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Article

Re-Linking Governance of Energy with Livelihoods and Irrigation in Uttarakhand, India

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Abstract: Hydropower is often termed "green energy" and proffered as an alternative to polluting coal-generated electricity for burgeoning cities and energy-insecure rural areas. India is the third largest coal producer in the world; it is projected to be the largest coal consumer by 2050. In the Himalayan state of Uttarakhand, India, over 450 hydroelectric power schemes are proposed or are under development. Hydropower projects ranging from micro hydro (run-of-the-river systems with generating capacity up to 100 kW) to large reservoirs (storage systems up to 2000 MW) such as the Tehri Dam are in various stages of planning, construction or implementation. Run-of-the-river hydropower projects are being developed in Uttarakhand in order to avoid some of the costs to local communities created by large dams. Stakeholders in this rapid hydropower expansion include multiple actors with often diverging sets of interests. The resulting governance challenges are centered on tradeoffs between local electricity and revenue from the sale of hydropower, on the one hand, and the impacts on small-scale irrigation systems, riparian-corridor ecosystem services, and other natural resource-based livelihoods, on the other. We focus 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.

Keywords: hydropower; governance; livelihoods; gender; irrigation; ecosystem services

1. Introduction

Rampant urban and industrial growth and an agricultural sector increasingly dependent on groundwater pumping for irrigation have placed rapidly mounting demands on electrical power generation across South Asia. The Gangetic Plain and Himalayan headwaters in India and Nepal are witnessing rapid social–ecological change. 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 residents' livelihood needs. Water is the central thread that interweaves energy (e.g., mechanically powered mills, electricity generation), agriculture (irrigated and rainfed crops, fodder for livestock), fishing, and ecosystems (provisioning of water, regulation of micro-climates)—a prime example of the water–energy–food nexus [1]. Yet, the integration of hydropower as the newcomer into local and basin-scale resource-use practices poses very significant governance challenges. Our purpose here is to identify strategies in the Bhilangana River basin in Uttarakhand state, in northern India, that safeguard or enhance the livelihoods of women, youth, and men in areas with hydropower projects, while also maintaining critical ecosystem services. By assessing the Bhilangana basin case in Uttarakhand, we also offer hydropower–livelihoods–irrigation nexus lessons for headwater regions across the Himalayas and globally.

Hydropower supplied about 16% of energy globally in 2014, on the rise since 2004 among countries in the Global South with the rising percentages of their growing populations demanding access to energy [2,3]. Hydropower is one component of the energy portfolio of India. It was estimated that in 2014, India used only 21% of its potential energy from hydropower [2]. Rural and urban electricity is highly subsidized by the central government. Electricity demand is increasing steadily. Most of the electricity consumers are either located in urban areas or in breadbasket regions where extensive groundwater pumping exerts electricity demand [4,5].

Low-income rural people must often make do with inferior sources of energy such as fuel wood, kerosene, animal waste and coal. They also do without power for oil expellers, rice hulling and wheat grinding, as well as for uses such as electrical tools, and dairy processing. Household needs that are often neglected are the blending of food, a fan for hot weather and lighting for use at nighttime for children's homework and to extend women's and men's productive hours.

The social impacts of the extraction of natural resources for energy production are often borne by rural communities. The urban populace, however, also pays for the current dependence on coal for energy production through very poor air quality; the capital city of Delhi has received the dubious distinction of the city with the worst air quality in the world [6]. Thus, urban and rural built environments, as well as ecosystems, are impacted by the water–energy–food nexus. As Rasul has argued [7] (p. 9):

> *Greater policy coherence among the three sectors (water, energy and agriculture) is critical for decoupling increased food production from water and energy intensity and moving to a sustainable and efficient use of resources. The nexus approach can enhance understanding of the interconnectedness of the sectors and strengthen coordination among them.*

The water–energy–food nexus is impacted by localized special interests that include hydropower developers, construction companies/contractors, landowners, village leaders, and others, each with their own agendas. A paradox related to the push towards hydropower for the production of energy in India is that it is a federal program, yet it is being executed in an ad hoc manner by usually private actors. Some of these private actors are based in areas distant from the villages impacted by the hydropower projects.

This paper examines the governance challenges of integrating hydropower with irrigation and other livelihoods by considering nexus dynamics in a headwater basin. This is set against the backdrop of rural–urban exchanges of energy through transmission–grid extension; agricultural production through market penetration; labor migration as a result of stark differences in wages and services; and a range of digital, financial, and other "divides" between plains cities and more remote headwaters regions. Based on this brief introductory framing, we proceed to discuss the case-study location, as well as its features of more generic relevance; present a social–justice conceptual approach centered on governance and institutions; analyze hydropower-impacted livelihoods; and conclude with a discussion of strategies to better balance livelihoods and ecosystem services.

2. Research Sites and Methods

Uttarakhand is a state in northern India bordering Nepal to the east and China (Tibet) to the north. Two major rivers of north India, the Ganges and the Yamuna, originate in Uttarakhand. These rivers and their tributaries provide the opportunities for hydropower generation. Uttarakhand has four ecological zones which, from South to North are: Shivalik, Lesser Himalaya, Great Himalaya, and Trans Himalaya. There are two administrative divisions: the Kumaon and Garhwal regions. This study was conducted in the Lesser Himalaya zone in the northwestern Garhwal division within the Tehri Garhwal district (refer to Figure 1). Eighty-nine per cent of the state of Uttarakhand is mountainous, which significantly restricts the area capable of sustaining agricultural production. In the mountainous terrain, factors such as deforestation due to climate change and heavy felling of trees for construction, other development projects and livestock grazing, have increased the incidence of landslides. Uttarakhand is also prone to erosion; 53 per cent of the state is categorized as severely or very severely eroded and dams in the state have experienced serious challenges with sedimentation [8]. Seventy per cent of the population in Uttarakhand is involved in agriculture, primarily subsistence agriculture [9]. The cropping intensity has been calculated at 160 per cent (i.e., all arable land is cultivated for at least one crop season, and an additional 60 per cent of this has a second crop). The average landholding in the hills per household is 0.68 acre (often divided into patches). The Tehri Garhwal district has a high poverty rate: more than 45 per cent of the population lives below the poverty line [8].

Figure 1. Map of Uttarakhand showing locations of Garhwal and Kumaon regions. Source: https://en.wikipedia.org/wiki/Garhwal_division.

Technocrats and policymakers in India in general and in the water-rich Himalayan states of Arunachal Pradesh, Himachal Pradesh, Jammu and Kashmir and Uttarakhand in particular, overwhelmingly believe that hydropower generation will have the least negative environmental impacts of any energy option, and it can also bring in state revenue. These states have been termed the "Power Banks" of India for their capacity to generate power for their own demand and that of other states [2]. As Reddy et al. have argued with respect to hydropower in Himachal Pradesh, the state northwest of Uttarakhand: "*the main winners are the state and commercial developers who have gained access to water for producing electricity*" [10]. Approximately 450 new hydropower projects are currently being developed in Uttarakhand to partially "fill the gap" between utilization and the state government's estimate of 27,039 MW of hydropower potential. The state and central (federal) governments, in joint ventures between public and private entities, or with private companies (nationally and internationally based) are coordinating these power projects.

