

# Evaluating Community Perceptions of the Socio-Economic, Environmental and Hydrological Impacts of Hydropower in Sainj Valley, Kullu

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## Abstract

Hydropower is a major source of renewable energy for sustainable development especially in mountainous regions like Himachal Pradesh. This study assessed the community perceptions of Sainj Hydropower Project addressing its socio-economic, environmental and hydrological impacts. A questionnaire survey of 304 respondents was conducted using a random sampling method and analysed using statistical methods in SPSS. The findings revealed diverse socio-economic impacts with majority of respondents reporting improved livelihoods (64.8%) along with enhanced infrastructure due to tourism (80.9%) and road connectivity (72.7%) however minimal employment generation (2.0%). Meanwhile considerable environmental concerns were highlighted including increased pollution (76.6%), soil erosion (77%), altered water flow (74.7%), deforestation (61.8%) and disturbance to aquatic ecosystems (71.1%) and wildlife (68.8%). Composite score analysis showed high environmental ( $2.53 \pm 0.45$ ), developmental ( $2.58 \pm 0.56$ ) and hydrological ( $2.54 \pm 0.39$ ) impacts however moderate socio-economic impact ( $2.16 \pm 0.62$ ). The statistical results further showed that the demographic factors like gender and education did not influence people's perceptions. Therefore the study overall underlines the need for more balanced planning in this eco-sensitive zone. Thus this survey based study highlights the need for monitoring programmes to ensure balance socioeconomic benefits for the community with the conservation of Himalayan environment.

**Keywords:** Socio-economic, Hydropower, SDG, People's perception, Environmental monitoring programme, Sustainability

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## 1. Introduction

Hydropower projects are the oldest and most widely used for generating electricity from falling and flowing water. It is a major source of energy providing about 16% of global electricity (IHA 2019a; Wasti *et al.* 2022). As a renewable source of energy hydropower plays a substantial role in generating sustainable energy contributing to industrial growth (Zarfl *et al.* 2015; Couto & Olden 2018 ; Brown *et al.* 2019 ; Grill *et al.* 2019 ; Huber 2019 ; Ghimire *et al.* 2021). The construction of these projects is essential to meet the energy demand however these large scale hydropower developments can affect the environmental and social scenario of the region such as ecological disturbance and community displacement thereby necessitating sustainable approaches.

In developing countries electricity not only supports the household welfare but also helps in the expansion of industrialization and supporting the nation's economy. In India access to electricity has improved with time rising from approximately 43% in 2000 to 82% in 2016 indicating the substantial growth in hydropower electricity generation (Hussain *et al.* 2019). Previously many studies have been conducted worldwide to provide insights into socio-economic and environmental impacts of hydropower projects (Jumani *et al.* 2016; Pandey & Poudel 2024; Sati 2025).

India's hydropower generation is majorly supported by the rivers of eastern and western Himalayan region (Rampini *et al.* 2016; Kumar *et al.* 2017; Sahu *et al.* 2020). Around 63% of India's electricity generation is obtained from thermal power plants with 24% of electricity generation from hydroelectric projects primary located in Indian Himalayan region (GOI 2015). In recent years the installed hydropower capacity has approximately reached 46-47 GW, contributing significantly to the country's renewable energy portfolio (CEA 2024). Hydropower also ensures energy security and mitigation in climate change by providing low-carbon energy aligning with SDG 7 (Affordable and clean energy). It also aids SDG 6 (Clean Water and Sanitation) by

