

Community Agreement on Social and Environmental Impacts of Mini Hydro Power Generation: A Case Study

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Abstract

Renewable energy sources are promoted under the Sustainable Development Goals. In Sri Lanka, the currently harnessed renewable energy sources include about 350 MW of mini hydropower plants developed by private investors. This case study attempts to establish views of the public living in the neighbourhood of a mini hydropower plant on the social and environmental impacts during the construction phase and the operation phase. This power plant belongs to the category “mini hydropower developed by private sector investors and supplying to the national grid”. The study uses a literature survey and a questionnaire survey on a sample of the neighbouring villagers to collect data. Inferences were drawn, at 5% level of significance, on the views of the population using statistical methods. It is found that in this case study, the majority of the public (i.e., over 50% population) agree that there are positive impacts by mini hydropower plants such as generation of new employment, and further agree that some of the major negative impacts discussed in some other cases are not experienced by them.

Introduction

Sri Lanka has a capacity to generate 1,740 MW of electricity through hydropower. This includes 350 MW of capacity in small power plants owned by the private sector. Further, it is claimed that the contribution to the national electricity generation by the new renewable energy (NRE) had been 11% of energy in 2017. Out of this, 59% was from 182 mini hydropower plants (MHPs) [1]. With new power plants built, the MHP capacity by 2020 increased to 410 MW across 208 power plants.

Renewable energy sources are being promoted under sustainable development goals (SDGs). Limitations that may be imposed on fossil fuel power plants have resulted in examining hydropower generation with a renewed

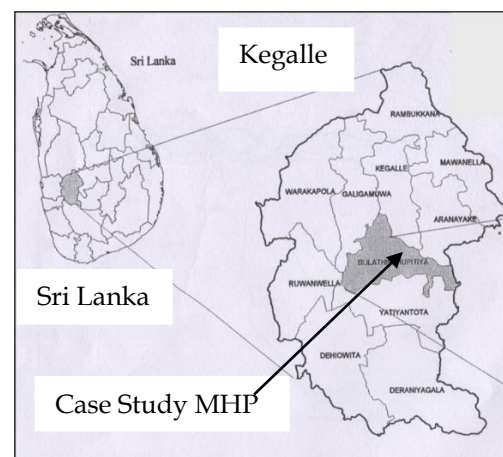
interest [7]. Although hydropower is expected to be clean energy, it has not always been green energy, as literature reports several social and environmental impacts of hydropower generation specially in large scale power plants. Conversely, MHP projects are considered to have lower impacts and can be considered as green energy as well.

In this background, this paper attempts to contribute to the sector by presenting outcomes of a case study on the community agreement or disagreement on social and environmental impacts, which is important for the development as well as sustainable existence of MHP projects.

Case Study

The hydro site in this case study is in the Sabaragamuwa province of Sri Lanka in Kegalle District. The location depicted in Figure 1 comes under Lower Gangaweraliya Grama Niladhari division of the Bulathkohupitiya Divisional Secretariat.

Figure 1: Location of the MHP [5]

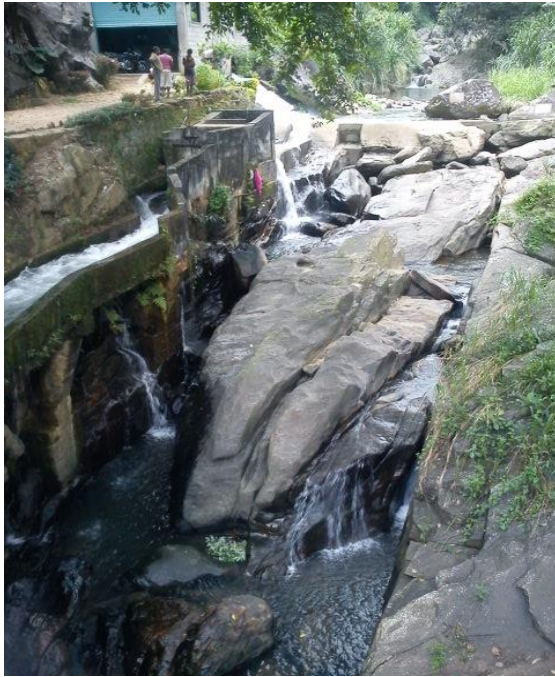


The MHP is of run-of-river type without pondage. The source of water is 'Ritigaha Oya' stream which is a medium sized tributary on the right bank of Kelani River. Consultants to the project, [5] claim that the catchment area is narrow and elongated with a rapid run-off

response due to its smaller area and the relatively steeper slopes. Tea plantations and forests predominantly cover the catchment. Further, at the time of feasibility studies, no other significant water use or users had been identified upstream of the weir.

