/protected areas, in the core area or inside the protected area or in the buffer zone which are home for the snow leopard, brown bear, musk deer and many other threatened species. Due to these project activities, the forests area is fragmented and the wildlife movement in this area increases the risk of poaching. During the construction phase, the hydropower projects and approach road heightened the risk of poaching of wild animals for consumption and for trading through smugglers, thus increases the illegal wildlife trade. This impact further increases due to aggregation of labour population.[42,29]

These HEPs would directly as well as indirectly impact upon the remnant wildlife habitats and consequently the species, particularly the snow leopard, brown bear and musk deer. Hydropower development in these basins will significantly alter the habitats of these species of very high conservation importance.[32]

We are already experiencing loss and extinction of wildlife species due massive HEPs (Commissioned & Under construction) in Alaknanda and Bhagirathi basin of Uttarakhand. If all the 39 proposed HEPs will complete, it would further gift us the more severe impact on our environment with respect to wildlife habitat degradation thus adversely affects on ecological balance.

RESULT & DISCUSSION

After reviewed various article/document, evidence collected through field visit and documented response of the local household in the selected study area, I have seen that hydropower project developments are the main responsible factor for microclimate change in Uttarakhand, India and in turn pose a valuable contribution on global climate change.

Large forest area submergence for the formation of reservoir, fragmentation of forest, forest cut, alteration of river flow, drying of river bed or springs along with springs use as irrigation channel, land cover/land use change and continuous landslides as a direct and indirect effect including other dam building activities are the major responsible factors for the adverse impacts of increase in temperature, decrease in rainfall, alteration of rainfall pattern, decrease/disappearance of fish and wildlife population including RET species, reduction in agricultural production in various ways (includes loss of agricultural land, soil nutrients and irrigation facilities), reduced water security, adverse impacts on health of wildlife species and humans, infrastructural damages etc. These are effects in both ways either short term but significant or irreversible and long-term.

Considering route cause of environmental degradation due to HEP development is forest clearance, for 25 proposed HEP (listed, as given in IMG report) out of 197 (21212.78 MW) proposed HEP, the calculated forest loss (considering the relation—1) Dense forest loss=0.28

ha/MW. 2) Forest areas submerged=0.53ha/MW. 3) Forests loss due to other dam-building activities=0.59 ha/MW. 4) Non-forest land submergence, 0.67 ha/MW) [46] are placed as under. (Table: 8)

Large HEP (17): 3291 MW
Small HEP (8): 140.30 MW
} 3431.30MW(Ins Cap)

Forest Land Submerged in ha. (0.53ha/MW)	Loss Of Dense Forest in ha. (0.28 ha/MW)	Forest loss due to others Dam Building Activities in ha. (0.59 ha/MW)	**Total Forest loss In ha. (a)**	Non Forest Land Submerged In ha. (0.67 ha/MW) (b)	**Total Loss Of Land In ha (a+b)**
3431.30 x 0.53	3431.30 x 0.28	3431.30 x 0.59		3431.30 x 0.67	
1818.59	960.76	2024.47	**4803.82**	2298.97	**7102.79**

Table: 8

Already we are experiencing the forest area diversion of about 18000 ha (40% of 45000 ha) since 1980 for HEPs, transmission lines and for road construction in Uttarakhand and we have already lost a major amount of forest carbon stock. As per estimation, we may lose additional 4804 ha of the forested area by completing only 25 proposed HEP. It may increase further due to the transmission line,
rehabilitation and for other requirements related to
HEP as an indirect effect.
Project proposal includes afforestation to get the FC (forest clearance) permission along with other parameters. But it has been observed that afforestation not done as per recommendation (proportionate area, species etc.).
It may be suggested that the afforestation should start at least 6 years prior to pre-construction stage with same tree species needs to be cleared for the project and area should be 4/5 times of the deforested area to maintain the proportionate carbon sequestration rate some extent.
As per study through collected historical/statistical data related to climate change, it has found that over the last 60 years (1951-2010) the winter and post- monsoon temperature has increased 1.2°C (Fig:6) and 1.8°C respectively with the mean maximum temperature trend 0.02°C/year.(Fig:7)