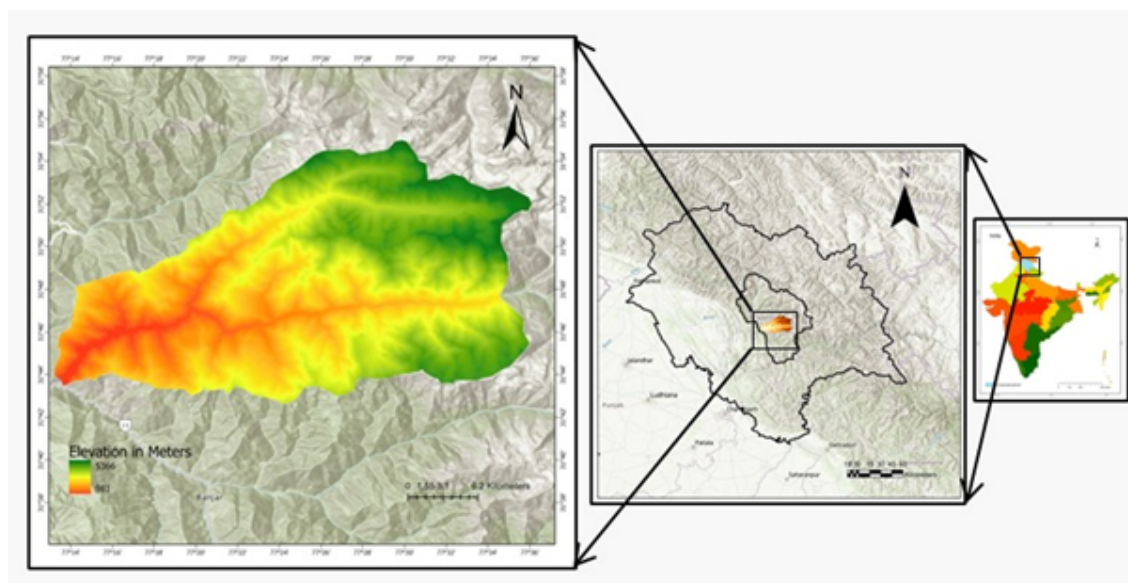
improving water management, SDG 13 (Climate Change) through reduction of greenhouse gas emission and SDG 9 (Industry, Innovation, and Infrastructure) by developing resilient infrastructure (Kishore *et al.* 2021).

Himachal Pradesh has significant hydropower potential due to its steep terrain, topography and fast-flowing rivers such as Beas, Ravi, Satluj and Chenab. Among various initiatives the Sainj Hydroelectric Project (100 MW) and Parbati-II Hydroelectric Project aimed at harnessing the tributary of Beas and attaining renewable energy targets in Himachal Pradesh. While the hydropower project offers multiple benefits however it may also lead to environmental and socio-economic impacts mainly during operation phase. These impacts can alter the river flow, water quality alteration and affect the biodiversity and livelihood of this region. A similar study has been conducted by Singh & Dash (2017) to understand the impacts of Parbati Hydro-Electric Project Stage-III (520MW) hydropower projects in this area. In this study survey based assessment serves an important tool to understand community perception and to formulate mitigation strategies. Despite several studies have prior examined the socio-economic impacts of hydropower projects in Indian Himalayan region however limited research have evaluated community perception particularly in Himachal Pradesh. This research focuses on the analysis of survey based assessment associated with Sainj Hydroelectric Project to evaluate the efficacy of hydropower project in this region. The findings of the study are intended to contribute towards promoting sustainability in the region.

## 2. Methodology

### 2.1 Study area description

The present survey was conducted in the Sainj Valley of Kullu district in Himachal Pradesh. This valley covers an area of 37.9 km<sup>2</sup> and lies between 31.7175° to 31.8142° N latitude and 77.2244° to 77.3369° E longitude (Fig.1). The study area is drained by Sainj River, a tributary of Beas River, which originates to the west of Rakti Sar at an elevation of 5,500 m (Singh & Dash 2017). This region experiences subtropical highland climate with mild summers and cold winters. Ecologically this valley is rich in biodiversity as it is adjacent to the Great Himalayan National Park, a UNESCO World Heritage site supporting rich flora and fauna.



