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Social and Environmental Impacts of a Mini-hydro Project on the Ma Oya Basin in Sri Lanka

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ABSTRACT

The protest against the severe negative social and environmental impacts of large hydropower projects made medium and minor hydro schemes a popular option. Even though mini hydro projects are usually assumed to have negligible negative social and environmental impacts, mini hydro projects can also cause such impacts, which are generally not considered at the project formulation stages.

This paper describes the application of a framework, which develops educated trade-offs between different resource uses in a river basin, to identify and quantify the social and environmental impacts of electricity generation through mini-hydro power plants. The framework is applied to a case study on a mini-hydro project at the upper catchment of Ma Oya river basin Sri Lanka. The case study identifies the social and environmental impacts of the mini hydro project through consultation of stakeholders of the area.

1 INTRODUCTION

Hydro-power is considered as the clean generation of electricity since the process cause little impacts to environment during generation when compared to the other modes of electricity generations. The magnitude of social and environmental impacts of hydro-power generation depends on the scale of the project. Major hydro-power projects invariably cause larger negative social and environmental impacts including displacement of human settlements, loss of large areas of productive land, ecological imbalances of the area etc. where as such impacts due to mini-hydro projects (MHP) are normally assumed to be minimal. Mini-hydropower projects are therefore considered environmentally friendly options when compared to some of the larger hydropower projects.

The history of small hydropower in Sri Lanka spans over a century. The early mini-hydro plants were setup in large-scale tea plantations in the central hilly regions where the colonial planters used this as the predominant source of power for their plantation needs. Most early hydropower plants provided mechanical power to factory machinery and later provided electrical energy for the motor driven process machinery (Fernando, 2001). The impacts of these hydropower plants were mostly contained within the estate.

In 1990 micro hydro plants were built for village electrification. A typical plant would consist of a small weir built across a stream that flows through the village and produced 2 to 10 kW. Over one hundred schemes are in operation at present and they are operated and managed by village level societies. The social and environment impacts of such plants were mostly limited to the village concern and the stakeholders (beneficiaries and the impacted) are usually empowered to resolve the impacts through the village level committee (Fernando, 2001).

The latest development of small hydro is as a supplier to national gird. These are commercial ventures of the private sector and the first grid connected plant was commissioned in 1994. Currently 59 MHPs are connected to the national grid with a generation capacity of 112 MW. A major difference of this type of projects when compared to the former estate owned plants is that these use public resources, both water and land, for certain parts of the project where as the former used all the resources within their private ownership. This situation results in local population being subjected to both positive and negative impacts created due to the project. Some of the issues which are ignored or not given proper attention at the project formation and construction could therefore, cause considerable social and environmental impacts in the operation phase.

The objective of this paper is to describe a framework, which is developed as a tool for developing educated trade-offs between different resource uses in a river basin, to identify and quantify the social and environmental impacts of electricity generation through MHPs. The framework is applied to a case study on a MHP at the upper catchment of Ma Oya river basin Sri Lanka. The case study identifies the social and environmental impacts of the MHP through consultation of stakeholders of the area.

2 FRAMEWORK FOR EDUCATED TRADE-OFFS

The term 'educated tradeoffs' means that stakeholders are able to engage in technically, economically and environmentally (including socially) informed (educated) decision-making between the critical resource uses/issues (trade-offs) in a river basin. The framework developed to determine educated trade-offs contains five steps as follows.

2.1 Step 1: Identify the Natural Resource Uses/ Issues that Need Stakeholder Participation

The first step identifies the Natural Resource uses/issues in a river basin, which need to be addressed through stakeholder consultation. Requirement for stakeholder involvement arises either in the development or management phases of a river basin.

In the management phase under Integrated Water Resources Management (IWRM) concept, when a natural resource becomes scarce, for example low flows during the dry months; it requires prioritizing the resource allocation. The methodology developed for identifying such uses and issues is to obtain feedback from the key personal representing the following sectors: government agencies in the river resource use sectors and administration; private sector institutions having a stake in the river resources; social, political, religious, and ethnic groups of public

On the other hand in the development phase, decisions are needed to ensure that the new project/s will not adversely affect any of the stakeholders enjoying the benefits of the natural resources prior to such implementations. In case of adverse effects, compensatory measures need to be introduced. The methodology developed for identifying such uses and issues is to survey, all present use sectors, as well as future possible developments and environmental concerns impacted by the proposed development project.