The feasibility study identifies a stream flow of 650 l/s and 63.5 m gross head available at the site, which permitted the construction of a MHP plant of 300 kW capacity. The MHP plant had been in operation since 2010. It provides electricity only to the national grid. It is connected to the national grid at Dedugala tea factory with a 1-km long transmission line. Figure 2 illustrates the weir location with the canal delivering diverted water to the MHP.

Figure 2: Weir Location with the Canal delivering Diverted Water



Methodology

Although hydropower is considered to be a clean and green energy source in comparison with fossil fuels, they too have their own impacts on the public and the environment. Literature provides evidence of such impacts, and illustrate remarkable differences between large and small hydropower projects in the nature of such impacts. Further, these impacts can be divided into 2 categories: the construction phase and the operation phase.

This study commenced with a literature review to prepare a list of social and environmental impacts identified in other studies on MHPs. Some of the identified impacts were specific to off-grid connections and they were left out to develop a list of impacts which can be considered for this case-study on a grid connected MHP project. The list of impacts was enhanced with the additional impacts revealed at a pilot study conducted prior to administering the final survey.

These impacts were arranged on a questionnaire as statements eliciting the agreement on each statement by the respondents on a 5-point Likert scale. The questionnaire was used as the instrument in a survey among the villagers in the neighbourhood of the MHP plant. Impacts were then categorised as positive and negative, and the time they occurred: construction phase or operation phase.

The main objective of this analysis was to identify social and environmental impacts of the MHP, both at the construction and operation phases, to which respondents agreed or disagreed. The analyses use percentage calculations and Relative Important Index (RII) as a statistical tool to rank the sample agreement on the identified social and environmental impacts of the MHP. Further, the impacts with higher rates of agreement or disagreements were subjected to hypotheses tests to develop the percentage agreement by the community.

Relative Importance Index (RII)

Relative Importance index is widely used in research work as a tool for ranking the factors to identify the most significant factors [4]. Therefore, to identify the social and environment impacts on which there is highest agreement or disagreement, data obtained through the questionnaire survey were analysed using RII. First the data obtained through the questionnaire survey were transformed to importance indices using equation 1 [6],

$$RII = \frac{\sum_{i=1}^m W_i * n_i}{A N} \dots \dots \dots (1)$$

Where, W_i is the weighting given to each statement by the respondents (ranging from 1 to m scale points), n is the number of responses at a particular Likert scale point, N is the total number of respondents and A is the highest weight (5).

Hypothesis Testing

Responses received on the 5-point Likert scale can be converted to dichotomous responses (agreed/not agreed or disagreed/not disagreed) so that the responses will form binomial distributions.

All hypotheses were tested with a 95% level of confidence. The statistical theory on which the computations were based is as given below.

Let p - probability of 'agreement (or disagreement) to a given statement'

$$H_0: P_1 = p$$

$$H_1: P_1 > p$$

$$P' =$$

$$\frac{\text{Total counts of agreement (Likert points 5 and 4)}}{\text{sample size}} ;$$

$$q = 1 - P'$$

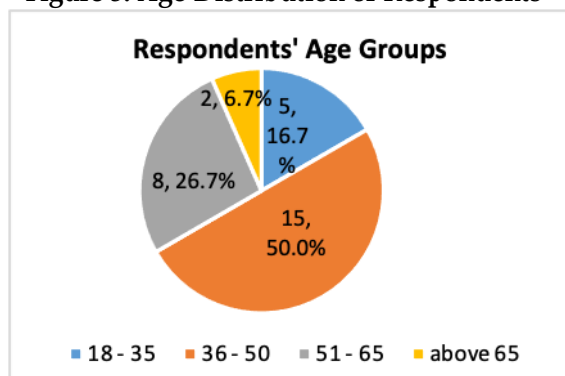
$$Z = \frac{(P' - p)}{\sqrt{\frac{pq}{n}}}$$

If, $Z_{\text{calculated}} > 1.645$ (table value at $\alpha = 0.05$), reject the null hypothesis.