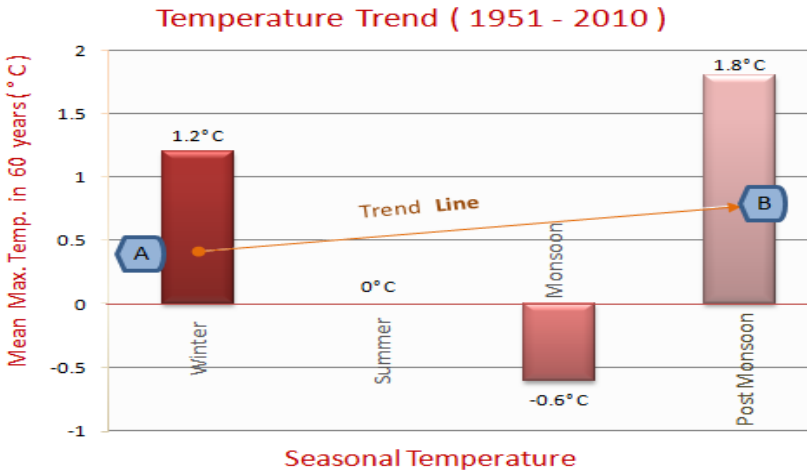


Fig: 6

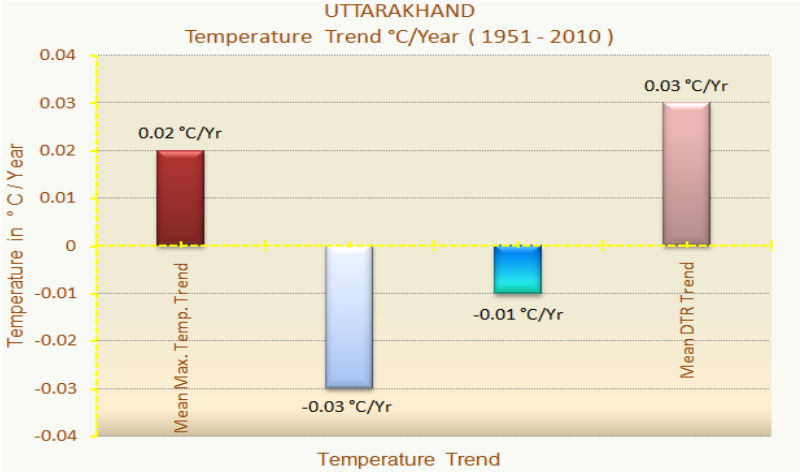


Fig: 7

A decreasing trend (1951-2010) of annual rainfall is also found, on which decrease of monsoon and post- monsoon rainfall is significant. (Fig: 8)

After analyzing the rainfall data of recent past (2001-2016), we found decreasing trend at a faster rate (Fig: 9). The remarkable change in rainfall pattern and change in seasonal rainfall has also been observed.

Forest area destruction due to hydro project coupled with the reduction of forested land due to rehabilitation, agricultural land, continuous landslide, drying of spring fed river bed in long stretch due to drying of spring etc. are one of the major responsible factors for increasing mean maximum temperature, decreasing rainfall and drastic seasonal change in temperature, humidity and rainfall.

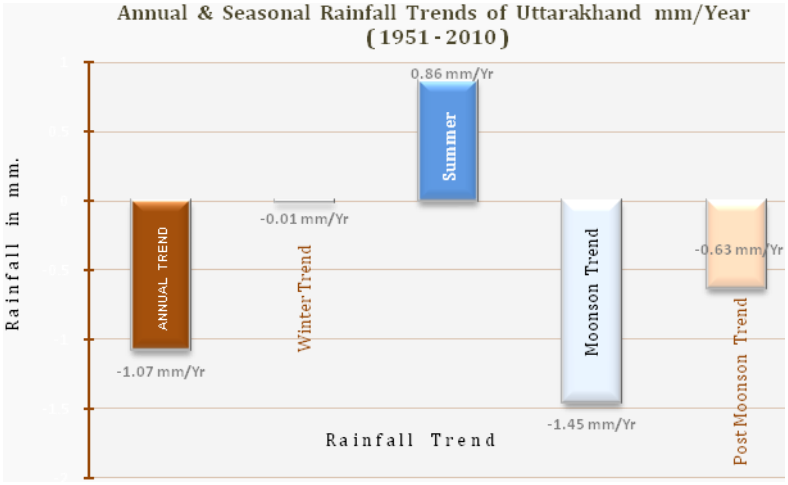


Fig: 8

Data Source for Fig: 6, 7 & 8: State Level Climate Change Trend in India, 2013. Ministry of Earth Science (IMD), GOI

Considering 100 yrs (1911-2012) rainfall data (A. Mishra, December 15, 2017), it has been observed decreasing trend in all the district of Uttarakhand except Hardwar. In five districts (Champawat, Pithoragarh, Bageshwar, Almora and Nainital), the decreasing trends are more significant. (Fig: 10)