The uses and issues of the natural resources in a river valley vary spatially and temporally. Therefore, both new projects towards river basin development and all user sectors under the IWRM concept are to be evaluated at different locations for the severity of issues at a time of scarcity. Thus the uses/issues that should be considered for trade-off will be identified. Decisions with regard to limitations in critical issues and priority allocations for water consuming issues will then have to be made through stakeholder consultation using educated trade-offs.

2.2 Step 2: Bound Technical Requirements of Natural Resource Uses/Issues

Methodologies to estimate the critical bounds of the technical requirements for utilization of the different resource uses are developed in this step. The engineering knowledge is utilized to develop critical bounds. Issues dominated by water such as requirements for irrigation, human consumption, hydropower and environmental needs would have the volume of required water as the technical measure with the **minimum volume to satisfy the requirements** being the critical bound. Other river basin uses such as sand mining, clay mining and discharging of pollutants would have the volume of clay or sand extracted and volume of pollutant discharged as the technical measure with the **maximum volume not to exceed assimilative capacity of the river basin** being the critical bound.

The critical bound of the technical requirement of hydropower sector is therefore the minimum volume of water required to generate power that will meet the project break-even cost

Knowing the technical requirement, the stakeholders could be educated which uses need to be prioritized in a year that has less water. For example, in the Ma Oya basin minimum requirements for water supply would be top priority, followed by the minimum requirement for power generation and balance for irrigation in a dry year. The farmers can be compensated for the loss of livelihood as result of the minimum requirements not been met. In a good year when there is surplus water irrigation could be given as much as it could absorb and even to recharge the aquifer (Seckler, 1996).

2.3 Step 3: Estimate the Economic Value of the Critical Bound of the Technical Requirement of Natural Resource Uses/Issues

Methodologies to estimate the upper/lower bounds of the economic values of different resource uses are developed in this step. For uses/issues dominated by water such as requirements for irrigation, human consumption and environmental needs, the **economic value is equivalent to the value of the volume of water required to satisfy the minimum water requirements**. For other river basin uses such as sand mining, clay mining (Ranasinghe, 1997) and discharging of pollution the economic value is equivalent to the **maximum volume of the damage not to exceed the assimilative capacity of the river basin (or the replacement value)**.

Knowing the economic value of the minimum water requirements, stakeholders could be educated which uses/issues need to be prioritized in a year that has less water. Even though the minimum irrigation water requirement in a river basin is larger than that required for human consumption in terms of the volume of water, the economic value of the lower human consumption requirement would be very much larger. The value of the farmers' compensation for the loss of livelihood as result of the minimum requirements not been met can now be determined. It is speculated that this economic analysis will show that the bounds in terms of economic value would be largest for human needs while smallest for irrigation. This also highlights that a water requirement analysis done from a technical (engineering) viewpoint alone would not reflect the true economic value of the resource use.

2.4 Step 4: Estimate the Environmental Value of the Critical Bound of the Technical Requirement of Natural Resource Uses/Issues

Implementation of a new project or prioritizing a resource allocation could cause imbalance in the existing system and create social and environmental impacts on other users. Valuations of such impacts as environmental and social costs (benefits) are carried out at this step. It must be noted that net environmental costs referred to here are those which are either 'not quantified' or 'underestimated' in the economic analysis as part of normal engineering practice.

All of the environmental benefits and costs of impacts valued in constant value terms become line items in the economic analysis. The net present value of the environmental costs (EnvioPV) can then be obtained as;

$$EnvioPV = \sum_{i=0}^{n} \frac{E_i}{(1+r)^i}$$

Where E_i is the net environmental costs of the resource uses in the i^{th} year, 'n' is the duration of the study period and r is the discount rate.

As suggested by Ranasinghe (1994), the present value of environmental costs of the next best alternative (i.e. externalities of the alternative that is not adopted) is considered to be environmental benefits of the preferred alternative due to the avoided environmental costs.

The economic costs and net environmental costs are separated in order to focus on environmental costs and benefits. As recommended by Pearce and Warford (1993), present value of the *E*s is construed to be a cost, but in a number of cases *E*s may well be a benefit. Economists use a range of primary and secondary valuation methods to assign value to environmental impacts.