Data Collection and Analysis

The survey was conducted among 30 villagers residing in the proximity of the MHP. The questionnaire was administered in face-to-face mode, which resulted in a 100% response rate. Figures 3, 4, 5 and 6 present the percentage analyses of the demographic factors of the respondents.

Figure 3: Age Distribution of Respondents



The majority (76.6%) of the respondents are middle aged and most of them are well educated (83.3% with secondary and tertiary education.) Further, their monthly household incomes are comparatively higher with around 96% being employed. This background suggests the respondents have an appreciable knowledge regarding the social and environmental impacts of MHP generation.

Figure 4: Household Income Distribution

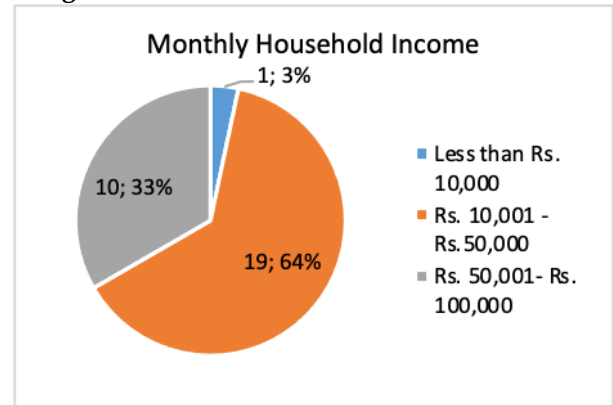


Figure 5: Education Levels of Respondents

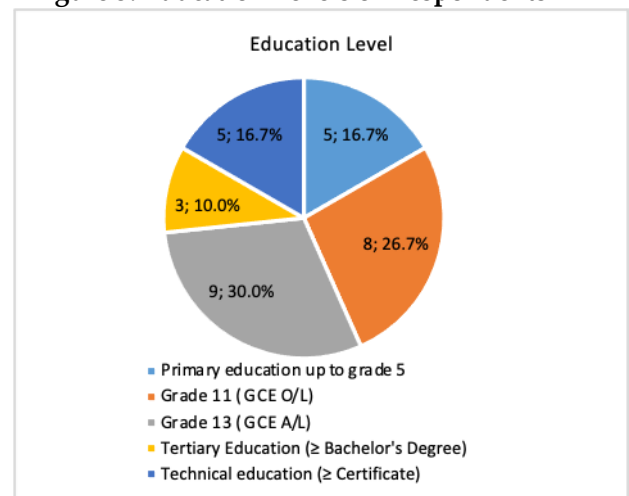
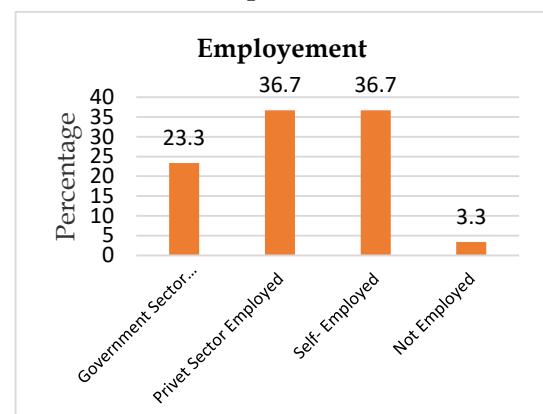


Figure 6: Employment categories of Respondents



Furthermore, views of respondents can be considered to be independent as they were neither employed at nor dependent on the MHP. Therefore, the demographic data allows considering the responses of these thirty (30) persons with high reliability.

Social and Environmental Impacts Identification

Table 1 gives the eight case studies found in the literature review and indicate some social and environmental impacts of MHPs around the globe [3].

Table 1: Social and Environmental Impacts of MHP projects

Case	Capacity	Author
Pakistan	50 kW, 25 kW	Amin et al., 2018
Sri Lanka	4 MW	Thoradeniya et al., 2007
Nepal	100 kW	Gurung et al., 2011
Andean Bolivian	1-70 kW	Gonzalez et al., 2019
Norway	1 -7 MW	Bakken et al., 2012
Ethiopia	NA	Demissie and Somano, 2016
Turkey	0.5-25 MW	Baskaya et al., 2011
Nepal	16 kW	Adhikari, 2014

Additionally, the pilot survey carried out helped to identify a few more impacts [2]. The total relevant social impacts identified through literature and during the pilot study are illustrated in Table 2 while the environmental impacts are illustrated in Table 3 with their nature and the phase of occurrence; Construction (C) or Operation (O).

