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Small Hydro-power Plants and Disturbances to Environment: Evidence from Sri Lanka

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Abstract

Hydro-power generation is prominent as a renewable, alternative, clean and green energy source of power generation in Sri Lanka, compared to solar power, wind and biomass. Among the available sources, Sri Lanka has many Small Hydro Power Projects (SHPPs) in rural areas. However, public protests in the recent past against the SHPPs rose because of their negative impacts on the environment. Many researchers view environmental influences as a result of activities of hydro-power plants, yet the findings deviate from the location and focus on the nature of the project. Therefore, this paper intends to analyze the residents' perceptions on environmental impacts related to three rural projects from Padiyapelella, Manakola and Elamulla areas in the Nuwara-Eliya District. The sample included sixty families and five responsible experts, purposely selected from the affected areas. Data was collected through a structured questionnaire, observations, and interviews. Descriptive statistics, average response value comparisons and content analyses were used to analyze the data. Results reveal that more negative effects are observed at the construction stage, and they diminish with the completion while a few tend to continue. SHPPs projects have a major impact on the soil structure and, secondly, the adverse effects on other environmental components such as biodiversity, water, and tranquility Findings underline the importance of preliminary studies in minimizing the harmful effects to enhance more benefits from establishing SHPPs.

Keywords: Small Hydro-power Plant; Environmental impacts, Energy Supply, Renewable energy, Public Perceptions

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INTRODUCTION

Energy plays a significant role in the socio-economic development of a country, increasing people's standard of living. Currently, the global energy supply is mainly based on coal, natural gas, oil, and to a lesser extent on hydro-power and nuclear energy, whereas hydro-power generates one-fifth of the global electricity production. Hydro-power plants are subject to several classifications related to their dimensions, such as Micro Hydro (<100 KW), Mini Hydro (100KW-1MW), Small Hydro (1 MW – 10MW), and Large Hydro (>10MW). Out of these types, Small Hydro-power Plants (SHP) have been developed in 149 countries, and their production of hydro-power was estimated at 75 GW, and potential hydro-power was approximately 173 GW (Abbasi & Abbasi, 2011, p. 1138).

Most developing countries face energy crises with mass-scale industrial developments and other related activities (Nasir, 2014, p. 22). It is a little costly to meet this demand via fossil fuels. In 2017, major hydro-power plants had contributed 20.5% of the total gross electricity generation in Sri Lanka and another 6.34% by mini hydro-power plants (SLSEA 2017). In the same year, the average unit cost of hydro-power was Rs. 2.77 per KWh when the unit costs of coal and fuel oil-based power generation stood at Rs. 9.74 and 25.75, respectively (SLSEA 2017). Recent studies on mini-hydro development in Sri Lanka have identified that the current grid-connected mini-hydro capacity of 393.5 MW can be increased up to 873MW (CEB, 2020). In 1979 on the First World Climate Conference in Geneva, urgent global actions were suggested to minimize or a total ban on fossil fuels consumption (Buotte et al., 2019, p. 8) . Therefore, the best solution is to develop renewable energy sources in the country. Hydro-power is the foremost renewable energy source in the global electricity production process. It plays a significant role in future energy needs, offering a valuable alternative to fossil fuels, leading to electricity generation, providing 19% of the planet's electricity in the world and supplying 71% of all renewable energy. Over 50% of the world's small hydro-power potentials are found in Asia, but it will be possible in the future that more small hydro-power potentials be identified in the American and African continents (WSHPDR, 2013).

Small hydropower plants (SHPPs) have gained more attention due to the economic, environmental, and social benefits and it has played a major role in Sri Lankan electricity production since its beginning in 1950.The first small hydro-power plant was constructed at Dick Oya by Hydro-Tech Lanka (Private) Limited in 1996. Supported by the Sri Lankan topography setting, an excellent opportunity is provided to generate hydro-power. However, there are critics that hydroelectric plants carry the potential of environment, and visual impacts (Rotilio et al., 2017, p. 04). During the constructional and operational stages of a SHPPs may cause several environmental and economic issues. Power generating plants create both adverse and beneficial effects on social and economic spheres, and more advantages can be gained by reducing its unfavorable counterparts. Though hydro-power plants are often considered the most eco - friendly and economic sources of power production, there are social and environmental effects which usually vary with the size of the hydro-power plant and location (Rupasinghe & Silva, 2017). Hence, it cannot be generalized. Therefore, recently developed sites need to identify similar effects or novel effects. Thus, this study focuses on identifying the environmental impact of SHPPs that are recently developed in the rural areas of Sri Lanka, and suggesting strategies to mitigate such influence on SHP development to ensure more benefits.