Experiences with large and medium scale hydropower projects, the types that have largely been promoted to date in Uttarakhand, have been mixed [11]. The recent shift from large reservoir-based hydropower generation to run-of-the-river (ROR) projects, are seen by proponents to have tackled displacement and rehabilitation issues, as well as the environmental impacts related to the construction and management of dams. In India, there are 22 large dams with a height of 100 m or higher. In Uttarakhand, some of these include the Tehri dam (1000 MW capacity), Koteshwar dam (400 MW capacity) and Ramganga dam (198 MW capacity). The Tehri dam, completed in 2006, has a height of 260 m (855 feet). It is the highest dam in India (and only one other dam is over 200 m high) and fifth highest globally. This dam caused the displacement of 110 villages and over 100,000 people [12] and the severe disruption of livelihood systems [13]. In terms of climate change, large dams, especially those located in tropical regions, have been implicated in large greenhouse gas emissions largely from decaying organic matter [14], putting into question the green credentials of hydroelectric power production [15].

ROR hydroelectricity, unlike hydropower via large dams, requires little to no water storage. Instead, the natural flow or elevation of the river is used to generate electricity; the water is diverted from the river with a diversion weir or small dam and then channeled into the powerhouse to turn turbines (see Figure 2). Sometimes a small dam is created called pondage where a small area is flooded but this area is much smaller than with conventional dams. These systems produce little or no greenhouse gasses except during the construction stages and are thus considered to be carbon-neutral.

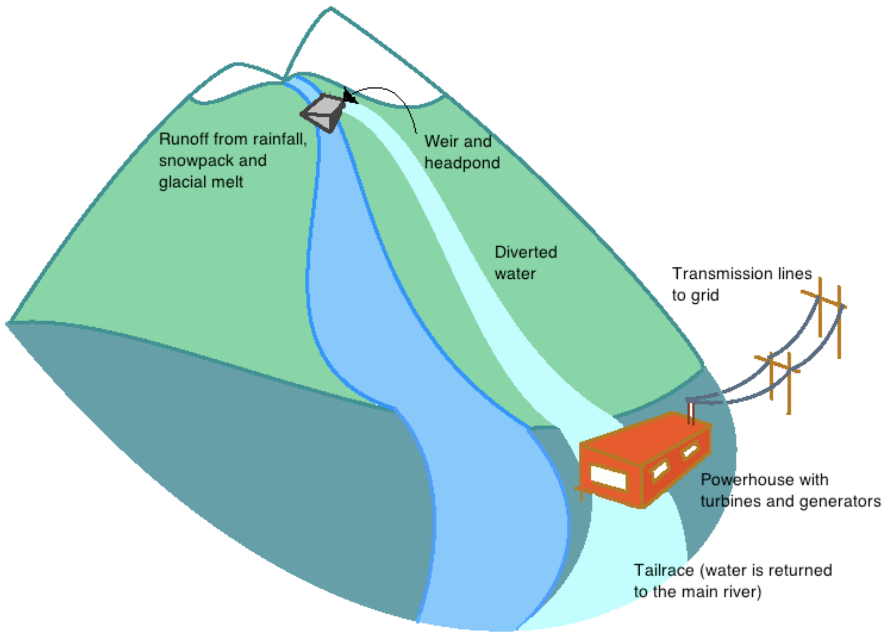

Figure 2. A small hydro, or run-of-river facility, drawing power from a mountain stream. Source: http://www.energybc.ca/profiles/runofriver.html.

ROR projects have not been as effective in the redress of local environmental concerns. ROR can affect the health of a watershed. Partly this is because the abstraction of water from the river leaves an area downstream, between the weir and the powerhouse, without normal river flows. Sufficient environmental flows of water (in this case river water made available via management regimes) are critical for ecosystems and the environmental, economic and social benefits these ecosystems bring. A healthy watershed provides multiple ecosystem goods and services for human, animal and plant populations within its boundaries. Postel and Thompson summarize these benefits as [16] (p. 98):

> … *water supplies for agricultural, industrial, and urban–domestic uses; water filtration/ purification; flow regulation; flood control; erosion and sedimentation control; fisheries, timber and other forest products; recreation/tourism; habitat for biodiversity preservation; aesthetic enjoyment; climate stabilization; and cultural, religious and inspirational values.*

Altering river flow leads to sedimentation, more turbidity, warmer water, and a change in nutrients that harms riparian biodiversity and the aquatic and animal populations dependent on the river [17]. Also, in Uttarakhand, water for ROR is often channeled through large pipes to achieve greater hydrostatic head (height difference between water upstream and downstream) and water flows to improve power production potential. The blasting techniques followed for constructing the tunnels through the mountains for diversions often leads to destabilization of the hillsides as well as detrimental effects on homes, cattle sheds and other infrastructure in the area.

Figure 3 indicates the location of Uttarakhand, the Bhilangana river basin, and the Tehri dam. The Bhilangana river is a tributary of the Bhagirathi river, which in turn is a tributary of the very large glacier-fed Ganges (known in India as the Ganga) river. The Bhilangana river basin is 2000 square kilometers in size. In April 2015 there were six operational projects, two under construction, six proposed, and nine identified sites for hydropower development in this basin [18] (fieldwork 2015). The hydropower projects are located in the narrow river valleys that are densely populated with villages and agricultural smallholdings on terraced land.

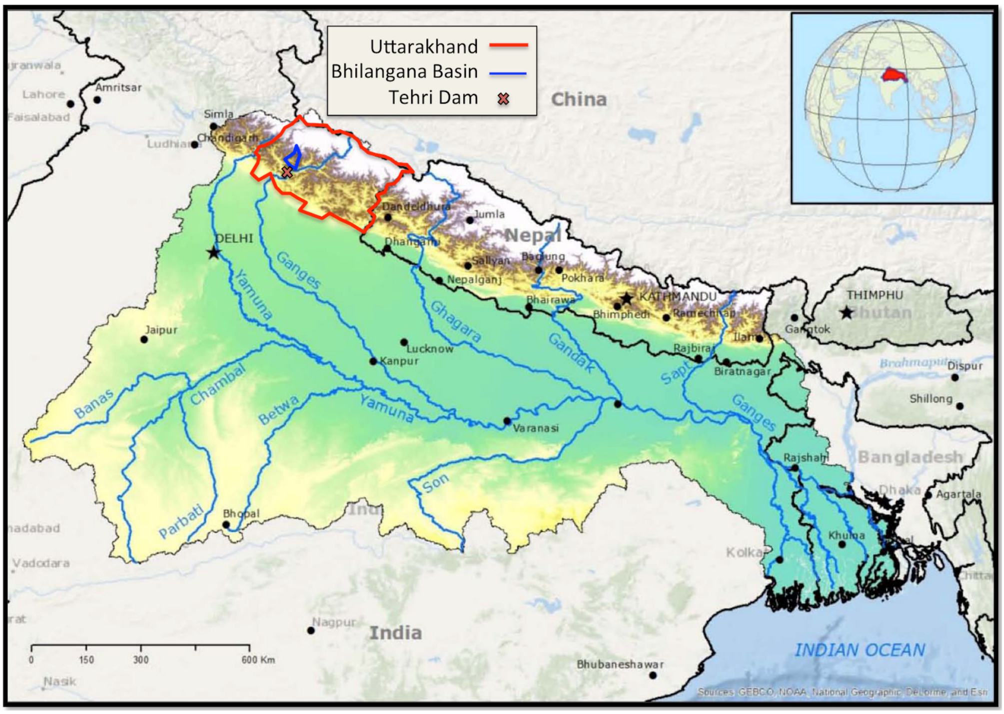

Figure 3. Study location in Uttarakhand. Source: Base map from Challenge Program for Water and Food (CPWF). http://waterandfood.org/river-basins/ganges-2/.

The research sites that include villages and their respective agricultural fields are located along the Bhilangana river and its tributaries including the Balganga river. These sites include villages impacted by the three operational run-of-the-river hydropower projects: Phalenda village (Bhilangana hydropower project with 22.5 MW capacity); Chakar Gaon and Devling villages (Bhilangana III with 24 MW capacity) and Chani village (Agunda–Thati with 3 MW capacity) (refer to Figure 4).

