

Development of Run-of-the-River Hydropower Projects in North-Western Himalayan Region of India: A Study about their Environmental Sustainability

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ABSTRACT

Himachal Pradesh is endowed with an estimated hydro power potential of 27,436 MW which is 25% of the national hydropower potential. The Government of India has embarked on a task of constructing several categories of large and small dams in the Himalayas region with an aim to double the hydro power capacity by 2030. The mighty Indian Himalayas will have the highest dam densities on an average in the entire world, if the dams are constructed at this pace. As compared to the multipurpose hydropower projects, RoR i.e run-of-the-river hydropower projects are considered more environmentally sustainable. However construction of such projects has an inherent risk of degradation of eco-system, loss of flora and fauna and associated changes in climatic pattern in this fragile mountain range of the world. This research paper aims to study the public perception on the environmental sustainability of large and small run-of-the-river hydropower projects in the North Western region of the Himalayas. Based on the analysis of primary data pertaining to the intangible impacts and secondary data on tangible impacts collated during the study on the environmental sustainability of these projects, it is concluded that the consequential impact on environment from small projects is no less significant as compared to environmental impact from large projects.

Key Words: Run-of-the-River Hydro Project; Sustainability; Large Hydropower Projects; North Western Himalayas; Beas Basin; Environmental Pollution; Himachal Pradesh

INTRODUCTION

Hydropower projects have been promoted as harbingers of socio-economic development across the globe because they are cheaper and greener substitute for fossil fuels electricity production (Tang et al. 2018). More than 18% of world electricity is produced by hydropower projects. Prominent reservoir based multipurpose hydropower projects in the world are: Three Gorges project in China (22,500 MW), Itaipu hydroelectric power project at the border of Brazil and Paraguay (14,000 MW) and Guri power project in Venezuela (10,400MW) (Bartle 2002).

India ranks seventh in the world in hydro-electric power generation potential. It has a hydro-electric power potential of 148700 MW with installed utility scale capacity of 44594 MW (28.77%) which has been developed so far and 13616 MW (9.2%) is under construction (Saxena and Kimar 2010). Tehri Dam Project in Uttarakhand (2400 MW), Koyna HEP in

Maharashtra (1960 MW), Sardar Sarovar Dam in Gujrat (1450 MW) and Bhakra Nangal Dam on Sutlej river in Bilaspur, Himachal Pradesh are some of the major power projects in India. India has not yet explored power potential from Central Indian regions of Godavari, Mahanadi, Narmada, Nagavali and Vamsadhara river basins on a major scale due to opposition from tribal population. An additional 6780 MW from smaller hydro schemes with capacity less than 25 MW is exploitable (MNRE 2016).

Himachal Pradesh has five major rivers flowing through the state namely Beas, Ravi, Satluj, Yamuna and Chenab; they carry about a quarter of India's total potential hydropower resources. Total identified hydropower potential in the state is 27436 MW; out of which 10460.47 MW is under operation, 2438.24 MW is under construction. Beas River originates from Beas Kund at Rohtang Pass at an elevation of 13,050 feet (3,978 m) and flows for a length of about 470 km

before joining the Sutlej River at Harike Pattan south of Amritsar in Punjab (DoE 2017). Table 1 below gives hydro power potential of Beas basin.

Table 1. Hydropower potential of Beas River Basin in Himachal Pradesh (from MOEF-CC 2019)

HEP Category	No. of Projects	Capacity (MW)
Commissioned	22	2820.9
Under Construction	5	947
Under Investigation	20	1028.9
Yet to be allotted	4	80.9
Total	51	4877.7

Hydropower Potential of Beas Basin

Beas Basin in Himachal Pradesh has 4877.70 MW of power potential, distributed among 51 hydropower projects spread throughout the basin. Out of these 51 projects, 22 projects are commissioned with total installed capacity of 2820.90 MW, 05 are under construction (total installed capacity 947 MW), 20 are at various stages of investigations (total installed capacity 1028.90 MW) and 04 are yet to be allotted. Out of proposed 24 projects, many of which are under different stages of survey and investigation, only 4 projects have installed capacity of more than 50 MW i.e. requiring environment clearance as category “A” projects. Two are with installed capacity greater than 25 MW but less than 50 MW i.e. environment clearance is applicable under category “B” and remaining 18 projects are less than 25

MW of installed capacity i.e. environment clearance is not applicable (MOEF-CC 2019).