**Fig.1. Spatial map of the study area**

### 2.2 Data collection and analysis

The present study collected data through the structured questionnaire survey in the Sainj valley. A total of 304 respondents were selected using a random sampling method to ensure unbiased representation of the individuals. The responses were recorded in categorical form and coded numerically (No=1, Can't say=2, Yes=3). The collected data were coded and analysed in SPSS (Statistical Package for the Social Sciences) version 24. Descriptive statistics such as percentage and frequency analysis were employed to summarize the responses. In addition, the association between different variables was analysed with cross-tabulation and calculating Chi-

square values. Composite scores were also employed to understand the overall impact of hydropower project across socio-economic, environmental, hydrological and developmental sectors.

### 3. Results and Findings

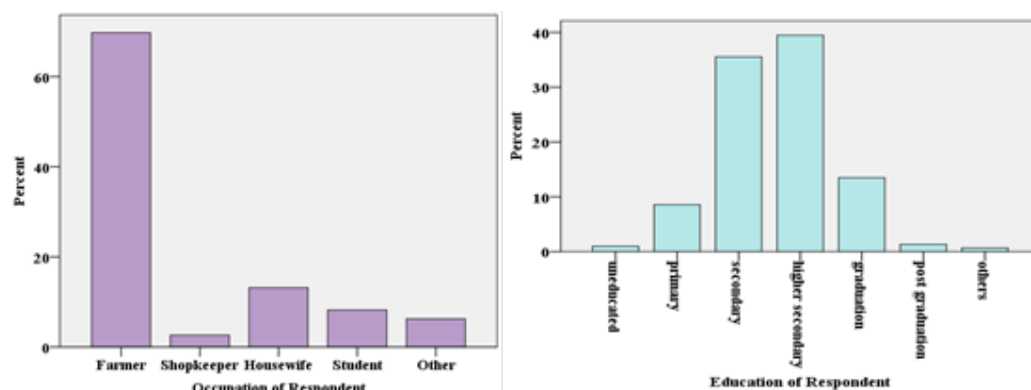
#### 3.1 Demographic profile of respondents

The data collected was analysed with respect to research objectives and the findings are illustrated through tables and descriptive explanations. The demographic profiles of the study area revealed that majority of the respondents were male (62.8%) while female constitutes comparatively smaller proportion of the sample (37.2%). The most of the respondents had attained secondary (35.5%) and higher secondary (39.5%) education reflecting the moderate literacy rate in the study area. A very small percentage of respondents had completed graduation (13.5%) and post-graduation (1.3%). Meanwhile very limited representation was found in other educational categories.

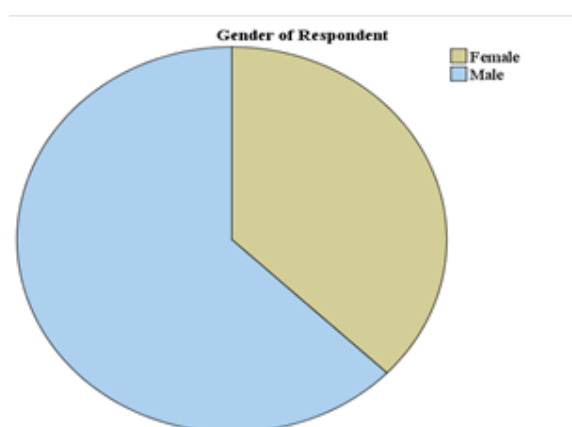
According to the occupation, the majority of respondents were active in agriculture sector (69.7%) reflecting the predominantly agrarian economy. However a significant proportion of individuals were housewife (13.2%) and only small proportion were involved in shopkeeping (2.6%) and other occupation. The descriptive statistics for demographic characteristics of the study area is given in Table 1 and graphical representation is given in Fig. 2, 3 and 4 given below.