LITRETURE REVIEW

Environmental impacts of small hydro-power

According to the definition of the European Environment Agency, the changes in environmental conditions lead to impacts on the social and economic functions of the environment. Impacts often occur in a sequence; for example, global warming (primary effect), which causes an increase in temperature (secondary effect), leads to a rise of the sea level (tertiary effect), which finally results in the loss of biodiversity (EEA, 2011). Similarly, it includes any effect or any such change in biodiversity and the condition, human health, physical and cultural heritage of any structure, site or thing that is of historical, archaeological, paleontological, or architectural significance, the quality of soil, water and air and outcome consequence or result to the environment brought about due to some project or action. Many SHPPs are found in Bhutan as a small country. According to the National Environment Commission (NEC)) in Bhutan, SHPP projects involve land clearing, diverting of the river courses, diverting of forests, changing the hydrological area, and the like. These activities change the natural environment of the project area. The harmful environmental effects that could result from hydro-power plant projects are remarkably diverse and complex. The significance of these impacts varies from one project to another, depending on the project scale and site sensitivity. Assisting construction activities also cause an additional effect on the environment scale and site sensitivity (NEC, 2012). The Table below lists the environmental effects likely to be

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caused due to SHPP projects by NEC of Bhutan.

Table 1 -Environment impacts of Small Hydro Power Projects

Aspect of Environment	Impacts
Land Environment	
Construction phase	• Inducing landslides. • Impact on soil • Generation of solid waste from labor camps/colonies and construction sites. • Change in land use patterns. • Loss of properties (movable and immovable). • Generation of waste (muck)
Operation phase	• River fragmentation • Reduction of the flood plain area. • Downstream erosion • Land contamination due to release of chemical waste, sanitary waste, oil and hazardous waste from induced development near the project area.
Water resources & water quality	
Construction phase	• Loss of natural coils due to tunnelling activities • Increased turbidity in the downstream due to waste disposal • Dust from crushed and ground rock material from the drilling, blasting and stone crushing plant (quarry) pollute the water bodies. • Oil and chemical spills from the workshop and the release of chemical wastes lead to water pollution. • Sanitary effluent from the labour camp is a significant concern that affects the water quality.
Operation phase	• Reservoir sedimentation over a while reduces the live storage and the power generation. • Eutrophication risks. • Changes in the hydrologic management of the river. • Decrease in dissolved oxygen levels, and thereby impacting the aquatic life. • Thermal stratification of the reservoir
Biodiversity: Aquatic and terrestrial ecology	
Construction and Operation phase	• Due to flow regulation, the riverine ecology in the upstream and downstream regions of the project gets degraded. • The drop in dissolved oxygen in the reservoir and eutrophication of the reservoir • Adverse impacts on flora and fauna • Loss of economically/ genetically/ biologically important plant species. • Loss of forest cover. • Impacts on wildlife habitats and • Migration of the change in hydrological regime downstream of the dam.

Source: (NEC, 2012)

Ecological impact

The initial necessity is a huge flow of water and prominent drop. The initial topographical features are found in the hilly area, which has several sensitive tropical ecological features. Though the environmental community widely criticizes Sri Lankan mini-hydropower plants over habitat losses (Kibler & Tullos 2013, p.3108; Mendis, 2019), any type of development other than hydro-power facilities can also cause the same or even more disturbance to ecological habitats (Herath et al., 2021, p. 42). This fact guides several environmental effects. Most SHPP plants are established in or near highly sensitive ecosystems in tropical forest areas. The waterway is essentially blocked at a weir, causing disturbance to the sensitive ecosystem, disturbance of traditional usage of water downstream and a massive construction site occupies the vicinity, disturbing the sensitive ecosystem. The villagers are compelled to adapt themselves to the changes in the environment, and such adaptations have a tendency for inappropriate behavior, which would be harmful to the society and the environment. As a result, various harmful consequences, such as deforestation, change of water flow, threats to flora and fauna, disturbance to the sediments flow, disturbance to the traditional usage of water could be inevitable due to these projects (Rupasinghe & Silva, 2017).