2.5. Step 5: Estimate the Net Value of the Critical Bound of the Technical Requirement of Natural Resource Uses/Issues by combining Economic and Environmental Values

The combined bounds would be in terms of economic values. Again, for issues dominated by water such as requirements for irrigation, human needs and environmental needs, the economic value to satisfy the minimum water requirements will be the critical bound. For issues dominated by other river basin uses such as sand mining, clay mining, and discharging of pollution, the maximum economic value of damage to exceed assimilative capacity of the river basin (or the replacement value) will be the critical bound.

The combined value of the technical bound thus can be estimated as;

$$CombNPV = \sum_{i=0}^{n} \frac{B_i - C_i}{(1+r)^i} - \sum_{i=0}^{n} \frac{E_i}{(1+r)^i}$$

Knowing the total economic value of the technical requirement at the critical bound would help stakeholders to be educated which issues/uses need to be prioritized in a year that has less water. It is speculated that minimum human requirements would be the top priority from economic values, followed by the environmental requirement for fauna and the least for irrigation.

3 CASE STUDY

The Ma Oya river origins in the central hilly regions of Sri Lanka around Aranayake, Bible rock and Kadugannawa and flows to the Indian Ocean through north western Sri Lanka. The river drains a catchment area of 1528 km^2 along its total length of 130 km. It flows through the Kegalle district at upper reaches and acts as the boundary between Kurunegala and Kegalle Districts in its mid reach, thereafter as the boundary between Kurunegala and Gampaha Districts. The right bank of the final reach of the river forms the Southern Boundary of the Puttalam District and flows into sea at Kochchikade. It picks up 21 tributaries of which Rambukkan Oya, Talagolla Oya and Hingul Oya are the main ones.

Annual average rainfall of the Ma Oya basin is 2219mm based on the 1961 – 1990 data (DHI, 1999). The monthly average rainfall varies significantly with low values occurring in the months of January, February, June, July and August. The basin covers five agro-ecological regions and the land use of the upper river basin is mainly characterized with paddy, rubber and mixed crop cultivations. The mountainous terrain is usually covered with forest and tea plantations.

Upper catchment of river Ma Oya is characterized with steep mountain slopes. The first major water fall of the river, Asupiniella, is in the upper parts of Aranayake Divisional Secretary area in the Kegalle district. This is a major tourist attraction point in the area. There are three mini-hydro power plants in operation at present on the main river and its tributaries in the upper catchment where power generated at all three plants are sold to the Ceylon Electricity Board.

The study was made in the Arama Grama Niladhari division where one of the mini-hydro plants is located on the main river down stream of Asupiniella. The installed capacity of the power plant is 4 MW out of which the present generation capacity allowed is 1.3 MW until the grid connection line is completed (CEB, 2007)

The Grama Niladhari division consists of 326 families. The direct impacts of the hydro-power plant, access road, and the grid connection is felt by about 20% of the population while the indirect impacts are felt by the majority in the area.

4 METHODOLOGY

The methodology adopted to apply the framework described above consisted of two stages.

Stage one - The objective was to obtain information required for the Step 1 of the framework. This was mainly achieved through a preliminary questionnaire survey. This survey was carried out in the GN divisions along the river, on both banks, in order to identify the natural resource user sectors, issues and conflicts of such resource uses and the stakeholders. At each GN division 3 to 5 persons were utilized to have a representative sample of the GN division.

The Steps 2 and 3 of the framework are already carried out by the hydropower developer. The maximum and minimum design flows required to generate the estimated power are 2.7 m^3/sec and 0.27 m^3/sec respectively. The internal rate of return on equity for the project was estimated at 23%. (Nividu, 2001)

Stage two – the objective at this stage was to identify and quantify the social and environmental impacts due to the project as required by the step 4 of the framework. A detailed questionnaire survey of the area is carried out to obtain this data. The questionnaire was based on the flow chart given in Figure 1. In addition, the representatives of the hydropower developer and the other relevant resource uses were also interviewed.

5 DATA ANALYSIS

5.1 Stage1: Preliminary survey

At the preliminary survey the stakeholders of the GN divisions on both banks of the upper catchment area and other resource developers identified the following positive and negative social and environmental impacts with regard to the hydropower generation sector.