Table 1 Descriptive statistics for demographic file of the study area

| Variable          | Category         | No. of respondent<br>(n=304) | Percentage (%) |
|-------------------|------------------|------------------------------|----------------|
| <b>Gender</b>     | Male             | 191                          | 62.8           |
|                   | Female           | 113                          | 37.2           |
| <b>Education</b>  | Uneducated       | 3                            | 1.0            |
|                   | Primary          | 26                           | 8.6            |
|                   | Secondary        | 108                          | 35.5           |
|                   | Higher Secondary | 120                          | 39.5           |
|                   | Graduation       | 41                           | 13.5           |
|                   | Post-Graduation  | 4                            | 1.3            |
|                   | Others           | 2                            | 0.7            |
| <b>Occupation</b> | Farmer           | 212                          | 69.7           |
|                   | Shopkeeper       | 8                            | 2.6            |
|                   | Housewife        | 40                           | 13.2           |
|                   | Student          | 25                           | 8.2            |
|                   | Others           | 19                           | 6.3            |



**Fig. 2 and 3.** Occupation and Educational profile of respondents



**Fig.4.** Gender composition of the study area

### 3.2 Socio-economic impact of Hydropower Project

The perspective of the respondents regarding the socio-economic impacts of the Sainj Hydropower Project showed heterogeneous responses given in Table 2. About 48.4% of the respondents described that their standard of living had improved meanwhile nearly equal proportion (48.0%) reported no improvement however 3.6% of the respondents were not sure. In relation to livelihood majority of respondents (64.8%) agreed about growth suggesting the positive impact of project. However 25.7% of the individuals did not observe any improvement while 9.5% were uncertain. On the other hand most of the respondents (96.4%) reported that project did not generate sufficient employment opportunities. Only about 2.0% people perceived a positive meanwhile 1.6% remained unsure. The living standards of the area might have resulted due to road connectivity through the hydropower project.

Table 2 Perception of respondents on Socio-economic factors of the Sainj Hydropower Project

| S. No. | Parameter                   | Yes (%) | No (%) | Can't say (%) |
|--------|-----------------------------|---------|--------|---------------|
| 1      | Standard of living improved | 48.4    | 48.0   | 3.6           |
| 2      | Livelihood improved         | 64.8    | 25.7   | 9.5           |
| 3      | Employment generation       | 2.0     | 96.4   | 1.6           |

### 3.3 Environmental impact of Hydropower Project

The perception of respondent revealed negative environmental impacts associated with the Sainj Hydropower projects as shown in Table 3. The majority (76.6%) of the respondents reported an increase in pollution level that might be due to the construction and tourism. Meanwhile 20.4% of the respondents disagreed and 3.0% were uncertain. Similarly 77.0% of the respondents documented increase in soil erosion whereas 17.8% did not observe these changes and 5.3% were indecisive.

The concern of deforestation was also emphasized with 61.8% of respondents reporting an increase while 31.6% opposed and 6.6% expressed uncertainty. For the biodiversity factor 68.8% of respondents reported disturbance to the wildlife suggesting that Sainj hydropower projects affected the wildlife corridors, accompanied by decreased aquatic fauna and natural resources depletion, however 18.8% of the respondents did not identify such impacts. The finding comprehensively revealed environmental degradation in the study area highlighting the adverse environmental impact of the project. Previously a study was conducted by Kumar, 2022 which highlighted the environmental impacts such as wildlife degradation and deforestation caused by increasing tourism activities in this region.

Table 3 Perception of respondents on environmental impacts of the Sainj Hydropower Project

| S. No. | Parameter                      | Yes (%) | No (%) | Can't say (%) |
|--------|--------------------------------|---------|--------|---------------|
| 1      | Increase in pollution          | 76.6    | 20.4   | 3.0           |
| 2      | Increase in soil erosion       | 77.0    | 17.8   | 5.3           |
| 3      | Increase in deforestation rate | 61.8    | 31.6   | 6.6           |
| 4      | Wildlife disturbed             | 68.8    | 18.8   | 12.5          |
| 5      | Decrease in aquatic fauna      | 71.1    | 18.1   | 10.9          |
| 6      | Depletion of natural resources | 78.3    | 16.1   | 5.3           |

### 3.4 Water and hydrological impacts of Hydropower Project

According to the respondents the Sainj Hydropower Project had negative impacts associated with water as 58.4% of the respondents revealed the limited supply of water for the agriculture where as 36.6% did not agree as given in Table 4.