Development of Run-of-the-River (RoR) Projects

The reservoir based hydropower projects have huge inherent environmental impacts in terms of deforestation, bio-diversity loss, habitat degradation, farmland loss, displacement of tribal communities and alteration of water regimes (Kaunda et al. 2012). The development of reservoir based projects involves formation of gigantic storage capacities behind the dams and submergence of huge tracts of forest land under water. The reservoirs receive organic sediments which decay and release methane and carbon dioxide. The methane released is approximately 8 times more potent as greenhouse gas than carbon dioxide. To off-set these negative impacts, run of the river projects provide an alternative which appear to have been more environmentally sustainable. RoRs are different in design and appearance from the conventional hydropower projects (Kumar and Katoch 2016). The conventional hydro dams store huge quantities of water in reservoirs, leading to flooding of large tracts of land. In contrast, run-of-river projects, the water is diverted to the powerhouse and it rejoins the mainstream after power generation. RoR projects generate electricity with the natural flow and elevation drop of a river water. The World Commission on Dams defines large dams as those that have a height of 15 m or more. Any project that generates more than 25 MW electricity is considered to be a large dam. Therefore, the height of a dam is not the only criterion determine

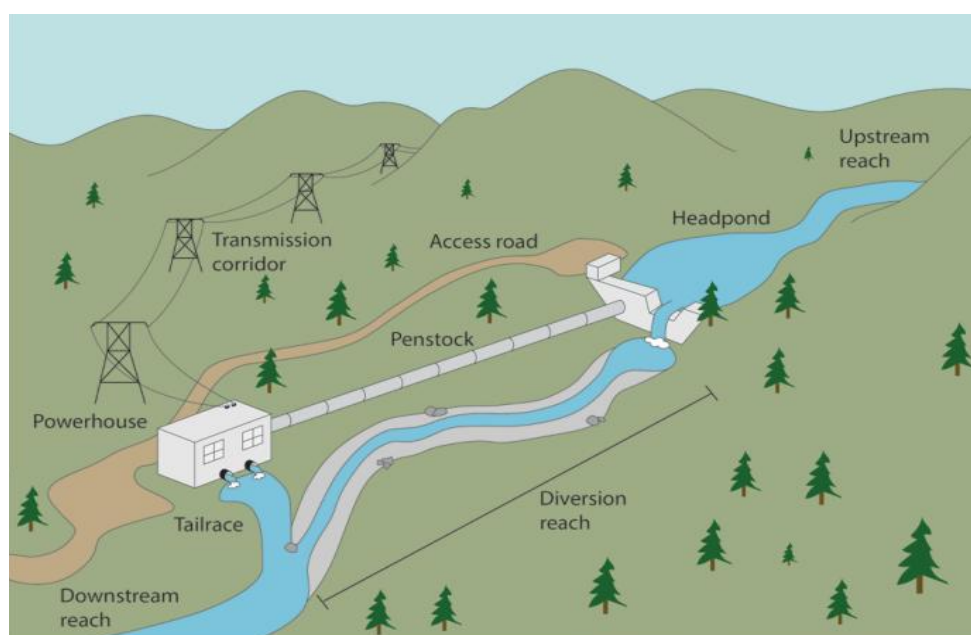


Figure 1. Graphic depiction of working of a basic run-of-the-river project

its type. Invariably the submergence area of an RoR dam is small as compared to conventional dams such as Indira Sagar dam (6,164,334 ha catchment area), Hira Kund dam (8,340,182 ha). Some of the RoR projects are Carillon Generating Station (752 MW) Quebec Canada, Upper Tamakoshi Project (456 MW) Nepal, Ghazi-Barotha Hydropower Project (1450 MW) on Indus river in Pakistan (Roy 2016). The present study aims to carry out comparative study of small and large RoR projects in the Beas basin in Himachal Pradesh to ascertain the scale and magnitude of their environmental impacts based on tangible indicators. Three large hydropower projects (LHPs) namely Parbati stage-II (800 MW), Sainj HEP (100 MW), Allain Duhangan (192 MW), and three Small Hydropower Projects (SHPs) namely Tosh (10 MW), Baragaon (24 MW), Lambadug (25 MW) are covered under this study. Further the research intends to analyse whether the environmental impacts of hydro power projects are proportional to their project size and scale.

by Parbati river. Beas Basin is characterized by rugged topography with high ridges and peaks with higher reaches covered with glaciers, ice and snowfields. The forest cover in Beas basin falls under 11 forest divisions in districts of Kullu, Mandi, Hamirpur and Kangra. As per forest survey of India (2015), 9.31% constitutes dense forests and 17.79% has moderate dense forest cover in the Beas basin region.

Three large and three small RoR hydropower projects located in the Beas river basin of Himachal Pradesh were selected for this study. Hydropower projects below 25 MW are categorised as small hydropower projects (SHPs). There are multiple types of diversion structures depending on the type and size of a hydropower project. The raised diversion weirs and drop type trench weirs are used for small HEPs. The most commonly used diversion structure for LHPs are Gated barrage type and gravity style diversion dam. The main function of diversion structures is to alter the flow characteristics of water by controlling its flow for outlets of the reservoirs. The salient features of these selected hydropower projects are listed at Table 2.