- Increased felling of trees in the upper catchment due to easy access
- Flash floods
- Water scarcities due to drying up of springs used as water sources for domestic needs
- Illicit brewing of liquor
- Water shortages for irrigation
- Environment pollution due to increased numbers of local tourists
- Reduced environment flow between the intake and the outlet affecting the flora and fauna of the jungle in the vicinity
- Power house access road facilitating increased numbers of tourists
- New livelihoods in the area

5.2 Stage 2: Detailed survey

The detailed survey involved 24 families from the Arama Grama Niladhari division. Each family was represented at the survey by either the male or the female adult of the family. The gender distribution of the sample, male: female ratio was 10: 14. These 24 families belonged to the category who felt the direct impacts of the project. Of them 18 families use the access road to the powerhouse. Others are impacted due to the transmission line, supply of earth for road construction and through their activities with irrigated paddy fields. Their background and age group distributions are shown in Figures 2 and 3.

23 (96%) out of the 24 respondents have the ownership of the house they live in. The other person lived in a house owned by his mother. Figure 4 gives the personal and family incomes of the respondents. 15 (62.5%) families belong to the category with a family income less than Rs.10,000/- month. There were only two families in the category of monthly income of over Rs. 20,000. One of them was a government employee and the other owned a small scale rubber plantation.