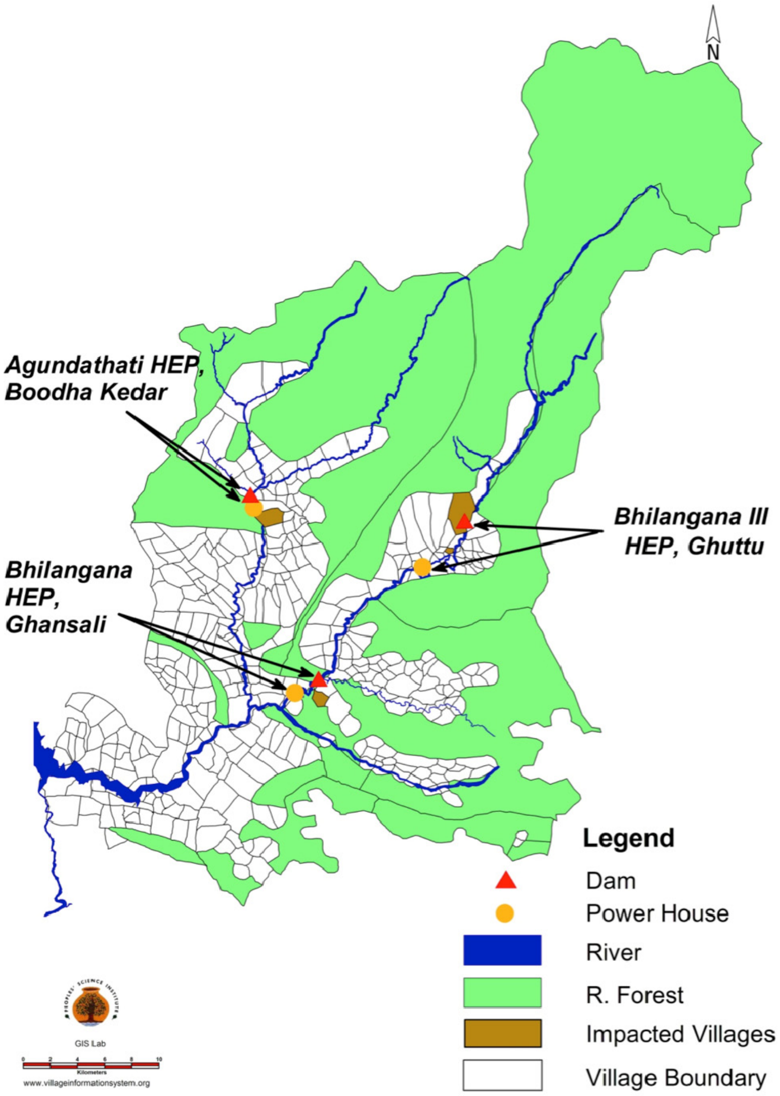

Figure 4. Research sites (impacted villages) and associated hydropower projects in the Bhilangana River Basin within Uttarakhand, India. Source: People's Science Institute, Dehra Dun.

Research methods utilized for this ongoing study include rapid rural appraisal (RRA), focus group discussions and household surveys (25 per cent stratified sampling) conducted between April 2015 and May 2016. Secondary research included a review of hydropower project related documents such as some of the detailed project reports (DPRs) on the hydropower projects, village agreements and writ petitions.

Urban-centered decision-making processes predominate in hydropower development. Pearce (2005) has argued, with respect to large dams in northeastern India, that [19] (p. 99): "Politically, they (large dams) have become a weapon for the rich, urban and powerful to take control of water resources away from the poor, rural and dispossessed". D'Souza's argument about the effects of large dams and other river diversions in India is also applicable [20] (p. 71):

> *. . . though announced as neutral technological artefacts, (large dams and diversions) are deeply implicated in several processes that have been integral to affecting types of enclosure, hydraulic transfer, the expropriation and elimination of other water management skills and traditions and inevitably the externalisation of real costs through displacement onto the most marginal and impoverished communities.*

In India, a large power gap exists between rural and urban residents. In 2012, those in rural areas consumed 7 kWh per capita per month whereas their urban counterparts consumed 24 kWh per capita per month [21]. Urban dwellers are thus benefitting more from hydropower development than rural peoples. However, previously energy-deprived rural populations are also deriving benefits in some cases. A range of actors including locally elected politicians, private developers, non-governmental organizations (NGOs), and others are actively working to secure funding for energy projects from Central and State government sources [22]. This is part of a general scramble for development projects in rural areas, a process that gained significant momentum with the National Rural Employment Guarantee Act, 2005 (later renamed the Mahatma Gandhi National Rural Employment Guarantee Act). Rural political leaders use the promise of such projects to bring development to their region. The desire to attract employment is an important component of such development projects. There is a rural employment crisis that has led to labor out-migration from rural areas. Gender is an important factor in employment and migration issues [23]. In the region studied in Uttarakhand, male migration is higher than female migration. Younger men migrate first for educational opportunities then for employment. The migration of women tends to occur more often after they marry to join their husbands. Ironically, migration to cities swells urban population, thus increasing urban demand for energy that contributes to a vicious cycle of rural expropriation (in this case of water) for largely urban energy use. It also has another societal cost: diminished food production in rural areas.

We take a social justice approach, especially as applied to energy projects [24], by contending that rural peoples should be given a stronger voice [25] than urban-based developers and political power brokers. This approach also leads to questions over centralized projects for resource provision and management, including hydropower in the case study we consider; however, centralized photovoltaic and wind-power projects are also limited in their capacity to meet social–justice criteria. Young [26] has characterized social justice as a condition in which the institutional context makes it possible for everyone to be included in governance processes and entails distributive results such as the satisfaction of basic needs. As Gross [27] (p. 2727) has argued with respect to fairness or justice in renewable energy projects (specifically, wind energy):

> *Questions of justice are . . . at the heart of many environmental disputes, such as . . . infrastructure development projects... While broad in scope these environmental disagreements share common characteristics which include how decisions are made and how public goods, such as power generation infrastructure, and environmental burdens . . . are distributed.*

Questions of fairness in a social justice framework incorporate issues pertaining to project benefits and costs and how these are distributed by gender, social class/caste, and geographical location [28]. In India, these distributional issues have so far been largely studied as they are related to the effects of large dams [29–31]. An overarching distributional issue is that which is mentioned above, that is, urban elites' expropriation of river water from rural populations living and farming in particular locations in riparian areas. In India, no water law exists that confers water rights to local people; only land rights exist [32].

Innovative technologies and social and legal processes and rules can help rural stakeholders generate energy for their own benefit rather than for urban, centralized, politically powerful actors. Rural populations are demanding regular power supply from the government. Electricity in rural Uttarakhand is used for lighting (including energy-saving compact fluorescent lights (CFL) bulbs), charging cell phones, and for blenders, irons, televisions, and refrigerators (usually only a few per village). Some of the benefits they seek from connection to small hydropower generation include longer hours of power and/or more reliable power, as the centralized grid supply in this area is still very poor. Smaller ROR projects that use the water alternately during the day and night for power generation and irrigation can help ensure power and livelihoods for local needs.

A more equitable distribution of environmental burdens can also be achieved in more centralized ROR power projects. Governance related measures that would help ensure this include the following: compensation by the developer for damage done to local populations' property during the construction phase. Minimization of the environmental burden on local livelihoods during the lifetime of the ROR project via government regulations applied to power developers' operations. Such regulations would incorporate sufficient environmental flows. Finally, governance measures would include more equitable distribution of benefits through profit sharing.