STUDY AREA

Beas basin comprises of river drainage catchment in Himachal Pradesh. Beas Basin is flanked in the North by drainage catchment of Ravi and Chenab rivers and in the South by Sutlej river. Beas river originates from Beas kund at Rohtang Pass at an elevation of 3978 m and flows for a length of 470 km. At Bhuntar, Beas River is joined

Advantages and Disadvantages of RoR Projects

It is widely believed that run-of-the-river hydropower projects are more eco-friendly than the conventional large reservoir based dams since there are no significant green house emissions as is the case with large reservoir based projects. The RoR projects are considered

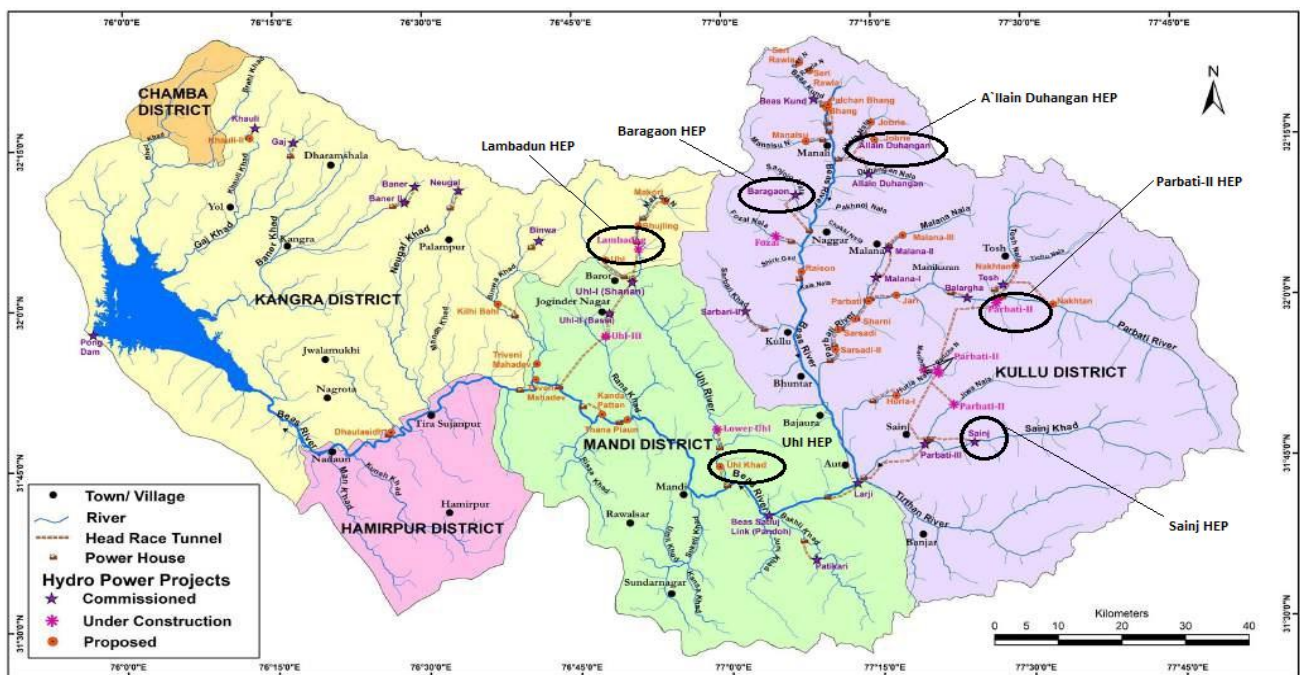


Figure 2. Study area in Beas Basin of Himachal Pradesh

Table 2. Salient features of six hydropower projects under study

Salient Features	Small Hydropower Projects			Large Hydropower Projects		
	Baragaon	Uhl	Lambadug	Sainj	Parbati-II	Allain Duhangan
District	Kullu	Mandi	Kangra	Kullu	Kullu	Kullu
Name of the River	Sanjoin Nala & Bijara Nala	Uhl River	Lambadug Khad	Sainj River	Parbati River, Jigrai Nala, Hurla Nala & Jiwa Nala	Allain Nallah, Duhangan Nallah
Installed Capacity (MW)	24	14	25	100	800	192
Status at the time of Study	In-operation	Under study	Under Construction	In-Operation	Under Construction	In-operation
Type, Length and Diameter of Head Race Tunnel, m	D Shaped lined upto Springing Level, 128.00, 1.80 x 2.25	D Shaped Pressurized Tunnel, 4624.59, 2.30 x 2.30	D Shaped, Concrete Lined, 4150, 3.7	Circular, Concrete Lined, 6360.75, 3.85	Concrete lined, 31.23, 6	D-shaped, Concrete lined, 2800, 1750
Diversion Structure	Trench Weir	Raised Diversion Weir	Drop Type Trench Weir	Gated Barrage	Concrete Gravity Dam, Trench Weir	Barrage, Trench Weir
Type of Power House	Surface	Surface	Surface	Underground	Surface	Underground
Penstocks: Type Number	Steel Liner One (Main), Three (Units)	Circular, Burried One (Main), Two (Branches)	Surface -	-	-	-
Diameter, m	Main 1.35 Units 0.80	Main 2.2, Branches 1.55	2	-	-	-
Length, m	Main 1480, two units -12, one unit-6	Main 197.5 Branches 26.5	550	-	-	-
Catchment area at diversion site (km ²)	26	365 (at Barot)	197	434.33	1155; 44; 67; 120	128.90; 66.2
Number of Turbines and type	3, Horizontal Axis Pelton Turbine	3, Horizontal Shaft Synchronous	2, Vertical Francis	2, Pelton, Vertical Axis	4, Pelton, vertical axis	2, Vertical Pelton
Rated Output (MW)	8	4.67	12.5	50	200	96