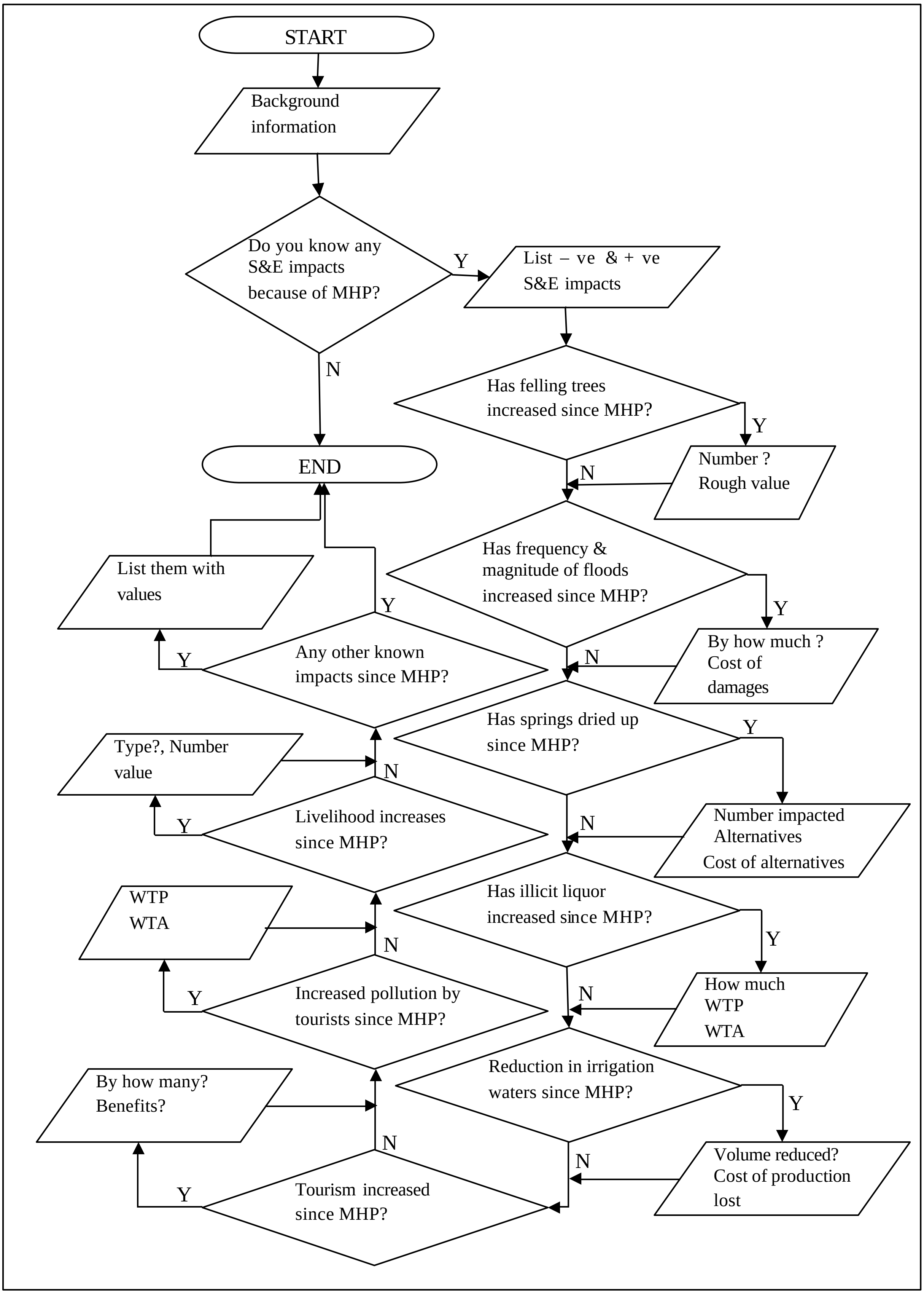

Figure 1: Flowchart for the questionnaire

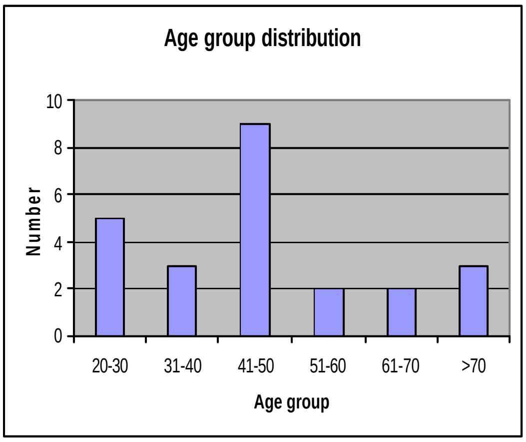

Figure 2: Age group distribution of respondents

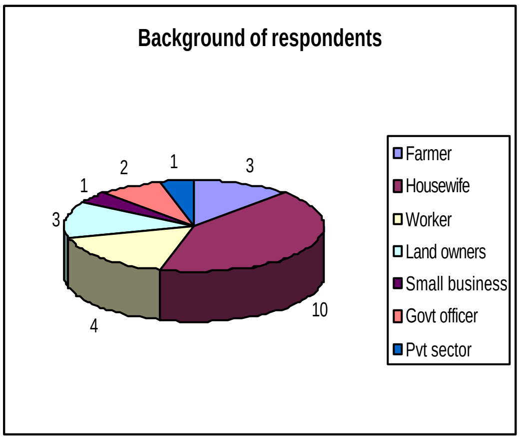

Figure 3: Occupations of respondents

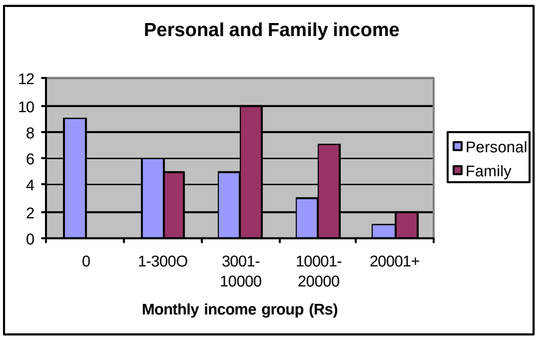

Figure 4: Personal and family income of respondents

Table 1: Stakeholder numbers according to Interest vs. Influence

Interest / Influence	5	4	3	2	1	Total
5	0	0	0	0	0	0
4	1	0	0	0	0	1
3	2	3	1	0	0	6
2	0	0	3	0	0	3
1	1	2	4	2	5	14
Total	4	5	8	2	5	24

Table 2: Stakeholder numbers on Influence vs. Positive Impacts

Impact / Influence	5	4	3	2	1	Total
5	0	0	0	0	0	0
4	1	0	0	0	0	1
3	1	1	1	1	2	6
2	1	2	0	0	0	3
1	1	4	4	4	1	14
Total	4	7	5	5	3	24

Table 3: Stakeholder numbers on Influence vs. Negative Impacts

Impact / Influence	5	4	3	2	1	Total
5	0	0	0	0	0	0
4	0	0	0	0	1	1
3	1	2	1	1	1	6
2	0	2	0	0	1	3
1	1	2	1	3	7	14
Total	2	6	2	4	10	24