Heavy vehicles and several types of equipment used for excavation and material transporting activities may cause noise during the construction period, while hydro plants operational phase turbines can produce continuous noise. In addition, the noise produced during the construction period could temporarily affect fauna. Similarly, emissions from chemicals such as fuel and lubricants used at the site negatively affect the biodiversity around the project site. The literature describing impacts of energy development on direct wildlife mortality have primarily focused on fish and bird species (Loss et al., 2019, p. 352). Small lotic ecosystems in the upper parts of river sheds support biological communities adapted to fast-flowing and dynamic habitats, and this makes the ecological impact of SHPPs even stronger (Lange et al., 2018, p. 399)

If water is stored or restricted at the upstream area of a stream, it affects the downstream area of the stream or the river. The small hydro-power generation always involves upstream areas of steam, which causes several impacts on the upstream area and the downstream area. Hence, diversion of the water flow for power generation significantly affects the aquatic ecosystem system, aquatic living organisms, and fishing migration between intake and outlet of the hydro-power plant. At the same time, it is a disturbance to other activities related to the stream; usually water shortages for agricultural activities, irrigation purposes and other traditional uses of the stream can be commonly observed

(Thoradeniya, 2015, p.366). Effects on habitats and other major environmental issues are caused by power projects that are under construction, and they are the most crucial problems of the project during the operational process. Observations and research reveal that activities such as excavation, cutting trees, filling areas, blasting, lakes or pool construction, construction of supply canals, and reduction of wetland contribute to habitats' deterioration (Kim, 2007, p. 414).

Ground Stability Impact

During the basic site area preparation stage, removing the vegetation cover with overburdened soil is essential. Several ground preparations like levelling may be required for a powerhouse site. The topsoil layer is the most critical environmental setting supporting vegetation growth and defying the subsoil from erosion. Loosened due to excavation and harrowing and clearance of vegetation cover, fine material washouts, soil instability and soil infertility of these soil layers are very likely to follow. Several small hydro-power plants are located on slope areas. A common occurrence in this area is soil erosion when due precautions are not taken due to basic site preparation processes. Similarly, minor level cuttings, levelling and fillings in access road development and construction of other project elements, incredibly close to the left bank of PSHPP project, have also prompted soil erosion mainly during the rainy periods (IEE, 2014).

Deforestation in the areas severely damages the sensitive aquatic structure of the land, displaces several habitats, destroys food for animals, affects the region's food chain, increases soil erosion, and affects topsoil, resulting in slope instability in the project effect area. During the construction of SHPs, cutting down trees for building infrastructure for power production impacts the earth structure and clears vegetation in the upper catchment forest area. Deforestation also damages the sensitive ecosystem structure of the power plant area; displacement of habitats, damages to food sources of animals, impacts on the food chain of the power plant area, soil erosion and damages to topsoil condition finally result in slope instability in the project location. Similarly, water springs dry due to deforestation, affecting the area's domestic water supplies and irrigation system (Thoradeniya, 2015, p.368).