more reliable and environmentally sustainable due to low transporting cost, high operating efficiency, less degradation to forest cover due to low submergence requirement (Sharma and Thakur 2017) However, diversion and subsequent drying up of perennial sources of water for RoR projects leading to change in water regime and reduction in environmental flow have severe impact on the lives of communities of the region. Many researchers like (Diduck et al 2014) and (Kumar and Katoch, 2015) have examined public perception on the RoR projects (Himdhara Environment Action Research Report 2016) brings out the impact of these projects on Beas basin. Tanveer and Rajiv Kumar et al., 2019 (Kaur and Kumar 2019) have brought out socio-economic dimensions of RoR Parbati Stage-II project in Kullu Valley of Himachal Pradesh. These studies have focussed on the environmental hazards associated with either small or large RoR hydropower projects. The present study has made an attempt to carry out public perception survey on environmental impacts of large as well as small hydropower projects.

The Ministry of Environment and Forests in India uses EIA notification 2006 as a tool to minimise adverse impact of hydropower projects on environment with installed capacity of more than 25 MW. Therefore, little concern has been shown to the adverse environmental impact of small hydropower projects. In view of the significant negative impacts of small projects (Table 3), the focus must shift to small RoR projects (Kumar and Katoch 2015). Therefore, the focus areas of the present study are:

- To carry out public perception on the impact on vital components of environment by RoR projects in Beas basin
- Obtain and collate primary data on the tangible indicators of environment from the target population
- Carry out comparative analysis of primary and secondary data pertaining to environmental impacts of large and small RoR projects
- Make recommendations based on study outcomes on the environmental sustainability of small RoR projects.

Table 3. Positive and negative environmental impacts of RoR projects

Advantages	Disadvantages
RoRs are termed as 'green energy' projects with little environmental impact because there are no green house emissions.	RoRs cause environmental impact with change and reduction in water regime affecting natural habitat, aquatic life, temperature/depth of water, and vegetation (Gleick 1992), (International Energy Agency 2000), (Kentel and Alp 2013).
These projects are sustainable and reliable since they require a small percentage of total flow to generate electricity.	There is reduction in availability of water for consumptive and irrigation purposes, water supply for dust emissions, air pollution.
The operating efficiency of RoR projects is high because their life can be roughly up to 40 years or so with low operating cost of approximately 20 % of the revenue.	Impact on crop yield pattern, horticultural produce due to reduction in sub-soil moisture with the diversion of water sources/natural springs.
As compared to large reservoir related problems like relocation of local communities, land acquisition, /compensation, reservoir related seismicity, submergence of land/forest areas, the RoRs produce electricity with small size of reservoirs.(Ibrahim et al. 2019.)	They lead to disruption of flora and fauna due to deforestation and disturbance of hill slopes, reduction in forest cover/tree felling and trampling of vegetation.
RoRs involve lesser social and economic adverse impacts as compared to reservoir based hydropower projects of equivalent installed capacity (Bhutto et al 2012).	Noise and air pollution due to blasting, excavation activities, drilling, movement and use of heavy machinery/equipment, vibration/cracks during construction activities
Electricity can be transmitted by connecting to local grid with a small percentage of transmission loss.	Depletion in traditional network of 'Kuhals' for local irrigation and impact on grinding system called 'Gharats' due to drying up of natural springs of water.

METHODS

In consonance with the objectives of present study outlined in the abstract, 'case study' approach was adopted to achieve the desired outcomes. A total of six run- of- the- river hydropower projects from Beas river basin in Kullu Dist of Himachal Pradesh were selected in various stages of construction/operation. Three large RoR HEPs and three small RoR HEPs were selected to study environmental impacts under similar environmental conditions to work out clear perspective. In addition these, some more hydropower projects in various phases of development in the region were included for the study to make the outcomes dynamic, realistic and progressive about various components of environment. The positive and negative impacts of RoR hydropower projects on the environment under study were selected from literature survey (Table 3), personal field trips, surveys and personal interaction with village representatives. The vital components of environment impacted by RoR projects which were selected for present case study are placed at Table 4. The questionnaire, as placed at Appendix-1, was designed to collect, collate and analyse the public responses. The environmental indicators were then analysed based on the data collected from same river basin. To have deeper insight into the environmental impacts of ROR projects on the tangible environmental indicators, the scope of the study was widened to factor-in more data from other RoR projects from adjacent river basins also.