Stakeholder Interest, Influence and Impacts

Table 1 gives an analysis performed on the interest of the stakeholders on the hydropower development and influence they could made on decision making with regard to the sector. Both interest and influence were requested on five point scales as indicated below.
5- High interest 4 - Good interest 3- Average interest 2- Little interest 1 - No interest
5- High influence 4 - Good influence 3- Average influence 2- Little influence 1 - No influence

This analysis indicates that there is only one stakeholder above the average influence category. He is of the view that he has a good influence on the project decisions with regard to the resource uses. Out of the 14 who do not have any influence 7 still have an interest above average. They are the people who are still hopeful of the promises made by the developer.

Both positive and negative impacts felt by the stakeholders were analyzed on a five-point scale (as indicated below) together with the influence they possessed (See Tables 2 and 3).
5 - High impact 4 - Good impact 3 - Average impact 2 - Little impact 1- No impact

All respondents claimed that they are aware of either good or bad impacts due to the mini-hydro power plant. Table 4 shows the number that agreed with different impacts identified at the preliminary survey due to the MHP as positive or negative. Increase in flood occurrences or magnitude as well as water shortages for flora and fauna was not considered by anybody. Table 5 gives the additional impacts identified at this stage together with the number of stakeholders agreeing with such impacts.

Table 4: Number of stakeholders accepted positive and negative impacts.

Item	Social/environmental Impact	+ve impact	-ve impact
1	Cutting trees		12
2	Increase in floods		0
2	Water scarcity due to drying up of springs		3
3	Illicit brewing of liquor	2	2
4	Shortage in irrigation water		3
5	Environment pollution by tourists		4
6	Water shortages to flora and fauna		0
7	Access road facilitating increase numbers of tourists	18	
8	New livelihoods in the area	9	

Table 5: Additional positive and negative issues/events identified and the frequency of identification

	ISSUE/EVENT	Number	Frequency
1	Promise to supply electricity is not honoured	4	17%
2	8% ETF is not paid back	2	8%
3	Promise of permanent employment after the project not honoured	4	17%
4	Lost land for access road	8	33%
5	Promise to build the house not honoured /(house area is reduced)	2	8%
6	Not paid for earth burrowed	2	8%
7	Environmental impacts due to high voltage line	2	8%
8	Compensation promised for land not honoured	2	8%
9	Damages to the house	2	8%
10	Supplied earth free for the road	2	8%
11	Wrong alignment of the road	1	4%
12	Ordinary people are not allowed to go beyond PH	1	4%
13	No compensation for cash crops (pepper etc.) destroyed	2	8%
14	Reduced flow in the river at times	1	4%
15	Promise to rehabilitate the anicut and canal bank not kept	1	4%
16	Widened road affect the bunds of the irrigation main canal	2	8%
17	Increased pollution /unacceptable behaviour by tourists	6	25%
18	Improved transport facility (Access road)	14	58%
19	Increase land value Rs. 25000 -300000 per Acre	2	8%
20	Build the boundary wall (one dissatisfied)	3	12.5%
21	Sold land for powerhouse	1	4%

A major positive impact stated by 9 (37.5%) respondents is the new employment created by the developer of the project. The data collected show that 10 -20 employments have been created either in this project or in some other projects with a monthly income ranging from Rs. 8000/- to 20,000/-.

Another positive impact is the land value increase by about 12 fold (from Rs. 25,000/- per acre to 300,000/-) due to the access road.

While only two respondents agreed that illicit felling of trees has increased after the MHP, 8 denied. However 13 (54%) people agreed that cutting trees on ones own land has increased due to access road and also as a requirement for grid connection power line. The trees include cash crops such as coconut, Coffee, cardamom as well as trees with timber value such as Jak, Lunumidella and Mahogany. Some people have received compensation for the trees according to the valuation by the GN. Usually these valuations are based on the timber value and not on the production value. (for example a coconut plant is valued at Rs. 200/- where as this is only about four months income – 20 nuts @ Rs.10). At present compensations are being paid to the people who lost trees due to the grid connection line. Majority who had given their lands to the powerhouse access road claimed that neither had they requested compensation nor compensation paid for their land. People valued their loss between Rs. 500 – Rs. 20,000

13 persons responded to the question on the illicit liquor brewing agreed that there is no increase in this sector. In fact some of them thought that the industry is now reduced as the MHP access road facilitate police flying squads. However, 2 persons agreed that there is an increase in this sector.

