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Technical and Socio Economic Assessment of Water Mill Sites for Micro Hydro Power Generation in North Shoa Zone of Amhara Region

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Abstract: Use of micro hydropower plants is an ideal method of providing power for off-grid rural communities especially in developing countries like Ethiopia. In Ethiopia only 8% of the rural community has access to electricity, and the power supply in the country is very low as compared to its population growth. The present study assesses the technical and socio economic aspect of water mill sites in North Shoa zone of Amhara regional state, Ethiopia for the development of micro hydro power plant. Through technical assessment of the flow rate measurement, head measurement and estimation of power generation potential of the mill sites has been done. The socio economic assessment was done by interviewing households, officials and mill owners. The results of the assessment shows that, out of the 14 mill sites investigated, 12 of them has the potential to generate power ranging from 5.52kw to 38.59kw with 80% efficiency during the dry season. It has been observed, the existing as well as former mill sites in North Shoa zone, are mostly located in the mountainous regions which offers an interesting opportunity for micro hydropower generation that would meet the energy demand of the villages at least 5km far from the main grid.

Keywords: Micro Hydro, Power Plant, Flow Rate, Head, Socio Economic

1. Introduction

Energy plays one of the most important role in the development of a country. The source of energy can be fossil fuel, nuclear power, solar, wind, hydro, geothermal, biomass and bio-fuel etc. These sources can be renewable or non-renewable and renewable energy sources can help countries meet development goals by fulfilling their energy demands.

Ethiopia has abundant renewable energy sources and has the potential to generate over 45,000MW of electric power from hydropower only [1]. As a result of the country's rapid GDP growth over the previous decade, demand for electricity has been steadily increasing. Almost 85% of the population of Ethiopia lives in rural area, where only 8% have access to electricity, and the power supply in the country is very low as compared to its population growth [2]. As a result rural area populations predominantly rely on kerosene and traditional fuel wood to meet their energy demand for various purposes.

Micro Hydropower (MHP) is one of the earliest small-scale renewable energy technologies, and is still an important source of energy today. Micro-hydropower systems are relatively small power sources that are appropriate in most cases for individual users or groups of users who are independent of the electricity supply grid. Micro hydro power systems does not require advanced techniques to facilitate and operate, which means that the installation and operation can be done by local communities [3]. Hydro-power systems are classified as large, medium, small, mini and micro according to their installed power generation capacity. Hydropower has various degrees of 'smallness'. There is still no internationally agreed definition of 'small' hydro [4-6], the definition varies from country to country [7].

A common classification of hydro power plants based on capacity is presented as follows: A micro-hydropower system is generally classified as having a generating capacity of less than 100 kW. Systems with a generation capacity of between 100 kW and 1000 kW are grouped in mini-hydro. Small hydro is defined as having a capacity of more than 1.0 MW and up to 10 MW. Systems with a generation capacity of greater than 10MW and less than 100MW are classified as medium. Above 100MW the system is referred to as large hydro power plant [8, 9].

Recently, the Ethiopian government in collaboration with other stake holders has been engaged to build many hydropower generations at different scales. Different universities in the country and nongovernmental organizations are also engaged in the study of potential of rivers for micro hydro power generation. The power generation potential of rivers in north shoa zone of the Amhara regional state is studied [10]. According to this assessment the rivers have the potential to generate up to 52.19kw.

However in its present conditions, it is not only economical, but also impossible to address the power supply to the rural areas. Thus, off grid renewable energy or climate proof system types are preferable. In view of above stated problems this study has been designed to assess the technical, and socio economic status of water mill sites for micro hydro power development.

2. Methodology

The methodology used for the technical as well as the socio economic assessment includes the collection of primary and secondary data through:

1) Interview Questionnaires, and;
2) Direct observation and measurement.

a. Interview.