Designing of Questionnaire

With an aim to obtain first hand information pertaining to the objectives of this study from the target population, a questionnaire was designed with close-ended questions. A total of ten questions were framed covering the subject matter. While designing the questionnaire due care was taken to incorporate only those vital areas of study on which the target population could provide realistic and cogent input on the basis of their experience and observation. Each questionnaire was given an alpha-numeric code. The responses from target population were recorded under three categories namely; 'Yes', 'No' and 'Can't Say'. Views of village heads were considered before framing the questions for easy understanding. The questionnaires were then translated into local language for convenience of the villagers where ever required. A probing pilot testing was carried out in smaller villages before finalising the questionnaire.

Sample size determination

The present study was carried out across 28 villages with a population of 10617 belonging to 1218 households. The method propounded by (Krejcie and Morgan 1970) was used to calculate the sample size since it is widely used formulae to determine the sample size. Their formula is given below:

$$S = \frac{x^2 NP (1-P)}{D^2 (N-1) + X^2 (P (1-P))}$$

Table 4. Tangible environmental indicators of RoR projects

Sr No.	Affected component of Environment	Causative Factors	Remarks
1	Air Pollution	Muck dumping, blasting, excavation	Dust from crushers impacts life of people and crop yield
2	Water Pollution	Spillage of oil, slurry, labour colony	Waste into water streams affects aquatic life, clean drinking water
3	Land/soil pollution	Dust, vibration, landslides, water contamination	Soil fertility, crop yield reduction
4	Noise Pollution	Blasting, crushing, use of heavy machinery	Impact on natural habitat, psychological/physiological effects
5	Flora and Fauna/aquatic life	Deforestation, water contamination	Displacement of species, depletion of water in streams
6	Crop yield pattern	Soil contamination, diversion of water regime	Social and economic impact on local communities
7	Landslides	Felling of trees, vibrations, blasting, excavation	Endangers life and property of people
8	Forest cover degradation	Forest submergence, construction activities	Soil erosion, impact on wild life and livelihood of people
9	Change in Water flow Regime	Seepage in tunnels, muck dumping, slurry	Wild life, flora and fauna
10	Environmental flow	Lack of monitoring, non adherence to mandate	Impacts crop yield, aquatic life

where:

S = required sample size

x^2 = the table value of Chi-square for 1 degree of freedom at the confidence level 0.05.

N = Population size

P = Population proportion (assumed to be 0.50 since this would provide the maximum sample size)

D = Degree of accuracy (margin of error) expressed as a proportion (assumed as 5% i.e. 0.05)

After calculating the sample size, the 'simple random sampling' technique was used to select the households to obtain their opinion as per the questionnaire.

Table 5 Gives demographic profile of the project affected villages along with the households selected to study public perception.

RESULTS AND DISCUSSIONS

On the basis of primary data collected from the project affected people and secondary data received from multiple sources, the results achieved on ten vital components which impacted the environment of the region are placed at Figure 3.

Outcomes Based on Questionnaire

The X axis shows the environmental impact indicators covered under the questionnaire on which the public

responses were sought. While the Y axis shows the percentage of project affected people saying 'Yes' to the corresponding indicator of environment.

The debris/muck disposal by the project proponents emerges as one of the most serious environmental concern expressed by the affected people irrespective of the size and scale of the project. Only 13% of the people for small projects and 18% of the people from large project affected areas indicated that the debris/muck has been disposed of properly. This leads the study to conclude that muck generated during and after commissioning of the project needs to be disposed of/dumped scientifically as per the terms and conditions agreed to by the project authorities with due regard to the environment. Mandated rejuvenation of the affected areas is often a cause of concern.

With regard to the agricultural/crop yield, almost half of the respondents (43% for small projects and 58% for large projects) brought out that the project activities have affected the annual crop yield due to low soil moisture, drying/diversion of water sources and change of water regime. A high percentage of people from project affected areas (78% for small projects and 83% for large projects) reported disappearance of various species of flora and fauna due to reduction in forest cover, blasting, noise pollution and water diversion. Many medicinal plants specific to the region/temperature used by traditional medical practitioners for various ailments have become scarce and inaccessible. Similarly natural habitats have shrunk. The respondents