Table 2: Social Impacts with their Nature (N) and Phase of Occurrence (P)

	Impact	N	P
S1	Villagers earn profit from land sales to MHPs.	+	C
S2	Removing trees (perennial crops such as coconut) for construction affect the economy of people who live in the area.	-	O
S3	Excavation work for weir construction caused turbidity in stream water used by people downstream for daily requirements.	-	C
S4	Disturbance to villagers owing to explosions of rock for weir construction.	-	C
S5	Road network of the area is	-	C

	damaged due to heavy vehicles used in the construction process.		
S6	Construction activities of MHP creates new job opportunities.	+	C
S7	Villagers' daily life is disturbed due to noise from turbine operations.	-	O
S8	New job opportunities are created due to operation and maintenance of MHP project.	+	O
S9	People's knowledge about hydropower generation is developed.	+	C
S10	Lighting conductors of MHP plant help to provide safety environment.	+	O

Table 3: Environmental Impacts with their Nature (N) and Phase of Occurrence (P)

	Impact	N	P
E1	Felling of trees for the construction of MHP cause soil erosion.	-	C
E2	Underground water sources dry up due to felling trees for construction activities.	-	C
E3	Construction of MHP affects natural beauty of the area.	-	C
E4	Disturbs biological processes in the stream and the surrounding area between the intake and outlet of the MHP, due to drying up of water streams.	-	O
E5	Bird strikes and electrocutions at transmission lines.	-	O
E6	Increased landslides in the area due to felling of trees and removing vegetation for plant maintenance.	-	O
E7	Created environmental problems due to felling trees for maintaining secure transmission lines.	-	O
E8	Created environmental issues from sedimentation by the dam for water diversion.	-	O

Questionnaire Survey on Social and Environmental Impacts

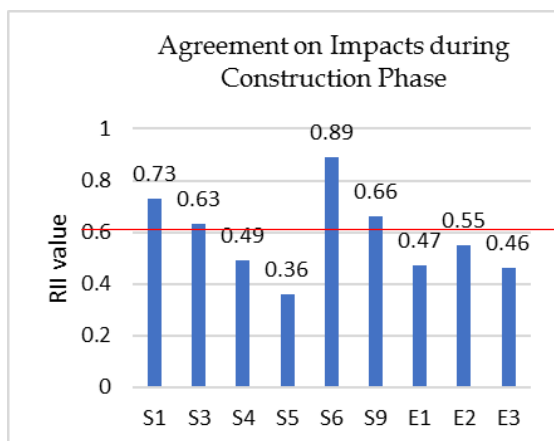
The above 9 impacts at the construction phase and the 9 impacts at the operation phase were presented to the survey sample as statements in a questionnaire. Respondents were requested to indicate their agreement for these statements on the following 5-point Likert scale.

- 5 - Strongly agree
- 4 - Agree
- 3 - Neutral
- 2 - Disagree
- 1 - Strongly disagree

Ranked Impacts

Responses received for the impacts were then ranked using RII method (Equation 1) to identify impacts on which respondents mostly agreed. Figure 7 shows the results of RII analysis with the RII value for each impact at the construction phase. It should be noted that the value range of RII for the selected 5-point Likert scale varies from 1.0 to 0.2. Hence, the mean value of RII is 0.6, which corresponds to Likert scale point 3 (Neutral). Therefore, the RII values closer to 1.0 and 0.2 show strong agreement or disagreement respectively, while RII values closer to 0.6 show the weaker agreements or disagreements.