Hydrology & water quality impact

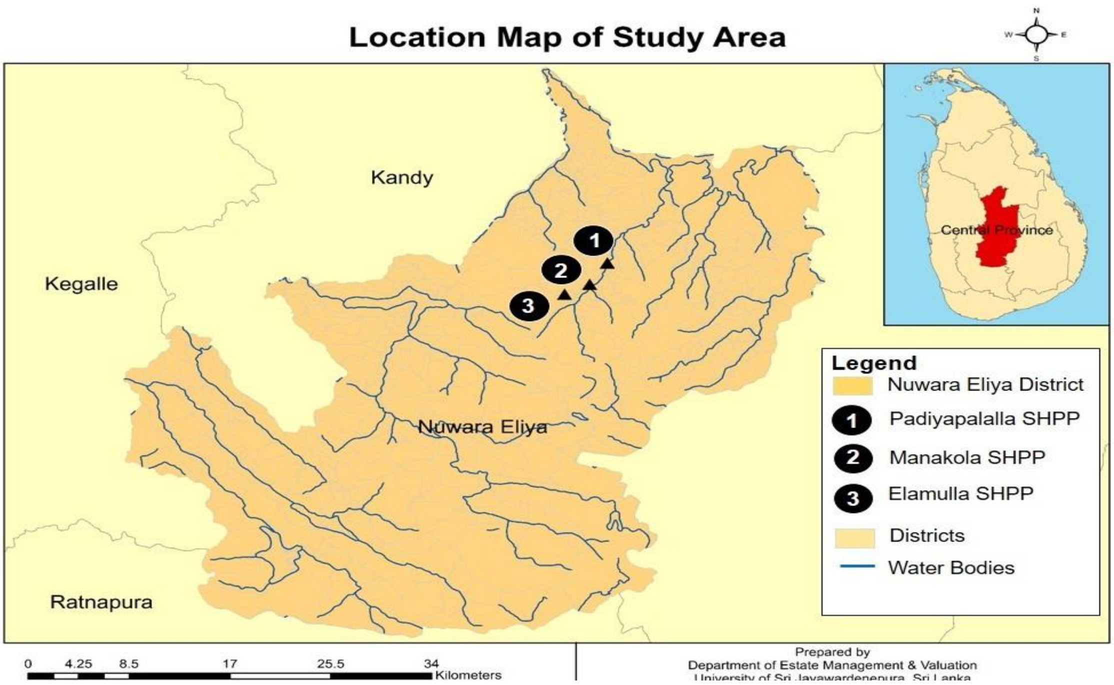
According to Naidu (1996), the small hydro-power plant projects are environmentally friendly and are non-polluting. Generally, these projects do not involve severe rehabilitation or deforestation. However, some impacts depending on the site and the layout of the project are noted. For instance, trees may have to be removed in marginal areas, but afforestation can minimize the effects. Normally, small hydro-power projects do not involve the construction of massive dams (sometimes small dams are constructed), and therefore, generally, no rehabilitation problems generally arise. Pollution and related adverse effects are not expected in small hydro-power plant projects. Anyhow, forest clearance is a significant impact on the downstream. According to recent literature, small hydro-power plants have a strong environmental impact on freshwater wetlands (Bunn & Arthington, 2002, p.502; Collen et al., 2014, p.47; Wu et al., 2019, p.485), and drinking and irrigation water.

RESEARCH METHODOLOGY

The method of data collection, selecting the variables and analysis depends, to a certain extent, on the scholarly work of others. Referring to various types of research conducted hitherto helps recognize several environmental issues of SHP projects. The study was carried out in three selected projects, located in the Nuwara-Eliya District, Sri Lanka; Padiyapelella SHPP (4MW), Manakola (1MW) SHPP and Elamulla (1.3MW) SHPP, which are referred to in this paper as Case 01, Case 02, and Case 03, respectively. These projects were developed based on two water bodies, namely, BelihulOya, and Ma Oya. The Nuwara-Eliya district has the most compatible surroundings for developing small hydro-power plants.

The following Figure 01 shows the location map of the study area.

Figure 01: Location Map of Study Area



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The primary data collection techniques were a Likert scale questionnaire, unstructured interviews, and observations. Perceptions on the selected environment effects, identified through literature, and confirmed observations were collected through five-point Likert scale questionnaires. Likert scale questionnaires are designed, ranging the weights from 1-5, representing responses from strongly disagree to strongly agree respectively (Subedi, 2016, p.43). In a typical five-point response, the mid-point is considered 3, below 3 is considered disagreeing, and above 3, as agreeing. In fact, the mid-points primarily represent a 'neutral', 'undecided' or 'no idea' response, where the respondents neither agree nor disagree. Thus, it is the researcher's choice to decide the interpretation of the results, considering the epistemological concerns (Kulas et al., 2008, p. 254) at the designing level of the questionnaire.

A total of 339 families in Padiyapelella, Manakola and Elamulla villages were considered the population of this research. The total sample was 60 families, selected according to the purposive sample, based on 20 families from each village living closer to SHPP, to collect data through the Likert scale questionnaire. For the unstructured interviews, five (05) members living in the village were considered responsible people and were selected randomly for each project area. The sample consisted of government officers, farmers, private sector officers and students.

Firstly, the data collected through questionnaires on different aspects of the effects on the environment were analyzed using some descriptive statistical techniques.

A descriptive analysis on environmental impacts explored impacts, dividing them into five categories: water, noise, biodiversity, soil/land, and air. Following are the sub-factors that were considered under each main heading.

1. Influence on Water – garbage disposal, oil and chemical spill into the water, water impacts due to construction of the weir.
2. Influence on noise – the movement of vehicles and machinery, electric generators and turbine and rock blasting and excavation activities.
3. Influence on biodiversity – cleaning up the forest, downstream of wire, and damaging flora and fauna.
4. Influence on soil/land – soil erosion, landslides, and on-site garbage disposal.
5. Influence on air – emissions from vehicles and machinery turbines and electric generators.