Table 5. Sample survey of project affected target villages

S.No.	Name of the project	Name of the project affected villages	Village Population	Female Population	Male population	Households	Household Sample size (n)
Large Hydro-power project							
1	Parbati-II (800 MW)	Tosh	496	273	223	95	82
		Pulga	367	186	181	78	51
		Barshaini	657	312	345	98	63
		Tahuk	261	128	133	53	38
		Tulga	159	88	71	32	19
		Shilla	483	237	246	86	55
		Nakthan	265	141	124	54	35
		Ueichdhar	249	120	129	41	29
2	Allain Duhangan HEP (192) MW	Prini	972	458	514	138	92
		Jagatsukh	1738	826	912	240	121
		Hamta	102	25	76	20	18
3	Sainj HEP (100) MW	Saithan	312	154	158	57	36
		Nihaarani	63	30	33	15	14
		Dharmeda	151	74	77	27	22
		Janglaa Bihalo	61	30	31	14	10
		Manaahara	201	102	95	29	17
		Kartaah	152	72	84	31	21
Small Hydropower project							
1	Lambadug (25) MW	Polling	928	460	468	136	90
		Swar	416	204	212	63	48
		Bhujling	758	382	376	109	83
		Chherna	257	126	131	42	33
		Khadi Nalla	356	169	187	59	31
2	Baragaon (24) MW	Galoon	51	26	25	14	11
		Makot	143	89	54	29	23
		Shilha	207	94	113	41	33
		Paankot	107	49	58	22	18
3	Uhl (14) MW	Ksheri	85	44	41	19	17
		Bara Garan	620	299	321	93	76

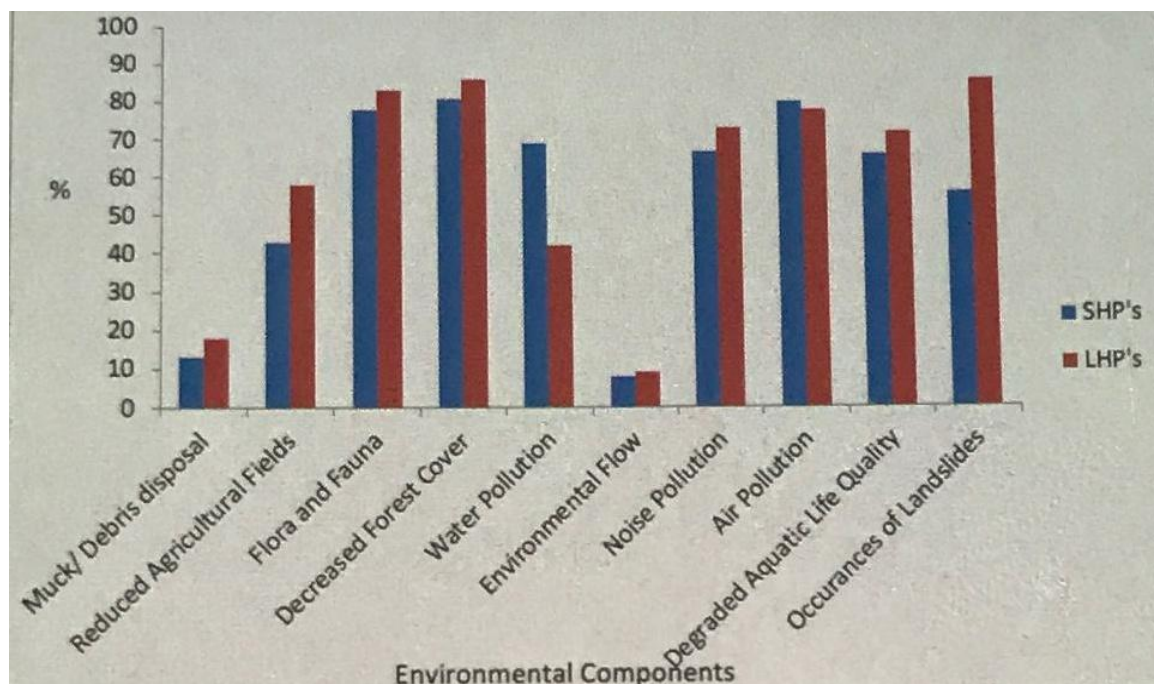


Figure 3. Study outcomes based on sample survey about impact of small and large RoR projects on vital components of environment

lamented that forest covers have reduced (81% for small projects and 86% for large projects) due to forest clearance/felling of trees and allied activities. This has impacted the livelihood of native communities as their lives are interwoven with the forests since centuries. The grazing pastures for the livestock have shrunk in size. As regards water pollution higher percentage of people for small project (69%) as compared to large projects (42%) have agreed that the indiscriminate muck disposal along water sources, polluting of water by labour colonies, dumping of slurry and domestic waste have contributed to the water pollution. Only 8% people in case of small projects and 9% of people in case of large projects were affirmative on the issue of release of mandatory environmental flow. Noise pollution due to blasting, drilling, use of heavy machinery/equipment during construction and operation phase is an inescapable environmental impact of these projects. It had an adverse impact on the natural habitat of rare species as well the inhabitants of affected villages. This fact was revealed by 67% of the respondents in case of large projects and 73% of the small projects. On the vital issue air pollution, majority of the people (80% for large projects and 79% for small projects) confirmed that dust emission, intensive movement of heavy vehicles, extensive use of diesel/petrol for construction activities, deforestation and vegetation removal has polluted the air quality. A large number of

respondents (66% for small and 72% for large projects) brought out that aquatic life has been affected due to diversion of water sources for electricity production. Lack of sensitivity on the part of project proponents towards requisite environmental flow essential for proliferation of aquatic life was brought out by the affected people. The blasting activities, earth excavation, cracks due to vibrations, laying of underground tunnels, movement of heavy machinery were cited as contributory factors leading to increase in frequency of landslides (56% for small projects and 86% for large projects). An analysis of the data on public perception indicates that the myth that smaller projects will have minimal impact on environment is not true.