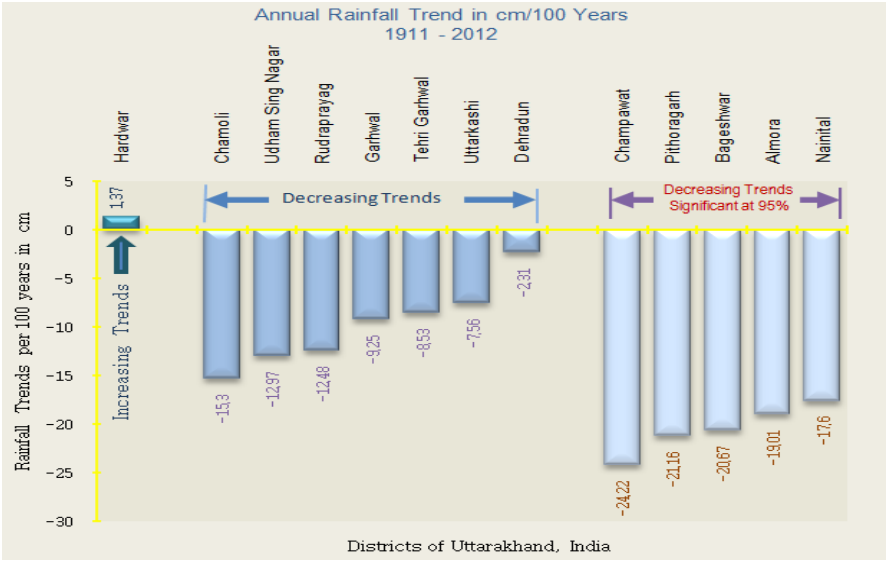
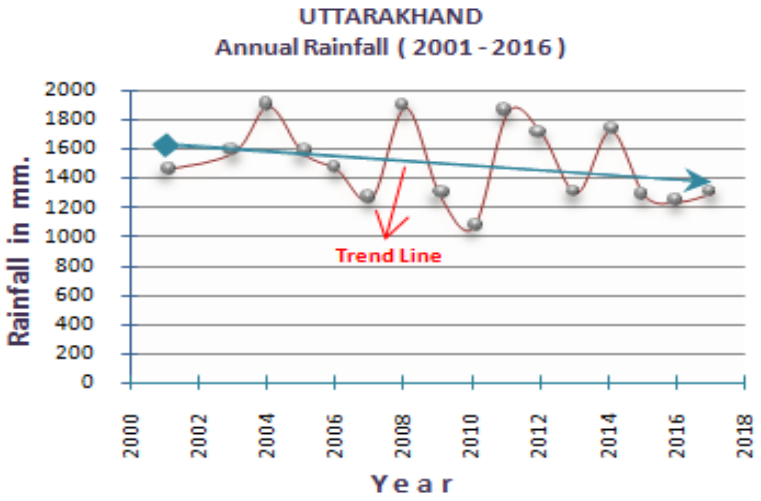


Fig: 10



Data Source: 1. Statistical Year Book, India 2016. 2. Uttarakhand State at a glance, Vol-1(5), 2015. 3. Annual Climate Summary 2011, IMD, GOI.
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Fig: 9

If it continues with the above rate, then we may predict the temperature will rise to 2.2°C in 2060 (considering the base value of 2010) and rainfall will decrease to 115.7 mm in 2060 (considering the annual decreasing trend in rainfall from 1951). This prediction considers the other parameters stands constantly.

The environmental impacts with respect to temperature and rainfall for further development of only 25 proposed HEP(out of 197 proposed HEP), will increase and decrease further from the estimated value and it will not follow the previous trend, it might more than the above trend due to cumulative impact on environment as a result of this development.

CONCLUSION

Uttarakhand Himalaya is experiencing massive deforestation (for hydro projects) and fuelwood, fodder collection (to meet daily need of population and livestock) reduces forested area resulting the decrease in forest carbon stock and reduce CO_2 absorption. On the other hand, fuelwood burning emits CO_2. As a result, the CO_2 emission increases and CO_2 absorption (sequestration) decreases leads to microclimate change and in turn takes a part of Global warming.

Electricity generation from hydropower plants are not at all the suitable way to limit the adverse impacts on environment (includes climate change and economic loss in terms of agriculture, water security, wildlife, health etc.) at the same time to meet the power deficit or upcoming electricity demand in this region as a result of economic development.

Uttarakhand has a huge potential of solar power with the good sunshine hour and wind power with moderate wind speed in the ridge and mountain pass region. As per record, the potential is limited to 16800 MW for Solar and 534 MW for Wind power @80m hub height till date.

Further research/study may result more solar energy potential and Wind energy @ 100m hub height.

After assessing the potential adverse impacts of HEPs in Uttarakhand for commissioned, under construction and proposed (not all listed), this paper concludes as a solution to utilize the potentially rich Renewable Energy like Solar and Wind as suitable alternative sources for electricity generation.

ACKNOWLEDGEMENTS

The author is highly thankful to Dr Mondal & Dr D. R. Sena, (Principal Scientist. Div. of Hydrology & Engg) and Mr U. Mondal (Research scholar) of ICAR-Indian Institute of Soil & Water Conservation for your necessary suggestion and guidance. I thank Mr. Jagdish Rawat, Ms Richa Sewmalty (Asst. Engg.) of PITCUL (Power Transmission Corporation of Uttarakhand Ltd.) and Mr B. B. Lal (Asst. Meteorology, Uttarakhand) for providing research-related data and assistance. I thank to Mr. S K Misra (GM), Dr D L Bhatt (Dy GM, Environment), Mr Atul Jain (AGM, Design-Civil) , Mr K P Singh (Director, Technical) of THDCIL, Rishikesh (RKSH) and Dr M M Conswal of THDCIL, Tehri for providing all the necessary documents, support and facilities related to my research work and valuable suggestions.

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