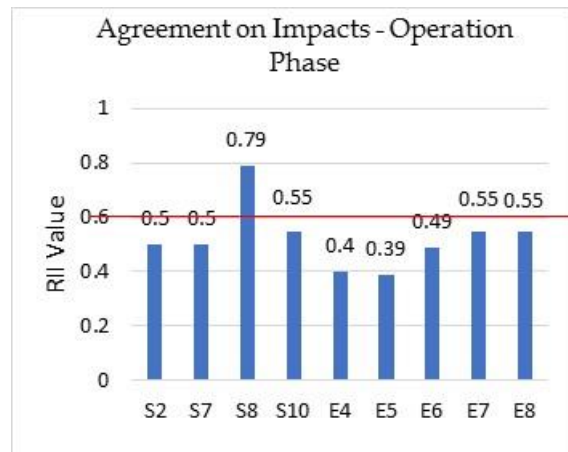
Figure 7: Agreement with Social and Environmental Impacts - Construction Phase



The analysis using RII found, S6 - generation of new job opportunities to villagers from construction activity of the MHP (RII=0.89), S1 - villagers' ability to earn profits by selling land for MHPP (RII=0.73), S9 - the knowledge they developed about hydropower generation (RII=0.66) and S3 - excavation work for weir construction caused turbidity in stream water used by people for daily requirements (RII=0.63), are the four social and environmental impacts at construction phase that were mostly agreed on by respondents. Of these, the first three impacts affect the villagers positively while the fourth impact affect negatively.

Figure 8 illustrates the results of RII analysis with the RII values of impacts obtained for the operation phase of the MHP.

Figure 8: Ranking of Social and Environmental Impact - Operation Phase



The RII analysis in Figure 8, S8 - Generation of new job opportunities to villagers for operation and maintenance of MHP plant, is the impact ranked number 1 (RII= 0.79) in the operation phase. For this statement, 8 respondents voted 'strongly agree' and 16 voted 'agree', which means generation of new job opportunities to villagers for operation of the plant has extremely high agreement by the respondents. Similarly, environmental impacts, E5 - bird strikes and electrocutions with transmission lines (RII=0.39) and E4 - disturbed biological process between intake and outlet of MHP plant due to drying up of water stream (RII=0.4) are clearly disagreed by respondents.

Hypotheses Analysis for Binomial Distributions

The impacts on which the respondents marked their highest agreement and disagreement were subjected to hypothesis analyses to establish their applicability to the population. Responses received on 5-point Likert scale is converted to Binomial distributions ('Yes' or 'No' responses) in two stages.

In the first stage, impacts with prominent agreement or disagreement counts ($n > 20$) were selected and their Likert scale responses were bundled into three groups (Table 4).

- Group 1 - Agreed (Sum of counts at Likert scale points 5 and 4)
- Group 2 - Neutral (Counts at scale point 3)
- Group 3 - Disagree (Sum of counts at Likert scale points 2 and 1)

Table 4: Bundled Counts of Impacts

Statement	Agree	Neutral	Disagree
Construction Phase			
S1	22	3	5
S5	2	4	4
S6	25	3	2
Operation Phase			
S8	24	2	4
E4	4	5	21
E5	2	6	22

In the second stage, the total dichotomous response required (i.e. Yes/No) to calculate P' was arrived at by further collating the 'Neutral' counts with the other two counts as indicated below.

Agreed statements:

Yes = Count of Group 1;

No = Count of Group 2 + Group 3

Disagreed statements:

Yes = Count of Group 3;

No = Count of Group 1 + Group 2

Tables 5 and 6 illustrate the six hypothesis statements framed for the impacts having higher agreements or disagreements at the two phases

Table 5: Framed Hypothesis (Construction)

Ref.	Null and Alternative Hypothesis
S1	H ₀ : At least 60% of the population agree that villagers earn profit from selling land for MHP. H ₁ : More than 60% of the population agree that villagers earn profit from selling land for MHP.
S5	H ₀ : At least 65% of the population disagree that the road network of the area was damaged due to heavy vehicles used in the construction process. H ₁ : More than 65 % of the population disagree that the road network of the area was damaged due to heavy vehicles used in the construction process.
S6	H ₀ : At least 70% of the population agree that the MHP generated new job opportunities to the villagers during its construction period. H ₁ : More than 70% of the population agree that the MHP generated new job opportunities to the villagers during its construction period.

Table 6: Framed Hypothesis (Operation)

Ref.	Null and Alternative Hypothesis
S8	H ₀ : At least 65% of the population agree that the MHP generated new job opportunities to villagers during its operation. H ₁ : More than 65% of the population agree that the MHP generated new job opportunities to villagers during its operation.
E4	H ₀ : At least 55% of the population disagree that the biological process between intake and outlet of MHP are disturbed due to dried up of water stream during the operation of the MHP. H ₁ : More than 55% of the population disagree that the biological process between the intake and the outlet of MHP are disturbed due to dried up water stream during the operation of the MHP.
E5	H ₀ : At least 60% of the population disagree that bird strikes and electrocutions occur on transmission lines H ₁ : More than 60% of the population disagree that the bird strikes and electrocutions occur on transmission lines

The summary of the six hypotheses tested at 5% level of significance is presented in Table 7 where all null hypotheses are rejected.