Later, the impacts were discussed using the percentages of the responses and the average values of scaled responses. Secondly, a content analysis was developed using the unstructured interview and the results collected from the selected five respondents.

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RESULTS AND DISCUSSION

The average response value comparison, made using the data collected from the Likert scale, is shown in the following Table No 04. The responses based on 1-5 scales were converted to percentages to discuss the results. Further, the average response value is calculated from the total value of the perceptions under each respective scale, dividing the total value by the number of sub-factors considered under each main impact.

Table 4 - Percentage Values of the Responses

Impacts	**Sub Impacts**	**Satisfaction Levels %**					**Highest Average Response %**
		SD	D	N	A	SA	
Water Impacts	Garbage disposal	-	-	16	32	52	
	Chemical & oil spills	31	47	15	7	-	
	Construction of weir	-	7	20	35	38	
	Ground water	48	34	13	5	-	SA-22.5
	Average Response Value	19.75	22	16	19.75	22.5	
Noise	Vehicles & machinery	-	10	20	42	28	
	Electric generators & turbine	33	44	18	5	-	
	Rock blasting &excavation	-	7	13	33	47	A-26.7
	Average Response Value	11	20.3	17	26.7	25	
Biodiversity	Cleaning up forest area	-	10	15	33	42	
	Flora & fauna	4	13	20	33	30	
	Down-steam of weir	5	12	17	40	26	A-35.3
	Average Response Value	3	11.7	17.3	35.3	32.7	
Soil Impact	Soil erosion	5	10	35	40	30	
	Landslides		10	18	40	32	
	Garbage disposal		10	30	38	32	A-39.3
	Average Response Value	1.7	10	27.7	39.3	31.3	
Air Pollution	Vehicles & machinery	37	35	20	8	-	
	Turbines & electric generators	60	33	7	-	-	SD-48.5
	Average Response Value	48.5	34	13.5	4		

Source: Compiled by author, survey data 2019
SD-Strongly Disagree, D-Disagree, N-Neutral, A-Agree, SA-Strongly Agree

Accordingly, considering the impact on water, perceptions on adding garbage show that 52% strongly agreed and 32% agreed on the issue. It means the majority of the respondents agreed that there is an issue with disposing of garbage into running water. It mainly occurs in the construction phase because several building materials are brought to the site for construction activities. Therefore, many wastes generated from these materials are not correctly disposed of and are hence added to the stream water. Similarly, with no proper disposal method, the wastes generated from labour camps had also been added to water. Another issue is the construction of the weir of hydro-power projects. When examining the construction of the weir, 38% strongly agree, and 35% agree about water impacts due to the construction of the weir. This is mainly due to the reduction of water quantity in the downstream areas of the weir and the change in the hydrological regime of the stream. In this setting, a considerable damage to downstream water quality could be observed. The spilling of oil and chemicals is not significant compared to water pollution in these sites. According to the analysis, 47% disagreed, and 31% strongly disagreed about water pollution due to oil and chemical spills. In addition, groundwater pollution is not a matter on this site, as 48% strongly disagreed and 34% disagreed about groundwater quality pollution from hydro-power projects. It can be noted that garbage disposal has affected water, but only during the construction time phase.

Similarly, weir construction has affected water even after the construction of weirs. However, oil and chemical pollution of groundwater quality reduction are not significant. Moreover, the highest response under the factor of water is 22.5% representing the average of the strongly agree column, proving the negative impact on the environment.

The next factor is noise pollution, which is also a significant issue. In the construction phase, construction works are carried out using machinery and heavy vehicles. The continuous high volume of sounds and vibrations causes due to the movement of heavy vehicles and machinery such as lorries, dozers, and excavation machinery, surrounding the project area. According to the above analysis, 42% agree, and 28% strongly agree that severe sound pollution exists. Similarly, rock blasting and excavation are other causes of noise pollution. Responses show that 47% strongly agreed and 33% agreed on this issue. Further, the majority agreed that there is not much disturbance from the electric generators and turbines. Therefore, it could be identified that there is no considerable noise pollution from turbines and generators. Finally, it is revealed that there is a considerable issue of noise pollution due to rock blasting, excavation activities, vehicles, and machinery. According to the highest response value, which is 26.7% in agreement, it is confirmed that noise is a disturbance to the environment. However, these issues are observed only during the construction time. Conversely, generators and turbines have no considerable noise issue in the operational phase.