Table 4 Perception of respondents on water and hydrology of Sainj Hydropower Project

| S. No. | Parameter                           | Yes (%) | No (%) | Can't say (%) |
|--------|-------------------------------------|---------|--------|---------------|
| 1      | Enough water for agriculture        | 58.4    | 36.6   | 5.0           |
| 2      | Loss of natural spring              | 82.2    | 13.5   | 4.3           |
| 3      | Change in water flow                | 74.7    | 6.9    | 18.4          |
| 4      | Increase in flash flood             | 86.8    | 9.2    | 3.9           |
| 5      | Impact on irrigation/drinking water | 69.4    | 22.7   | 7.9           |

According to the statistics 82.2% respondents reported a decline in natural water springs, whereas 13.5% did not agree, 4.3% remained uncertain. A majority (74.7%) of respondents observed a changed in water flow indicating hydrological alterations in the area with 6.9% people reported that they did not observe the same. However 18.4% of the people were unaware about this. Meanwhile 86.8% of the respondents reported occurrence of flash

flood due to construction of project and small proportion 9.2% opposed this decision. About 69.4% of the respondent agreed that the project led to irrigation and water changes highlighting the serious implications about water security in the area and 22.7% of the respondent remained unaffected. Thus the survey highlights a trend in water flow, increased flash floods and their impact on water resources of the Sainj valley. Vatsal *et al.* 2023 also highlighted the alteration in study area through loss of forest area and snow cover reflecting immense pressure on natural resources. These all changes might be due construction of hydropower project such as blasting road construction and diversion of water flow.

### 3.5 Developmental impacts of Hydropower Project

The finding revealed that area is expressing prominent infrastructural development particularly in terms of increased tourism and improved road accessibility. The descriptive statistics is shown in Table 5. According to the survey statistics 80.9% of the respondents observed increase in tourism activities enhancing the economy of this region. Around 72.7% people reported better road connectivity therefore improving the lives of the community in this region. This enhanced tourism in this area might be due to its scenic beauty, adventure treks biodiversity exploration and cultural richness from different parts of the country.

Table 5 Perception of respondents on infrastructure and development of Sainj Hydropower Project

| S. No. | Parameter           | Yes (%) | No (%) | Can't say (%) |
|--------|---------------------|---------|--------|---------------|
| 1      | Increase in tourism | 80.9    | 15.1   | 3.9           |
| 2      | Road accessibility  | 72.7    | 15.1   | 5.6           |

### 3.6 Cross-tabulation analysis

The analysis showed that respondents with secondary (61%), higher secondary (61.7%) and graduation predominantly supported the project whereas primary and uneducated groups showed lower level of support and higher disagreement as shown in Fig. 5. However Chi-square test ( $\chi^2=19.33$ ,  $df=12$ ,  $p=0.081$ ) revealed that the correlation between education level and favourability was not statistically significant at the 5% level. This suggested that education level did not have strong influence on respondent's opinion. The findings revealed that about 57.6% of all the respondents were in favour of the project, where slightly higher percentage of females (59.3%) favoured the project compared to males (56.5%). The Chi-square test ( $\chi^2=2.81$ ,  $df=2$ ,  $p=0.245$ ) indicated that there was no significant relation between gender and favourability for the project. It might be due to the similar distribution of developmental benefits resulting in no significant difference in their level of favourability.