For the socio economic assessment, a structured interview questionnaire were designed to access qualitative, multi-aspect information of the water mills, rivers and the villages [11]. The numbers of households were selected randomly based on the population size of the area. Mill owners, staffs from Kebele, and other institutions were interviewed to collect general data about the village and the water mill.

b. Head Measurement.

The gross head in this study is the altitude difference between the inlet and outlet of the water mill. In addition to measuring the gross head of the existing water mill we measure the maximum head that can be generated using the run of river around that area. The head measurement is carried out through on site measurements with the help of GPS.

c. Flow rate measurement.

The measurements of river flow rate were done by floating method. Although not as accurate as a measuring device such as a flume or a flow probe, the float method can provide an educated estimate. This method involves measuring the surface velocity of the water with a floating object, and then multiplying this velocity by the width and average depth of the channel [12, 13].

$$Q = A \times V \tag{1}$$

Where the area A and velocity V are calculated as:

$$A = W \times D$$

$$V = s / t$$

Q =flow rate, W = Width of Channel, D = Depth of Water, s = distance traveled, and t = time.

To measure the flow rate using the float method:

a) Choose a suitable channel section with minimum instability.
b) Mark the beginning and end of the distance the floating object will travel.
c) Throw the floating object at the beginning of the stream.
d) Using a stopwatch, measure the time the float takes to travel down the length of stream.
e) Repeat step (d) at least three times and determine the average time taken for the float to travel the stream.
f) Measure stream's width and depth across the downstream marker section using a meter stick. Finally, take at least five depth measurements at regular width intervals.

3. Study Area

The present study was done in areas covering North Shoa zone of Amhara region, Ethiopia, one of the promising Zones for development of micro hydro in the Amhara Region, according to a previous study [4]. The Zone is bordered on the south and the west by the Oromia Region, on the north by Debub Wollo, on the northeast by the Oromia Zone, and on the east by the Afar Region. The studies were conducted on 14 selected water mill sites, on seven rivers.

4. Results and Discussion

i. Technical aspect assessment and analysis.

The objective of the technical assessment is to investigate the water mill site power generation potential for micro-hydro power generation. One of the most important activities in potential site identification is to measure the water discharge and the head that could be utilized for micro-hydropower generation.

The head and flow rate measurements and calculations are done as described in the methodology section. The hydropower generation potential of the sites was computed using [3, 10, 14]:

$$P = \rho g Q H \tag{2}$$

Where:

P = Power (*Watt*).

ρ = Density of water (kg/m^3).

Q = flow rate (m^3/s).

g = the gravitational constant (m/s^2).
H= Head measured (m).
Table 1 shows the measured head, calculated flow rate, the hydraulic power generation of the sites, and the status of the mills.

Table 1. *Technical Assessment and Analysis.*

No	Name of Woredas, kebeles and sub-kebeles	Name of rivers (water mills)	Status of the mill	Measured Head (m)	Flow Rate (m^3/sec)	Hydraulic power generation (kW)
1	Hagere Miriam, kidiste	Jambere (mill 1)	Working during the visit but far from the community.	17	0.179	29.851
		Jambere (mill 2)	Working	17	0.27	45.03
		Jambere (mill 3)	Working during the visit and near to the community compared to 1 and 2.	15	0.229	33.63
		Jambere (mill 4)	Not working	15	0.229	33.69
		Jambere (mill 5)	Not working	15	0.167	24.28
		Jambere (mill 6)	Not working, and near to the village compared to other mills.	14.7	0.071	10.238
2	Ankober	Shema matebia	Not working	16	0.101	15.8
		Jema	Not working	15	0.128	18.84
3	Tarmaber, sina	Setatie (Tikuriti)	Out of service	14	0.219	30.077
		Teter wuha	Out of service	11	0.053	5.72
4	Efratanagidm, ambober	Gereb	Not working	33	0.149	48.24
5	Menz mama	Mofer wuha	Working	15	0.047	6.9
6	Menzgera	Shay wenz	Not working	20.44	0.20	40.103
7	Mojana wedera	Wereda wenz	The water mill not available	No water		

He calculated power generation potential is the theoretical optimum limits of hydroelectricity production of the mill site which represents the maximum power that can be generated during the dry season [15]. The estimated minimum power generation potential is 5.72kw from Teter wuha mill site, and the maximum is 48.24kw from Gereb mill site. The average flow rates obtained here can be taken as the minimum values since the assessments were conducted during the dry season.

ii. Socio economic assessment.