The impact on biodiversity is another considerable issue due to the construction of hydro-power projects. During the construction, it is necessary to clear some forest areas. It is mainly prominent in weir, canal path and penstock line way building. According to the analysis, 42% strongly agreed, and 33% agreed that the above problem exists. Therefore, the majority have agreed that cleaning up forest areas due to hydro-power projects is a problem. In the construction phase, several implications in destroying biodiversity are observed. The analysis shows, with 33% agreeing and 30% strongly agreeing, that the impacts on biodiversity are considerable, mostly on flora and fauna surrounding the hydro-power projects area. Similarly, the constructions of the weir have affected downstream of the weir. The majority, i.e., 46% and 26% agree and strongly agree on this issue. Accordingly, the impact of flora and fauna, cleaning up forest areas and the construction of weir have affected the biodiversity of the hydro-power projects area. According to the highest average, 35.3% agree, proving that the hydro-power project has a negative impact on the biodiversity within the area.

Another issue is the impact on soil due to the construction of hydro-power projects. Soil erosion in the project areas was analyzed, and the results show that 40% strongly agreed and 30 % agreed on this issue. The outcome is mainly due to the cleaning up of the forest cover, and heavy excavation activities done using heavy vehicles. The other aspect observed is that these hydro-power projects are in deep sloping areas facilitating the water flow. Therefore, it naturally encourages the above-mentioned influences on the soil.

Meanwhile, small to medium landslides follow continuously. In the construction phase, several excavation activities cause loosening the soil structure, while cleaning up forest areas destroys the water-absorbing power. According to the analysis, 40% agree and 30% strongly agree with the landslide issue. Soil contamination is another problem because of garbage disposal on the soil. A higher percentage, i.e., 58 %, agreed with this factor. In the construction phase, these wastes, such as construction materials and the wastes from labour camps garbage are disposed and added into the soil. It is mainly prominent surrounding the weir, canal path and penstock line area of projects. Soil pollution occurs from the construction phase of small hydro-power projects. Hence, it can be concluded that all the above factors affect soil instability, and the highest average value representing 39.3% agree, proving that there is a negative impact on the environment due to the hydro-power plant projects.

Air pollution is not a significant issue in these hydro-power projects, as proved by the responses. The results present that 48% disagreed about air pollution from vehicles, machinery, turbines, and

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generators. However, it is observed that vehicles and machineries for construction activities release some harmful toxic gases into the atmosphere during the construction period. The respondents were of the view that it is not significant.

The following Table No. 05 summarizes the results on the total percentages of each scale. Accordingly, the results are consistent with the findings of Thoradeniya, (2015, p. 366) and Rupasinghe & Silva (2017).

Table 05: Summary of results on total percentages of each scale

Factor	Highest Impact	Results
Impact on soil	Negatively Impact	Agree 39.3%
Impact on biodiversity	Negative impact	Agree 35.3%
Impact on Noise	Negatively impact	Agree 26.7%
Impact on water	Negatively impact	Agree 22.5%
Impact on air	not considerable impact	Strongly Disagree 48.5%

Source: Compiled by author, survey data 2019

Content Analysis

As per the following Table No 06, content analysis was developed based on data collected from unstructured interviews. For the unstructured interviews, five members living in the village were considered responsible people and were selected randomly for each project area.

Table No 06: Content Analysis

Environment impacts	Sub impacts	Case 01	Case 02	Case 03
Water pollution	Garbage disposal	✓	✓	✓
	Chemical & oil spills	×	×	×
	Construction of weir	✓	✓	✓
	Groundwater	×	×	×
Noise pollution	Vehicles & machinery	✓	✓	✓
	Electric generators & turbine	×	×	×
	Rock blasting & excavation	✓	✓	✓
Impact of biodiversity	Cleaning up forest area	✓	✓	✓
	Flora & fauna	✓	✓	✓
	Downstream of weir	✓	✓	✓
Soil pollution	Soil erosion	✓	✓	✓
	Landslides	✓	✓	✓
	Garbage disposal	✓	✓	✓
Air pollution	Vehicles & machinery	×	×	×
	Turbines & electric generators	×	×	×

Source: Compiled by author, survey data 2019

The results show that soil and bio-diversity pollution are the most crucial factors due to the execution of the hydro-power projects than other factors. As per all the findings, Table No 07 compares the descriptive analysis and the content analysis.