Social justice issues related to water resources have emphasized that water for multiple different uses must be protected in any watershed. The concept described above of environmental flows helps bring to light the multiple human and non-human water needs in a particular, managed, area. Chowdhury and Rasul's argument [25] (p. 46) with respect to irrigation projects also holds true for hydropower's effects on agricultural and domestic water resource distribution and access across different socio-economic groups: "*(a project) ... may affect their initial water access and use rights, entitlements and affect their well-being differently*". As competition grows between different water users (agricultural, fishing and hydropower in this case study) due to increasingly scarce water resources, social justice issues will become an increasingly pressing area for policymakers to address.

3. Results

3.1. Main Actors and Governance Linkages in the Study Area

The main local actors in the Bhilangana basin involved in hydropower projects include: Village Councils (*Panchayats*), Farmers' Groups, Irrigation Users' Groups, Non Governmental Organizations, Trusts, Cooperative Societies, Producer cooperatives or businesses, Village Energy Committees, Forest Councils (*Van Panchayats*), Self Help Groups, Government Departments, village women's welfare groups (*Mahila Mangal Dals*, MMDs), and village youth welfare groups (*Yuvak Mangal Dals*, YMDs). According to the villagers in the rural communities studied, the hydropower developers and state energy department are the least significant and accessible in terms of services and benefits accrued; in Figure 5 below, this is indicated by the smaller size of the circles for the developers, state energy department and courts, and the distance of the circles from the hydropower impacted villages.

An environmental impact assessment (EIA) must be undertaken for hydropower projects by Indian law (the Environmental Protection Act passed in 1986). The Ministry of Environment, Forestry and Climate Change, through environmental appraisal committees executes the EIA for hydropower projects before they decide on whether or not to approve them. The assessment is used as a tool to identify the environmental, social and economic impacts of a hydropower project. Recently, however, the National Institute of Disaster Management (NIDM) recommended in a report that disaster impact studies should be part of the EIA. This recommendation stemmed from the common perception that hydropower projects have increased the damage in Uttarakhand caused by floods, especially flash floods and lake bursts from glacier-fed lakes, such as the catastrophic one that caused large loss of life in 2013. The NIDM study also pointed out that: "hydro-power projects are blamed for disturbing ecological balance in the sensitive fragile zone of Himalayas, leading to more landslides and other associated risks" (NIDM in [33]). Small hydropower projects of up to 25 MW with an outlay of less than Rs. one thousand million (i.e., one billion) are exempted from the EIAs but they do need to obtain all clearances from the corresponding state government.

Women are the cultural and economic backbone of life in the Garhwal Himalayas (as well as in the neighboring Kumaon Himalayas of Uttarakhand [34]). They do most of the farming and household work, which involves collection of drinking water, fodder, fuel wood and attending to the cattle (mostly cows and water buffaloes for their milk), besides all the daily household chores. Girls often work alongside their mothers. Male out-migration from the area has further heightened women's roles in agriculture such as in paddy (rice) cultivation, the cultivation of other grains and pulses such as lentils and the production of vegetables. Similar patterns have been documented in other areas of Uttarakhand state such as in the Nanda Devi biosphere reserve area [35], which is located to the northeast of the Bhilangana river basin research sites we studied. Women's welfare groups i.e., MMDs are therefore recognized as one of the most important institutions by the local communities and are therefore represented by the biggest circle. In all the impacted villages studied, MMDs were also reported to have actively participated in the protests against hydropower developers to fight for their rights related to land, forest and water. Therefore, these are perceived to be closer to the village in terms of their relationship with the villagers.

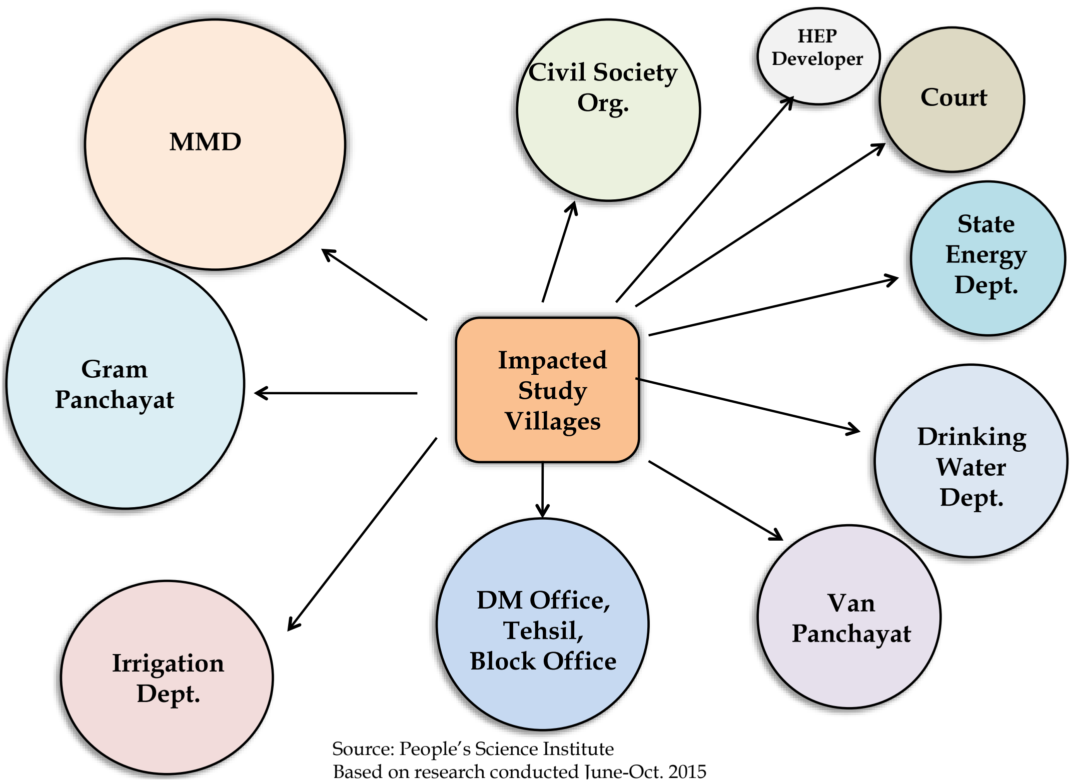

Figure 5. Stakeholder mapping: Bhilangana River Basin study sites.

An example of MMD's brave, active and prolonged (therefore costly) participation is reflected in the words of a woman who is a former member of the MMD of Phalenda village and was a leader in the protest:

> *We came to know about the ongoing construction plans only when we saw the machines. We led the group and reached the construction site. The moment villagers went to stop the construction, police were employed. The police would not even let us access our fields. We did not want them to take away the water used for irrigating our fields. So we started the protest that lasted for about a year. We would take turns going to our fields for work, attending to the needs of our children and also participating in the protest. For hours, groups of men and women would sit determined by the side of the road and would get up only when surrounded by the police. We participated in frequent hunger strikes. In my memory we stayed hungry for four days continuously one time and eight days another time. We were sent to jail at three different places three times. A settlement was reached after one year of tiring agitation, when we got water for irrigating our fields. However, if you ask me, the most important impact has been on our mental peace of mind and well-being, which can't be reimbursed (translation from Hindi ours).*

Due to the prolonged agitation by the MMD, farmers of Phalenda managed to get a better share of irrigation water from the hydropower developers in comparison to other affected villages.

Gram Panchayat as an institution in the three-tier local governance system is the lowest institution in the hierarchy through which communities participate in the planning and execution of all village development activities. So, it is perceived as the second most important and still close to the village in terms of accessibility and usefulness to the villagers.

Yuvak Mangal Dal or the youth welfare's group is still active but heavy out-migration from the area has diminished its level of activity to a considerable extent. Among all the village level institutions, this is perceived to be least active.