Estimates for number of tourists visited the water fall (As upiniella) before the MHP varied between 15 and 500 with an average of 250 per year. These visits are made in the dry season and mostly on the Independence Day (4^{th} February). While people agree that there is an increase in the number of tourists (to 2000 -3000) just after the construction of access road now it is noted that there is a decline. The local stakeholders do not have any positive impact due to the visits by the tourists but experience a negative impact due to the pollutions caused by dumping waste (empty glass bottles, tins etc.) by them. Three respondents have expressed a willingness to pay value between Rs.100 – Rs. 500 per month for durations between 2 to 12 months in order to evade the impact due to pollution.

Only one person stated that there is a shortage in irrigation water supply with an estimated loss of Rs. 6000/- per year. This response was doubtful as were no other evidence to prove this and also the diversion weir for irrigation is located downstream of the powerhouse outlet.

The major negative impacts were the breaches of confidence the local stakeholder by the developer. The promise to supply electricity to the peasants living in the vicinity and along the final 200 meters of the access road has not been kept. One person has obtained the electricity connection at a cost of Rs. 80,000/- on his own. In two occasions the promises made to rebuild the houses that were affected due to the access road has not been kept Both parties were poor and non-influential. Most of the people have not requested for compensation for the land acquired for the road. Developer has paid compensation only for few people and the basis for such payments is not known by the people.

The payments made to the labourers hired from the area during the construction have been comparatively less. The promises to provide with labour employment after the projects have also not been kept. Those who worked have contributed to the EPF (8% of the salary) are not been issued with necessary documents for reclaims.

Three persons agreed that there is a shortage in drinking water due to drying up of springs. Majority of the people were unable to respond as they were supplied by a community water supply scheme even before the MHP plant was commissioned.

The intake of the Hemmathagama water supply scheme is situated down stream of the intake weir of the power house. The officials of the National Water Supply and Drainage Board claims that the agreement between the two developers to give priority to water supply sector at water scarcity situation is not being honoured by the power generation developer even at the present power generation level of 32.5%. Due to this fact the water supply developer is unable to store water as required by the purification process.

6 DISCUSSION

The discussion is focused on the social and environmental impacts caused by a resource development project (a mini-hydropower plant selling its power to the national grid) whose direct benefits are external to the population in and around the project location.

All respondents were permanent residents of the area as they lived in their own houses either inherited by their parents or bought by them. Only 2 (8.3%) of the respondents had a family income of more than RS 20, 000. Hence the vast majority in the area belong to the low income group. Out of the two respondents who were government employees, only one come under the directly impacted group. As such, 18 households out of 21 in the direct impacted area which are mainly the lands along the access road to the power house, could be categorized as low income families. The stakeholder analysis for influence shows that 17 are in the categories of "little" and "no" influence.

The study showed that only a minority (0-4) of respondents of the detailed study agreed most of the negative impacts identified at the preliminary survey. The two identified negative impacts agreed by a larger group were the waste disposal by tourists (6 persons - 25%) and felling of trees (12 persons - 50%).

The major positive social impact of the project to the people in the area is the widening and reconstruction of the powerhouse access road. A majority of the stakeholders has not claimed compensation for the land used for the road as a gesture of goodwill towards the developer who had promised them permanent employment, restoration of houses affected during road construction and supply of electricity to the village. 16 (66%) has indicated very high to average positive impacts mainly because of the access road.

However 10(41%) have indicated very high to average negative impacts because of the breach of promises made by the developer on employment, reconstruction/ restoration of affected houses, non-issuance of documents for Employee Provident Fund (EPF) deductions of the laborers employed at the time of powerhouse construction,

The developer being the powerful stakeholder in this case has created an unexpected social impact on the non-influential, non-beneficiary population of the area. Generally these types of social impacts are not reported under environment assessments of hydropower projects.

We do not believe that this scenario is an exception in mini-hydro project development. The social impact is created when the influential stakeholder disregards the concerns and welfare of less influential stakeholders of the project. Therefore it would be prudent for developers to take note of the significant social impacts that is caused when promises made freely to achieve the developers objectives are not fulfilled after the completion of the project.

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