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Table 07: Comparison of descriptive analysis and content analysis.

Environment impacts		Descriptive analysis	Case analysis
Water pollution	Garbage disposal	✓	✓
	Chemical & oil spills	×	×
	Construction of weir	✓	✓
	Groundwater	×	×
Noise pollution	Vehicles & machinery	✓	✓
	Electric generators & turbine	×	×
	Rock blasting & excavation	✓	✓
Impact of biodiversity	Cleaning up forest area	✓	✓
	Flora & fauna	✓	✓
	Downstream of weir	✓	✓
Soil pollution	Soil erosion	✓	✓
	Landslides	✓	✓
	Garbage disposal	✓	✓
Air pollution	Vehicles & machinery	×	×
	Turbines & electric generators	×	×

Source: Compiled by author, survey data 2019

Accordingly, Table No 07 clearly shows that the effects are prominent in all sub aspects of soil pollution and damaging biodiversity. Water and noise pollution comes second. No issue is significant with the air pollution. The comparison also confirmed that both results from the descriptive statistics and the content analysis are equal.

CONCLUSION

This research focuses on identifying the environmental influences of the SHPPs in three selected projects from the Nuwara-Eliya district in Sri Lanka. Based on the literature review, the environmental impacts were categorized into five main aspects.

Data were collected through a structured questionnaire, observations, and interviews. Descriptive statistics and content analyses are used to analyze the data. Both analyses reveal more negative effects observed at the construction stage, which will diminish with the completion, with a few continuing. SHPPs projects significantly impact soil structure and, secondarily, adversely affect other environmental components such as biodiversity, water, and tranquility. These negative influences continue even after the construction phase. Water pollution and noise pollution is observed at the construction phase of the projects, implying that noise pollution is a temporary impact. However, water pollution can contaminate drinking water, bringing about deadly diseases even after the completion of the project. However, no issue related to air pollution is observed. The results are consistent with the findings of (Thoradeniya, 2015, p. 366; Rupasinghe & Silva,2017), and findings underline the importance

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of preliminary studies in minimizing the harmful effects to enhance more benefits from establishing SHPPs.

RECOMMENDATION

The research study has identified several harmful impacts on the environment due to Padiapelella, Manakola, Elamulla small hydro-power projects. Following are some recommendations for the above hydro-power projects and proposals for any small hydro-power projects.

- Vegetation removal should be kept to a minimum at all places, with special attention paid to riverine habitats.
- Replanting the disturbed sites with native and endemic species.
- Mitigation measures should protect downstream aquatic flora and fauna, and aquatic habitats. A continuous base flow should be released from the weir at all times through an uncontrolled valve in the operational stage. The size of the valve should be kept according to the recommendations of the Irrigation Department and the Technical Committee.
- Dust generation and nuisance to the environment due to vehicle movement and increased vehicle usage in the area could be identified as one of the leading environmental impacts of material transport. As the construction phase spans nearly two years, such impacts could be moderately significant. Conducting earth or material stripping only in places where necessary, proper coverage of transporting material and the use of properly maintained vehicles are suggested as general mitigation measures.
- Waste generated is evident as the projects should employ a considerable number of workers. These wastes contain food, plastic and polythene, mainly. Food waste should not be dumped openly into the site, which may lead to unnecessary conflicts. Similarly, solid and sanitary waste released from labour camps and sites should be adequately collected and disposed of.
- Sites should be maintained during the construction phase. Proper and safe storage of materials should be conducted to avoid accidental spills or wash-offs of chemicals/materials.
- Sanitary waste shall be hygienically disposed of /buried on site, as it is not practical to install septic tanks or any other mechanism.
- All blasting activities should be performed in controlled conditions under the supervision of a qualified civil engineer. Chemical blasting should be performed to remove excessive boulders at the weir location
- In order to prevent sedimentation due to erosion, the adoption of soil conservation measures on agricultural lands and home gardens are recommended.
- Clearance of vegetation and trees should be minimized, and mulching should be applied.

- Awareness programs should be carried out to educate local communities on the importance of environmental protection, and monitoring responsibilities should be assigned to community-based organizations.
- Before following the EIA process to identify the environmental impacts, decision-making is necessary. Its main objective is to predict the environmental effects at an initial stage in project planning and design, find the solution and explain to minimize the harmful effects, make projects to precious the local environment, and propose options to the decision-maker.

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