The next set of primarily government institutions are mainly service providers and are approached only in case of need. According to the villagers' own words: "As and when these institutions are approached, our work gets done. However, we have no additional expectations from them". The irrigation and water departments are shown separately, as per their roles, but according to the villagers, the majority of the repair and maintenance work for the pipelines and *guhls* (irrigation canals) is performed by the villagers themselves via voluntary labor contributions. Therefore, the villagers' perceptions of their need for these organizations and these departments' efficacy is lower (represented by smaller circles) and they are placed further away.

Lastly, hydropower developers and the district courts are the two institutions that are perceived to be least important. The developers' main interest appears to be earning revenues from energy generation; local communities' interests do not come first within their agenda and often get sidelined. Similarly, the communities have had largely negative experiences with the courts in terms of resolving conflicts over benefits sharing and compensation related to hydropower projects. However, as we discuss below, the state and federal governments could play a role in mandating, through legal instruments, more equitable benefit sharing between the community and hydropower developers. This would also translate into a better balance between meeting the needs of rural and urban populations. The courts would then be responsible for upholding these legal measures aimed at achieving social justice and environmental sustainability. In addition, a stronger, more socially just water–energy–food nexus would be ensured because of the critical role rural populations continue to play in the production of food for both rural and urban areas.

3.2. Case Studies

Developers of ROR projects have frequently overlooked the energy and irrigation needs of the local communities. They have not allowed for sufficient environmental flows downstream of the ROR projects. This lack of transparency and coordination with local communities has translated into negative impacts on the livelihoods of female and male villagers neighboring the project sites, as highlighted below in the case studies of four villages in the Bhilangana basin in Uttarakhand.

3.2.1. Observed Common Social Impacts in All Studied Hydroelectric Project (HEP) Areas

The negative effects of hydropower development reported by villagers living and farming in the vicinity of these ROR projects include land destabilization, leading to infrastructure damage including cracks/seepage in houses and/or community buildings; and destabilization of slopes with greater chance of landslides, fissures and land subsidence (some of these effects are due to dynamite blasting of tunnels for the HEP project); as well as an accumulation of muck (rock and debris created by tunneling during the construction of hydropower projects) on grazing/agriculture land. There are also myriad water-related effects such as reduced water resource availability including defunct water mills (for grinding grains) due to less water in the river in locations where water has been extracted for the HEP; reductions in domestic and irrigation water supply due to spring sources disturbed especially by tunnel blasting; irrigation canals destroyed due to landslides or abandoned due to too little water available; water pipelines carrying spring water for domestic water use and home gardens destroyed; dry riverbeds during part of the year; more wild animal attacks on crops and livestock due to deforestation affecting food supply for these animals; and less water in the river; reduction in irrigated area; reduction in availability of fodder and fuelwood due to less vegetation along the river banks; reduction in manure due to less livestock kept because of decreased availability of fodder; loss of cremation ghats (riverside cremation grounds); and a reduction in fish population due to less water in the river and poorer water quality. These effects are not limited to the study area. Dry springs and increased vulnerability to landslides and deforestation, for example, were similarly identified as effects of hydropower projects in the Nanda Devi biosphere reserve in Uttarakhand to the northeast of the Bhilangana study sites [34]. Damage to and lack of water for water mills and irrigation canals was also reported in a study conducted on the effects of small ROR projects in Himachal Pradesh state, India [36]. These environmental burdens are experienced by agricultural communities that depend on natural resources for their livelihoods and reside in the ROR project areas. As will be seen, some local residents are affected even more than others.

3.2.2. Impacts Observed in the Case of Devling and Chakar Village, Bhilangana III HEP Area

Impacts of blasting for the construction of the tunnels for the HEP can be clearly seen at the Bhilangana III HEP areas. Some of the respondents expressed that: "The land beneath our houses would shake, as if an earthquake had hit the area. We couldn't sleep during those nights". In Devling village located near Bhilangana III HEP (24 MW), as many as 86 out of the 110 resident households observed visible cracks in their houses after the construction of the HEP started. In terms of their springs (also a source for irrigation), seven out of eight are reported to have subsequently partially or completely dried up. Due to the construction of tunnels, irrigation channels in the neighboring villages have been affected. The agricultural fields have suffered a loss of productivity due to reduced irrigation water availability, which also led to a reduced amount of fodder (straw) from paddy and wheat crops. Approximately 95% of the households reported a loss of productivity in agriculture. The reduction in irrigated area has affected food availability from farm and agricultural income. Agricultural land has also been affected through the dumping of construction material from the hydropower projects on this land. Dependency on the market for food grains has therefore increased.

Debris from the blasting of the tunnels for the hydropower projects has been dumped on grazing lands accessed by all households in the village. When asked how the hydropower project has impacted their daily life, a respondent immediately reacted by forcefully stating that:

> *They caused damage to our agricultural fields and did not compensate us for it. Our harvest has been reduced due to less water available for irrigation and a lot of dust from the construction. The springs feeding our guhls (irrigation channels) have disappeared because of the blasting. This pollution in the area has also impacted our grazing land. It's just not the same grass anymore and animals won't consume it. Many of us have therefore sold off fifty per cent of our milch (dairy) cattle.*

Households that earlier ran water mills from the mountain streams for additional monetary income and for food security, have now been affected by a loss of income due to greatly reduced water flows. As many as ten water mills have become defunct in Devling and Chakar villages.

The People's Science Institute's (PSI) field research team, together with residents of Devling village, carried out mapping of impacts on a village map of Devling, indicating present land use and land cover, which was available with the revenue official at the site (see Figure 6). A range of features including impacted springs, impacted irrigated/unirrigated area, houses that developed cracks, defunct water mills, land deposited with muck, etc. were marked after visual verification by the field research team.