Collation and Analysis of Tangible Environmental Factors

The environmental impacts as listed at Table 4 are primarily result of four tangible environmental indicators namely forest area acquired for construction of the project, the quantity of muck generated and dumped, the length of diverted reach of stream and area of land used for project development. Table 6 and Table 7 show the data collated for these four tangible indicators with respect to the large and small run of the river hydropower projects. The quantitative values of these

Table 6. Environmental Indicators of some RoR projects from Beas river basin

S.No.	Project	Installed Capacity (MW)	Environmental Indicators		
			Estimated quantity of muck (in 1000 m ³)	Length of the diverted reach (km)	Land area acquired (ha)
Small Hydropower Projects					
1	Baragaon	24	75.37	4.12	12.39
2	Lambadug	25	77.13	4.52	12.6
3	Fozal	6	41.22	2.73	1.79
4	Uhl	14	71.23	3.94	3.66
5	Palchan Bhang	9	44.11	3.5	6.35
6	Hurla Top	3.5	25.1	1	2.15
∇	Jigrai	5	29.63	2.42	2.05
∧	Balargha	9	54.21	2.5	5.37
∩	Bhang	9	49.12	3.27	2.36
	Total Value	104.5	467.12	28	48.72
	Avg Value per MW		4.47	0.267	0.466
Large Hydropower Projects ≥ 25 MW					
1	Sainj	100	1165.04	8	56.76
2	Parbati-II	800	5234	22.13	298
3	Parbati-III	520	3446.91	13	155.08
4	Allain Duhangan	192	1197.5	7.67	79.32
5	Malana-I	86	422.5	3.5	68
6	Malana-II	100	509.37	5.5	39.61
	Total Value	1798	11975.32	59.8	698.77
	Av Value per MW		6.66	0.033	0.387

Table 7. Data on Forest area used for construction of small and large RoR projects

S.No.	Name of the Project	Installed Capacity (MW)	Environmental Indicator	Mean Forest Area, ha MW ⁻¹
			Forest area acquired for other construction activities (ha)	
Small Hydropower Projects \leq 25 MW				
1	Baragaon	24	11.36	0.445
2	Lambadug	25	11.34	
3	Uhl	14	5.369	
	Total Value	63	28.069	
Large Hydropower Projects (\geq 25 MW)				
1	Sainj	100	56.763	0.369
2	Parbati-II	800	214.0607	
3	Allain Duhangan	192	132.2223	
	Total Value	1092	403.046	

indicators have been computed per MW of the installed capacity of the project. While compiling information for these environmental indicators, data from a few more HEP projects in the region has been obtained to arrive at more realistic results for the study. The study considers that the value of these environmental indicators per MW are truly reflective of environmental impacts for projects of varying scales. Earlier studies which have effectively adopted this methodology are (Bakken et al. 2012; Bakken et al. 2014).

Quantity of Muck Generated

Table 6 indicates that the quantity of muck generated in case of SHPs is 4.470 (x1000) cum per MW whereas in case of LHPs (Large Hydropower Projects) this value is 6.660 (x1000) cum. Therefore the environmental impacts associated with LHPs due to muck generation and consequent environmental impacts are higher than SHPs. During construction phase of the project huge quantity of muck/debris is generated due to excavation, blasting, adits, laying of tunnel and construction of power house etc. In addition this muck is not disposed of by the project proponents at the designated dumping sites, as mandated, due to cost factor or sheer negligence. This indiscriminate muck disposal often leads to many environmental problems such as soil degradation, water pollution due to spillage of muck and slurry into water streams, air pollution when dust is generated while dumping the muck/debris from various heights, landslides when loose muck gets washed away during rainy season.

Length of Diverted Reach of Stream

The data on environmental impacts caused by diversion of water streams in respect of SHPs is 0.267 km per

MW as compared to 0.033 km per MW in respect to LHPs. The study shows that the Large Hydropower Projects are more environmentally sustainable for this indicator as the value of length of diverted reach of the water sources is only 0.033 km per MW as compared to 0.267 km per MW in case of SHPs. The perennial water sources in this part of Himalayan region are lifeline for the survival of people, aquatic life as well as for rare flora & fauna. The diversion of these water sources for hydropower projects has adversely impacted the survival of local communities due to shortage of water, depletion of forests and reduction in crop yield. The Government authorities have mandated release of 15% discharge to the down stream for survival of aquatic life and consumptive use of water for the people of the affected areas. To ensure the release of mandated 15% of discharge, the government has introduced monitoring system of 'On line data logger' and discharge measuring devices. However the study reveals that this mandate is not being adhered to by the project proponents for obvious reasons. As the length of diverted stretch is longer in case of LHPs, there is severe environmental impact on the populace of affected areas.