Table 7: Results of the Hypothesis Tests

Ref.	P	P'	q	Z	Decision
S1	60%	0.73	0.26	1.825	H ₀ Rejected
S5	65%	0.80	0.20	2.278	H ₀ Rejected
S6	70%	0.83	0.17	2.138	H ₀ Rejected
S8	65%	0.80	0.35	2.278	H ₀ Rejected
E4	55%	0.70	0.30	2.022	H ₀ Rejected
E5	60%	0.73	0.26	1.825	H ₀ Rejected

Accordingly, within 5% significance level it is inferred that (1) 70% of the population of the area agrees that new job opportunities are generated to villagers during the construction phase (2) 65% of the village population agree to the job opportunities are created during the operation phase and (3) 60% population agree that the villagers have earned profits from selling lands to construct the MHP.

Further, 55% to 65% of the village population do not agree with the three negative impacts; (1) biological process between intake and outlet of MHP are disturbed due to dried up of water stream during the operation of the MHP, (2) bird strikes and electrocutions occur

on transmission lines and, (3) road network of the area was damaged due to heavy vehicles used in the construction process.

Discussion

The literature survey identified 18 social and environmental impacts which usually occur during the construction phase or the operation phase of MHPs. Some of them are positive impacts and the others are negative impacts to the society and the environment. Based on the data collected through the questionnaire survey among a sample of 30 villagers living in the surrounding area, the agreement or the disagreement for those impacts at the studied MHP plant were established.

The social impact at construction phase (Figure 7) that respondents highly agreed with, was the creation of the new job opportunities for villagers during the construction period ($R_{II}=0.89$). This includes incomes generated through construction activities (masons and labourers), food supply for workers, provision of food and accommodation for technical officers and hire charges earned for transporting construction material and equipment. At the operation phase too, the respondents strongly agreed on the creation of job opportunities ($R_{II}=0.79$).

The second highest agreement is received for the social impact 'Villages can earn profit from land sales' ($R_{II}=0.73$). Here the villages agree that the lands were sold at a higher price than the market price and hence it was a profitable deal for the villagers.

Normally people living in villages cannot capture knowledge about hydropower generation, but respondents selected "Developing the knowledge of people about hydropower generation in particular area" the third highest impact they agreed on ($R_{II}=0.66$), which is a positive impact during the construction stage.

It should be noted the statements which received R_{II} values below 0.5 can be considered to have disagreement from the respondents. As such, it is evident at this MHP, 2 social impacts (S4 and S5) and 5 Environmental impacts (E1, E3, E4, E5 and E6) were either not present or may have been present in negligible magnitudes, as the

majority of respondents have disagreed with their existence.

Further, 8 impacts (5 social – S2, S3, S7, S9, S10 and 3 environmental – E2, E7 and E8) were regarded as neutral. This means inability to clearly agree or disagree, which may be due to their lack of awareness of such impacts.

The hypotheses tested inferred that 60% to 70% of the village population would agree with the three main positive impacts (S1, S6 and S8), while their disagreement of 55% to 65% population for three impacts (S5, E4 and E5) was strongly demonstrated.

Conclusions

This case study on a MHP situated in Kegalle district of Sri Lanka reveals that the random sample of the public of the area has a positive attitude on the impacts of this MHP. They strongly agreed that the MHP provided new job opportunities to villagers at both construction and operation phases. However, they have not shown a considerable agreement with any of the negative impacts reported in the literature as experienced at other MHPs in Sri Lanka and elsewhere.

Sample data projected to the population views through statistical tests allowed to infer that the majority of the village population (over 50% in all cases) living in the neighbourhood of this MHP would agree with the positive impacts and would agree to not having significant negative impacts due to the MHP generation.

It is recommended to further study the reasons behind the positive attitude among villagers, which is not the usual case. Revelation of such reasons would help design the future MHPs with minimum opposition from the public.

Acknowledgement

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