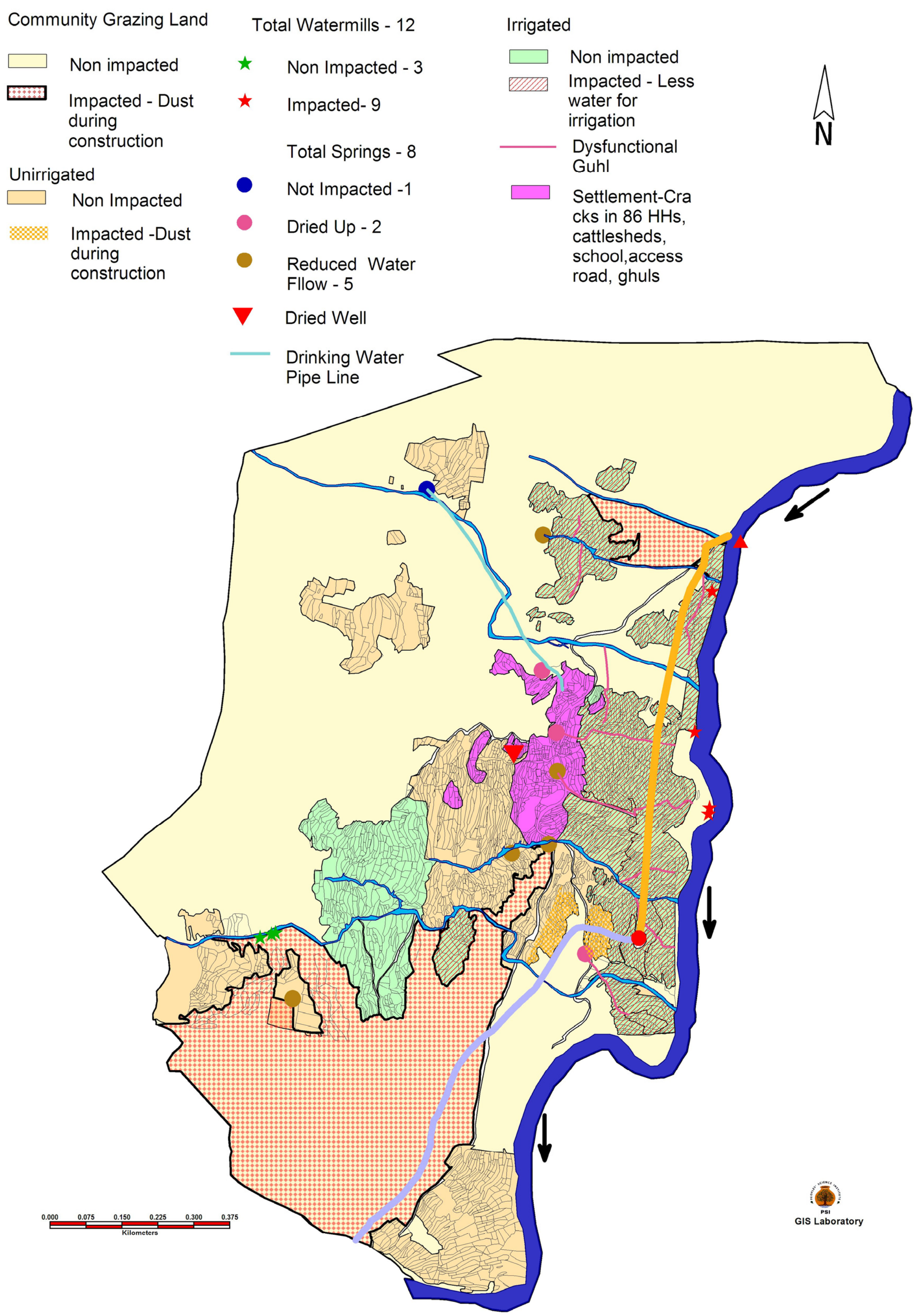

Figure 6. Map of Run-of-the-River (ROR) Project Impacted Areas in Devling Village.

The map shows the extent of the damage exacted on important livelihood-related infrastructure, privately-held and common lands and on water resources for domestic and agricultural use.

Gendered Impacts

All hydropower projects have had gendered impacts; in the study area, in the case of all women interviewed, their workload related to the collection of water, fodder and fuelwood increased. Loss of fodder and fuelwood sources has forced them to go deeper into the forests for collection. More men were reported to have migrated in the post hydropower project period to make up for livelihoods-related losses from the hydropower project. Women have been left alone to tend to animals and to farms with decreased access to the means of production.

Villagers have responded by reducing their herds of cows, bulls and buffaloes, and/or by renting the use of bulls for ploughing. In Devling village, the average annual loss in income per household from milk has been around Rs. 14,000 since the HEP started functioning. In Chakar village near the Bhilangana III hydroelectric plant, women told our research team:

> *The forest is far away. Lower availability from other sources has increased our time and effort. There is a fear of wild animals in deeper nooks and crannies in the forest. We have no help from the men. So we have reduced the number of animals we keep.*

Thus, hydropower projects in this area have clear social–justice related implications for rural populations, revealed in gendered impacts on labor allocations, income and access to food.

Compensation for Losses

Some livelihood compensation has been offered by the hydropower projects but these vary across and within the affected villages causing a great deal of unhappiness. Very few households from the affected villages received employment at the hydropower projects, for example, only three from Devling. Only some households in the villages received monetary compensation and this compensation was reported to be inadequate. In Devling, only four out of nine households received compensation for defunct water mills. Land compensation rates for land taken over by a hydropower developer ranged from Rs. 40,000 to Rs. 95,000 per *nali* (50 *nalis* = 1 ha) for 20 households. No compensation was given for damaged houses and cattle sheds in any of the affected villages. A few households reported investing Rs. 15,000 to Rs. 20,000 for reconstructing cattle sheds. In some villages, pipelines have been built by developers from the sources of springs to the village. However, in Devling village, due to disputes over labor charges for villagers volunteering to help, pipelines were not installed. An ad hoc compensation of Rs. 1 lakh (Rs. 100,000) was given to the *Gram Panchayat* of Chakar Gaon village.

3.2.3. Impacts Observed in Chani Village, Agunda–Thati HEP Area Despite Signed Agreement

In Chani, a village affected by the 3 MW Agunda–Thati hydropower project, the villagers stated that they were warned by nearby villages in the area about the negative effects that they had endured. Villagers interviewed in adjoining Agunda and Thati villages said that they had turned down the hydropower developers' requests to construct a hydropower project in their location. As a result, the project was moved to Chani. The signed agreement stated that, aside from the land handed over on paper to the developers by the villagers, no other land would be affected. The signed agreement also assured that any individual in the *gram sabha* (i.e., all villagers over age 18) who suffered any kind of damage to their property during the HEP construction phase would be compensated by the company. Muck disposal would be done in the depositing yard, not on farmers' land. They were promised that any destruction to the canals, crops, paths and fields would be repaired. However, none of these promises were subsequently met.

The villagers explained that:

> *We have been living here for generations and now they have taken everything away. The developer belongs to the same district (but is now a large industrialist living in the large city of Dehradun). We told others: learn a lesson from our village.*

Most of the landowners (127 out of 135 households) reported having irrigated land along the riverbank. This land of the village had become barren downstream of the power project due to the diversion of river water for power generation. In Chani village, families lived for six months near the river and farmed there and then moved up to higher elevation lands and lived and farmed there for six months. Now they must live up in the higher elevations year-round.

A reduction in the number and depth of pools in the river has caused fish populations to diminish, affecting male fishermen primarily and their household food and income security. A fisherman farmer from Chani village explained that fishing has been harmed by the Agunda–Thati hydropower project. He decried that:

> *I have seen three varieties of fish in the river. We call them as machibag, machhi, gadiyal locally. One of them is red and yellow in color. Earlier we would go for fishing in the summers. In the monsoon season, we would catch fish from standing water in the paddy crop (coming up from the river). Now, since most of the water is diverted in the hydropower channel, I do not see any fish in these waters. My fellow men and I from the village do not visit the river for fishing anymore.*

Nine fishermen households from Chani village reported an average annual economic loss of over Rs. 10,000 due to the fact that there are almost no fish in the river anymore due to inadequate flows in the dry season. These households attempted to intensify their agricultural production, but several factors have limited their opportunities to do so. Thus, fisherfolk are particularly vulnerable to the environmental burdens of hydropower projects, with clear social justice implications for their livelihoods and for household food security.

Wild vegetation used to grow on land along the riverbank in Chani but now it has been affected by the hydropower project construction debris and the lower volume of water in the river. This reduces the availability of proximate fodder for livestock. Since women and children (mainly girls) collect fuelwood and fodder, the intensity of women and children's fodder-collection labor has increased.

The residents of Chani realized that they were fooled and demanded that the developers should have at least abided by the signed contract. The villagers shared with us that: "our lawsuit focuses on compensation for our land, forest and water . . . How do we keep the youth here when what we have are land and water based which also has been taken away?" They contended that their skills as farmers and their farm-based livelihoods provide a strong degree of self-reliance and as a result are more respectable than urban-based menial jobs as laborers or hotel employees.

The villagers now obtain most of their food grains at subsidized rates from the ration store that is reserved for families living below the poverty level, or, for families above the poverty line, from the market. Even the hydropower project operator from the village complained about receiving low wages for his work from the developer. He is also pressured by the developer to tell the villagers not to protest otherwise he will lose his job. He thinks that the village should take over the project and he would work for them instead. Fear of retribution by developers or the government was also noted in a study of HEP projects in Sikkim state in Northeast India [37].