Area of Land Used for Project Development

The study data indicates that LHPs are marginally more sustainable in terms of this environmental indicator of land use. The data compiled at Table- pertaining to the land area used in respect to SHPs is 0.446 ha per MW as compared to 0.387 ha per MW in case of LHPs. The land acquired by the project proponents is both forest and non forest land for construction of project related infrastructure. It invariably leads to displacement of local communities and damage to the natural habitat of forest species causing adverse environmental impact.

The compensation issue for the land acquired from local people by the project proponents often leads to prolonged protests and dissatisfaction as they are often exploited. The harm caused to the eco-system and land needs to be rejuvenated by the project authorities but this is seldom done as mandated by the project document.

Forest Area Under Submergence and Other Project Activities

The data at Table 7 shows that the forest area affected in case of SHPs is 0.445 ha per MW whereas it is 0.369 ha per MW in case of LHPs. The ROR projects invariably harness water sources in higher reaches of the mountainous region covered by forests which provide livelihood to the natives/ flora & fauna and are thus vital to the eco-system. Their depletion or degradation has severe tangible impact on the environment.

An analysis of cumulative data given above indicates that the impact on all environmental indicators collectively per MW in case of SHPs is 4.83 as compared to 6.822 for LHPs. Although damage to forest covers is significantly higher in case of SHPs i.e. 0.445 per MW as compared to 0.369 per MW in case of LHPs. The study reveals that damage caused by the small hydropower projects on the environment indicators is higher as compared to their impact on large hydropower projects barring muck generation/disposal. This finding of the study is contrary to the widely held perception that small hydropower projects do not cause significant damage to the environment hence they are environmentally more sustainable than the large hydropower projects. Perhaps that is the reason why SHPs have been kept out of the purview of EIA which needs to be reviewed.

CONCLUSIONS

Pollution of water, air and soil in the fragile Beas basin, irrespective of the scale and magnitude, has impacted the environment and thereby the lives of people residing in the region. The primary reasons of this environmental degradation have been reduction in forest cover, depletion/ degradation/ diversion of water sources, indiscriminate muck disposal, displacement of natural habitats and allied project related activities undertaken by the project proponents. A comparative analysis of the tangible environmental indicators for the large and small hydropower projects of the study area reveal that the size of the project has little to do with degree of damage to the vital environmental components. The study suggests that it would not be fair to hold on to the widely held perception that small hydropower projects

cause minimal environmental degradation in terms of environmental sustainability especially in the fragile Himalayan region. Hence there is a need to reduce the threshold limit for EIA in respect of hydropower development from existing 25 MW to 10 MW in Indian context. The untapped river basins should not be opened for hydropower development without Cumulative Environment Impact Assessment.

The change in water regime, loss of flora and fauna, depletion of aquatic life, shrinking of forest cover have a devastating impact on the lives of local communities. Hence their involvement in the decision making process from conception stage to commissioning phase of hydropower projects is essential for their sustainability. The rejuvenation of forest cover, judicious release of environmental flow is the responsibility of project proponents and monitoring agencies to make these projects environmentally sustainable.

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Appendix-1

Questionnaire

1. Has the debris/muck produced due to construction activities of the project disposed of to the designated dumping sites without causing damage to the water sources, forest tracts, grasslands, vegetation in the vicinity of project site?
2. Has the construction related activities like blasting, change of water regime, laying of underground tunnels, air pollution, removal of forest cover, land acquisition etc led to reduction in the yield of region specific crops?
3. Has there been an adverse impact /displacement/ loss of flora and fauna of the region due to deforestation, diversion of water sources, noise & air pollution during/subsequent to the project activities?
4. Has there been reduction in forest cover due to tree cutting/vegetation removal/trampling by heavy machinery, lying of roads, drying of water sources after diversion and associated activities by project proponents?
5. Has there been contamination/degradation in the quality of water due to indiscriminate disposal of waste from construction sites/crushers, workers' colonies, dumping of slurry/muck, oils and lubricant waste and sedimentation?
6. Has there been any noise pollution in the region due to blasting/drilling/digging, intensive movement of heavy vehicles/machinery for project activities?
7. Has there been adverse impact on the quality of air /air pollution due to project activities involving extensive use of diesel/petrol-run heavy machinery/equipment for excavation, drilling, blasting, transportation, use of fire wood by labour, indiscriminate muck/waste disposal?
8. Has/Had there been visible increase in the frequency of landslides in the area due construction activities of the project proponents?
9. Has there been any notable change in the aquatic life especially in diverted stretches of downstream consequent to the development of the project?
10. Has the project proponent been releasing stipulated minimum discharge of water in the rivers/ streams to sustain aquatic life and human consumption?