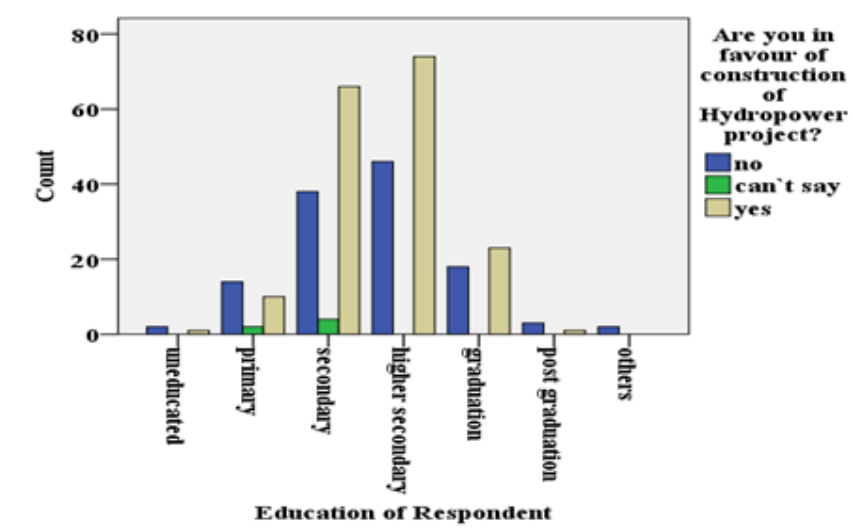


Fig. 5 Relationship between education level and attitude towards Hydropower Project

### 3.7 Composite scores analysis

Composite scores were classified as Low (1-1.66), Medium (1.67-2.33), and High (2.34-3) based on equal division of the scale range by adopting the Likert Scale (1932). The composite score findings of the hydropower project showed different level of impacts across different dimensions as shown in Table 6. Among the various components infrastructure and developmental impact recorded highest mean ( $2.58 \pm 0.56$ ) indicating that respondents of the study area received positive development from the proposed project. However water and hydrological impact ( $2.54 \pm 0.39$ ) and environmental impact ( $2.53 \pm 0.45$ ) reflected the higher concern and urgent need of proper measures to ensure sustainable resource management and environmental protection. Meanwhile the socioeconomic impact showed the moderate mean score ( $2.16 \pm 0.62$ ) suggesting comparatively less benefits among the respondents.

Table 6 Composite score of Hydropower Project

| Composite variable                      | Minimum | Maximum | Mean $\pm$ SD   |
|-----------------------------------------|---------|---------|-----------------|
| Socioeconomic impact                    | 1.00    | 3       | $2.16 \pm 0.62$ |
| Environmental impact                    | 1.00    | 3       | $2.53 \pm 0.45$ |
| Water and hydrology impact              | 1.00    | 3       | $2.54 \pm 0.39$ |
| Infrastructure and developmental impact | 1.00    | 3       | $2.58 \pm 0.56$ |

## 4. Conclusion

The study provided the integrated assessment of community perceptions regarding the Sainj Hydroelectric power project in Kullu, Himachal Pradesh. This project contributed in the development of the region however it also raised environmental and water related concerns in this region. The findings revealed the improvement in the infrastructure especially in the tourism and road connectivity enhancing the quality of life for the local communities. Additionally the survey results showed serious concern about environment and hydrological resources as the ecological balance of this region is being deteriorated and required proper measures. Meanwhile for the socioeconomic impact the results revealed varied outcomes. Many respondents felt the project had not created sufficient employment opportunities for the local population which might have affected the livelihood security of this region. The study also found the factors like gender and education did not influence the respondent opinions suggesting that their views were solely based on their direct exposure to the project. These insights from the study revealed that Sainj Hydropower Project had improved the regional development with respect to tourism however it also led to environmental concerns in this eco-sensitive zone. Therefore it is necessary for the policymakers to implement strategies which balance the development and ecological status to achieve sustainability in this Himalayan region.

## References:

- Brown, C., Zakaria, V., Joubert, A., Rafique, M., Murad, J., King, J., & Alonzo, L. (2019). "Achieving an environmentally sustainable outcome for the Gulpur hydropower project in the Poonch River Mahaseer National Park, Pakistan," *Sustainable Water Resources Management*, 5(2), 611-628.
- Central Electricity Authority (CEA) (2024), *Power Sector at a Glance (All India)*. Ministry of Power, Government of India.
- Couto, T. B., & Olden, J. D. (2018). "Global proliferation of small hydropower plants—science and policy," *Frontiers in Ecology and the Environment*, 16(2), 91-100.
- Ghimire, H. R., Phuyal, S., & Singh, N. R. (2021). "Environmental compliance of hydropower projects in Nepal," *Environmental Challenges*, 5, 100307.
- GOI, Energy Statistics, Central statistics office, Ministry of Statistics and Programme Implementation (2015) New Delhi: Govt. of India, 22.