3.2.4. Impacts on Environmental Flows Observed in Phalenda Village, Bhilangana HEP Area

In a hamlet of Phalenda village there is a small hydel project (Bhilangana) of 22.5 MW. Villagers had protested the construction of the HEP for a long period, demanding benefits such as the construction of an access road and a school, in addition to a fair share of water for irrigation. Women and even children went to jail due to their active participation in the protests. Though the villagers here got a better share of irrigation water compared to villages affected by the Bhilangana III and Agunda–Thati projects, they reported a loss of productivity from their fields in the lowlands especially in the winter season (wheat crop) when HEP developers did not come through with a timely and adequate release of irrigation water. This community could possibly have benefitted from power generated for lift irrigation for their fields in the upland areas but due to a lack of community awareness no such demand was made during the protests or during the signing of the agreement between the HEP developer and the impacted residents.

Fifty to sixty houses of Phalenda, especially in the upper slopes, developed cracks in them from the blasting for the tunnel construction. Although in Phalenda there was a distribution of compensation for infrastructure-related damage, according to villagers, the distribution was not done properly and not all families got the same sum. In the words of a respondent: "the sum is not enough to get the repair work done. I had to take a loan from a neighbor to get it done". About seven springs were reported to be affected by the blasting operations, four of which were partially affected earlier by the 1991 earthquake. Only eight people from the village derived employment from the project.

The women and men in the villages have a keen understanding of the political, social, economic and environmental dynamics associated with the abstraction of natural resources from rural areas for the provision of power to urban areas. The diversion of water from the river for the hydropower project did not allow for sufficient environmental flows to sustain local livelihoods. A woman from Gawani hamlet (in Phalenda village) told us: "Food (i.e., power) is being prepared in our village but someone else is getting to eat it". In other words, their lived experiences with hydropower production have enabled them to understand the true costs of the expropriation of river water near their villages in terms of its effects on their access to water for irrigation and household use.

4. Discussion

4.1. Governance of Run-Of-The-River Hydropower

Studies conducted on the social and environmental impacts of centralized hydropower schemes in India have revealed negative gender impacts related to access and control over resources [30,38]. The risks to which women of affected communities have been exposed, through such projects, include loss of land, loss of houses, resettlement, loss of fisheries, loss of access to forests, influx of (male) workers, etc. Even the more recently commissioned Tehri (Uttarakhand) and Sardar Sarovar (Gujarat) projects seem not to have learned lessons from the past experiences of Bhakra–Nangal (Himachal Pradesh) and Hirakud (Odisha) dams [39–43]. This situation is not restricted to India, as the report of the World Commission on Dams [44] (p. 114) highlights how large hydropower projects all over the world have "*widened gender disparities either by imposing a disproportionate share of social costs on women or through an inequitable allocation of the benefits generated*". There have been no strategic efforts by the developers, either private or governmental, to involve women right from the planning process. A recent gender analysis of renewable energy projects in India states that there has been a "*lack of gender mainstreaming in the energy sector and a lack of understanding of how to incorporate gender concerns in a sector that has primarily been technology-driven*" [45] (p. 93). In other words, within the water–energy–food nexus, women's roles are not recognized even though they are the principal agricultural producers in rural communities in Uttarakhand.

Hydropower projects are also subjected to risks and damage from natural disasters including earthquakes and floods. The disastrous Koyna earthquake of 10 December 1967, is often attributed to reservoir-induced seismicity [46,47]. Questions are often raised about the earthquake resistance ability of the Tehri dam, the tallest dam in India, which has been built in a seismic zone [48]. The 2013 floods of Uttarakhand have highlighted that the design of most of the 24 existing and under construction hydropower projects in the Upper Ganges basin have not accounted for events such as cloud bursts, suffering not only damage but also aggravating the proportion of the disaster [49,50]. This has further raised concerns over the viability of such projects, especially in the context of a changing climate. Thus, one can argue that there are hardly any examples of centralized hydropower schemes in India that have been informed by more progressive gender and risk-based impact assessment.

4.2. Benefits Sharing

The concept of benefits sharing in hydropower projects has evolved over time, starting from a notion that local communities would derive trickle down benefits of hydropower development initiated by a regional or national entity and then encompassing compensation to local communities for harm done to their property or livelihoods. Currently, though, as Shrestha et al. (2016) explain, there is greater potential for local communities to gain "*less conflict and greater voice as well as greater ecosystems services*" because "*benefit sharing is increasingly defined as going beyond the mitigation of project impacts and beyond compliance to a situation where the local affected population directly benefits from the project.*" [51] (p. 7). A benefits' sharing partnership enables the local population to have an equity stake in the project and to strive for more socially just project outcomes for villagers. Hydropower developers in the Indian Himalayan region need to be encouraged to invest in livelihood enhancing activities of local villages. According to hydropower developers in the study area in Uttarakhand, they allocate 1 per cent of project costs towards a local area development fund (LADF). Similarly, 3 per cent of generated power is to be given to the concerned Panchayti Raj Institutions of the impacted villages. However, discussions with local communities and members of Panchayati Raj Institutions (PRIs) revealed multiple discrepancies between such policy measures, signed agreements and ground realities (fieldwork, 2015). Village communities in the study area are largely unaware of such policies and contributions made to PRIs. This calls for revisions in institutional mechanisms and ensuring transparency in the process. It also requires enforcement of rules and legislation.

It is worthwhile to mention here that the neighboring country of Nepal is moving toward a new electricity act that would mandate that ten per cent of the shares of the hydropower project would go to the impacted local community, with the smallest bids considered first in a market-based bid allocation system [51,52]. Private companies are creating public companies to distribute shares in hydropower projects. Chilime, a 22.1 MW hydropower project in Nepal, distributed shares to the affected local people in 2010 for the first time in the history of Nepal. Since then, other ROR hydropower projects have also allocated 10% shares to affected communities [51] (p. 16). This is particularly salient in the context of the continued expansion of hydropower in Nepal, where the government has been actively promoting hydropower in order to reduce the country's power load shedding to zero. Nevertheless, the April 2015 earthquake had serious impacts on hydropower facilities and infrastructure of all kinds. With the urgent need for urban housing and commercial reconstruction, however, these delays in hydropower expansion may provide the opportunity to enhance integrated governance, including benefit sharing [51].

4.3. Decentralization

Decentralized Distributed Generation (DDG) through community managed small hydro projects can be a suitable method for the provision of electricity to the forest fringe and scattered villages in the Indian Himalayan region [53,54]. Operation and maintenance of these projects can be undertaken by the local community after formal training. Such projects have a short gestation period with minimum environmental impacts. In the mountain state of Uttarakhand, the Uttarakhand Renewable Energy Development Agency (UREDA) is a state agency, established in 2001 as a registered society under the Department of Alternate Energy, Government of Uttarakhand. Its primary purpose is to promote the development of renewable energy resources in Uttarakhand. It has constructed 44 off-grid and on-grid micro-hydel projects with a total installed capacity of 4.29 MW. Another 19 projects (2.315 MW) are under construction [18]. The off-grid projects are managed by committees of the beneficiary villages. These projects are meant for electricity generation for feeding into the central grid or for local domestic household consumption, in cases where they are not already electrified by the central grid. Small hydropower schemes with lower head can incorporate fish ladders, for example, that can protect fish migration routes and thus livelihoods derived from fishing.

Jansamarth, a Delhi-based voluntary organization with the goal of promoting local livelihoods, has helped in the installation of 17 micro-hydro power projects in the two Himalayan states of Jammu and Kashmir and Uttarakhand. One such example is that of a community-managed 50 KW capacity hydropower plant established in 2006 in Agunda village located in Balganga valley of the Bhilangana study area in Uttarakhand [52]. This multipurpose hydropower unit mechanically powers an oil press, rice huller and flourmill, creating livelihood opportunities for the village community consisting of 65 families. The same water is used to irrigate 6–7 hectares of land. The villagers are proud owners of the project, because they put in the labor for its construction and because it is now operated by trained community members. An older man from this village stated: "This project is ours—we brought it here. While we are living we won't allow any other project".