- Grill, G., Lehner, B., Thieme, M., Geenen, B., Tickner, D., Antonelli, F., & Zarfl, C. (2019). "Mapping the world's free-flowing rivers," *Nature*, 569(7755), 215-221.
- Huber, A. (2019). "Hydropower in the Himalayan hazardscape: Strategic ignorance and the production of unequal risk," *Water*, 11(3), 414.
- Hussain, A., Sarangi, G. K., Pandit, A., Ishaq, S., Mamnun, N., Ahmad, B., & Jamil, M. K. (2019). "Hydropower development in the Hindu Kush Himalayan region: Issues, policies and opportunities," *Renewable and Sustainable Energy Reviews*, 107, 446-461.
- International Hydropower Association. (2021). *2021 Hydropower Status Report*.
- Jumani, S., Rao, S., Machado, S., & Prakash, A. (2017). "Big concerns with small projects: Evaluating the socio-ecological impacts of small hydropower projects in India," *Ambio*, 46(4), 500-511.
- Kishore, T. S., Patro, E. R., Harish, V. S. K. V., & Haghighi, A. T. (2021). "A Comprehensive Study on the Recent Progress and Trends in Development of Small Hydropower Projects," *Energies*, 14(10), 2882.
- Kumar, D., & Katoch, S. S. (2017). "Dams turning devils: An insight into the public safety aspects in operational run of the river hydropower projects in western Himalayas," *Renewable and Sustainable Energy Reviews*, 67, 173-183.
- Kumar, V. (2022). "Environmental Impacts of Ecotourism Developments In Great Himalayan National Park, Kullu, Himachal Pradesh," *International Journal of Multidisciplinary Educational Research*, 11, 24-32.
- Likert, R. (1932). A technique for the measurement of attitudes. *Archives of psychology*.
- Pandey, S., & Poudel. "A socio-economic impact of the ankhukhola hydropower project on the residents of tripura sundari rural municipality dhading."
- Rampini, C. (2016). "Impacts of hydropower development along the Brahmaputra River in Northeast India on the resilience of downstream communities to climate change impacts. University of California, Santa Cruz."
- Sahu, N., Sayama, T., Saini, A., Panda, A., & Takara, K. (2020). "Understanding the hydropower and potential climate change impact on the himalayan river regimes A study of local perceptions and responses from himachal Pradesh, India," *Water*, 12(10), 2739.
- Sati, V. P. (2025). "Socio-Economic and Environmental Impacts of Jamrani Irrigation Dam Project, Kumaon Himalaya, India," *Rural and Regional Development*, 3(3), 10007.
- Singh, M. K., & Dash, A. K. (2017). "Local Area Development through Hydropower Project: A Case Study of Parbati Hydro-Electric Project Stage-III (520MW) in Kullu district of Himachal Pradesh (India)," *International Journal of Community Development*, 5, 1-12.
- Vatsal, A., Brar, K. K., & Irfan, M. (2023). "Assessment of LULC changes in western himalayan mountain landscape: A case of Sainj river Valley, Himachal Pradesh (India)," *Current World Environment*, 18(2), 775.
- Wasti, A., Ray, P., Wi, S., Folch, C., Ubierna, M., & Karki, P. (2022). "Climate change and the hydropower sector: A global review," *Wiley Interdisciplinary Reviews: Climate Change*, 13(2), e757.
- Zarfl, C., Lumsdon, A. E., Berlekamp, J., Tydecks, L., & Tockner, K. (2015). "A global boom in hydropower dam construction," *Aquatic sciences*, 77(1), 161-170.

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