River basins can be glacial or spring-fed. The performance and life of hydropower projects located in the basins of spring-fed rivers depend on sustained discharge of springs contributing to the river flows. Over the last two decades a substantial decrease in spring discharge has been reported to be affecting flows in spring-fed rivers in the Himalayas [55,56]. This is mostly due to environmental degradation caused in the catchments of the springs due to anthropogenic activities and more recently due to climate change. Spring-shed development can help revive springs. Sustained flows are essential to sustain hydropower projects, especially those with a smaller capacity and those run by spring-fed rivers. Spring development therefore needs to be incorporated into hydropower planning in Himalayan states. Springshed development involves hydro-geological mapping, delineation of the concerned aquifer, seasonal monitoring of spring discharge, identifying the potential recharge area, formation and capacity building of spring user group, planning and implementation of treatment measures in the recharge area with community's participation, and subsequent monitoring and impact assessment. Treatment measures include a combination of tree plantation, staggered trenches, brush wood check dams, etc. which reduce surface run off and increase infiltration leading to spring recharge [57].

People's Science Institute (PSI), a research and development organization based in Dehradun in Uttarakhand, together with other non-governmental organizations such as WWF-India, ACWADAM-Pune, and Arghyam–Bangaluru, assisted the government of the state of Sikkim in the eastern Himalayas in India to successfully launch the Dhara Vikas (Springs Development) initiative in 2008. This spring-shed development initiative was launched under the centrally sponsored Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) scheme, covering a total area of 400 hectares and resulting in an annual groundwater recharge of 900 million·L. The scheme led to the revival of five lakes and fifty springs. PSI is in dialogue with Uttarakhand and other Himalayan states concerning similar initiatives to link hydropower with livelihoods, taking into special consideration ecosystems and climate change.

4.4. Planning for a Basin with Decentralized and Centralized Distributed Generation Solutions

Decentralized power projects cater to energy requirements that transcend local needs. However, these projects have their own limitations in terms of accessibility (high cost of transmission lines and maintenance) and quality (reduced supply hours and poor load), especially in remote areas as evident in the Himalayan region of India. In such cases, there is a clear need for integrating decentralized projects with centralized schemes. This would result in a more cost effective delivery of power in addition to a decrease in undesirable environmental and social impacts. Apart from the above, such decentralized projects could open up new and enhance existing economic activities as demonstrated by the small-scale, community-based hydropower projects established by Jan Samarth in India. Integration of centralized and decentralized projects would involve (1) proper estimation of energy requirements at the basin level and even beyond considering different sectorial needs such as household lighting, potable and irrigation water supply, health and sanitation, education, communication and economic activities; (2) identification of vulnerable areas within the basin which cannot be reached by centralized supply; (3) identification of alternative energy sources which could be owned and run by vulnerable communities; (4) participation of local communities especially women in the planning/decision-making of centralized solutions to minimize detrimental effects and ensure access to natural resources; (5) strengthening of local institutions (such as *panchayats* i.e., local governance bodies) for ensuring just flow and sharing of benefits for affected communities; and (6) robust institutional mechanisms at various levels within the basin involving various stakeholders to monitor and evaluate benefit sharing activities in the impacted areas. This also calls for the establishment of a grievance redressal mechanism for negotiated settlements of disputes benefiting local communities as well as developers. Thus, integration of centralized and decentralized power schemes needs "adaptive, multilevel, and collaborative institutional arrangements" [58] that are decentralized and account for local conditions [59].

5. Conclusions

Multipurpose, run-of-the-river hydropower development can contribute to a healthier water–energy–food nexus in the Himalayas. However, at present, the benefits are skewed in favor of urban populations and hydropower developers. The study, based on a social justice approach, illuminated imbalances in decision-making power between these urban interests and rural villagers who are dependent on agriculture and from whom river water has been expropriated. Mountain communities are caretakers of ecosystem services. Run-of-the-river hydropower, especially larger projects, has been causing environmental harm (albeit less harm than large dams) that in turn has gendered livelihood impacts. A social justice approach and the inclusion of the exact words of villagers interviewed shed light on the desires of local populations with respect to hydropower projects and the areas where social equity in hydropower governance could be enhanced. Rural populations desire local hydropower for livelihood activities, irrigation benefits, household chores and the education of children. Locally controlled, smaller HEP projects in Uttarakhand have enabled rural peoples to be prime decision-makers in the control over power generation and water allocations.

Where the HEP project will negatively impact environmental flows for agriculture and fishing, fuelwood and fodder, and will damage village infrastructure, populations in Uttarakhand are demanding compensation and, increasingly, benefits sharing. Women are strong actors in these protest movements. This is largely due to the fact that women bear an unequal burden within their rural communities when irrigation and household water, land, and forest resources are reduced due to hydropower, climate and land intensification-induced changes. Rural men and youth are migrating to urban areas at a higher rate than before, partly because of diminished income from agriculture and livestock rearing due to HEP impacts; this migration is adding to urban energy demand and adding to rural women's work. These HEP impacts on labor reduce rural food production; they thus also exact a cost for the central government in terms of increased urban demand for services such as energy, and declining rural food production at a time when it is necessary to feed growing urban populations. Perhaps, if more women were involved at the global level in renewable energy issues, these regional water–energy–food nexus challenges could be addressed. At present, at the global scale in energy governance institutions, only 4% of the top World Energy Council (WEC) chair positions are women and only 18% of the secretary positions in WEC are women [60].

Participatory governance and clear guidelines and mechanisms for benefits sharing are essential at the local, basin, and transboundary scales. Following the example of neighboring country Nepal, higher rates for benefit sharing between hydropower developers and local communities near the hydropower project could be instituted and enforced to ensure greater equity. State and federal governments could play a role in mandating, through legal instruments, more equitable benefit sharing between the community and hydropower developers that would be enforced by lower courts. If disaster impact assessments were mandated as part of environmental impact assessments carried out by the Ministry of Environment, Forests and Climate Change, disaster could be redefined to include the negative effects found in the villages in this study of the Bhilangana river basin. Such assessments would ideally contain a greater emphasis on gender-related assessments to avoid both greater workloads for women and girls and negative impacts on household food security and income.

These measures would also translate into a better balance between meeting the needs of rural and urban populations. Springshed development has shown promise in other regions in India and could help prevent some of the harm to water sources for irrigation and household use for riparian communities in Uttarakhand. Small hydropower schemes, built and operated by local populations and that meet hydropower generation and irrigation needs, can reduce the negative impacts and increase the benefits of hydropower for rural communities, as can a combination of decentralized and centralized schemes.

Future research needs include an examination of how local, state and central governments can support the local management of hydropower schemes and how springshed development and other initiatives shown to be successful in one area can be adapted by communities in other states to meet their needs. Other research topics that need to be studied include analyses of hydropower–agriculture tradeoffs and an examination of HEP effects on female and male youth's labor-related decision-making to gain a clearer vision of future scenarios for these rural communities and possible policy responses.

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Abbreviations

The following abbreviations are used in this manuscript:

DPR	detailed project report
EIA	environmental impact assessment
HEP	hydroelectric project
LADF	local area development fund
MMD	*Mahila Mangal Dal* (women's village welfare groups)
NIDM	National Institute of Disaster Management
PRI	Panchayati Raj Institution
ROR	Run-of-the-river
YMD	*Yuvak Mangal Dal* (youth welfare groups)

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