After interviewing households, mill owners, and officials of the kebele, and analyzing the information collected the following table were prepared.

Table 2. *Socio - economic assessment.*

No	Woreda	Kebele	Name /water mill	No. of house holds	Side Effect on the village community	Social institutions
1	Hagere Mariam, kidiste	Kidiste	Jambere (mill 1-mill 6)	55	No effect	Kebele, agricultural and police office, health center, and a church.
2	Ankober	Layegorbela	Shema matebia	200	No effect	Church and satellite school (1-4).
		Mehale wenz	Jema	67	No effect	-
3	Tarmaber	Sina	Setatie (Tikuriti)	60	No effect	-
		Sina	Teter wuha	35	No effect	-
4	Efratanagidm,	Ambober	Gereb	85	No effect	-
5	Menz mama	08 kebele	Moferwuha river	120	No effect	School (1-4)
6	Menzgera	Tsehayisina08 Kebele	Shayi wenz	128	No effect	
7	Mojana wedera	Wedera	Wedera wenz			

Table 2. *Contiuned.*

No	Willingness of the community and concerned local administration person.	The village community energy source for lighting	Distance to the national grid	Population distribution	Willingness of the mill owner to cooperate?
1	They are voluntary	Solar, Kerosene	Very far from the grid	Partially dense	Yes
2	They are voluntary	Kerosene, solar, wood	Around 2.5km	Scattered	yes
	They are voluntary	Kerosene, solar, wood	Around 10km	Partially dense	yes
3	They are voluntary	Kerosene, solar, wood	Around 5km	Dense	yes
	They are voluntary	Kerosene, solar, wood	Around 5km	Partially dense	yes
4	They are voluntary	Kerosene, solar, wood	Very far from the grid	Partially dense	Yes
5	They are voluntary	Kerosene, solar, wood	----	----	Yes
6	They are voluntary	Kerosene, solar, wood	----	----	Yes
7	Above 100 households but no water flow through the river				

From the socio economic analysis:

a. There will be no side effect on the community if the project is implemented.
b. All the community members including the mill owners agree voluntarily for upgrading the mill sites to micro hydro power plant.
c. Almost all mill sites (villages) are at least 5km far from the main grid except Shema matebia which is 2.5km
d. In the case of Shema matebia mill site, the estimated power generation potential is 15.5kw, the number of households is 200, and the population density is scatted. Considering this, it will not be feasible to implement MHP for this site.

5. Conclusion

Use of micro hydro power plants is a promising way to deliver energy for off grid communities in developing countries. However, an assessment on technical and socio economic aspects are very essential before constructing and implementing it. Conducting the right assessment by participating the stake holders is crucial in identifying practical solutions and solving the energy problems of remote areas.

There are a number of existing and former mill sites in the study area. A technical and socio economic assessment of mill sites in North Shoa zone of the Amhara regional state, Ethiopia has been done for micro hydro power generation. All the sites except teter wuha and wedera wenz, found to be technically, socially, and economically feasible. No water flows through Wedera wenz mill site.

Through this study, out of the 14 mill sites investigated, 12 of them can generate above 5kw with 80% efficiency during the dry season, which predicts a tremendous potential to harvest energy using micro hydro power plants and power the communities.

The study also shows that the Existing as well as former mill sites in North Shoa zone, were mostly located in mountainous regions which offers an interesting opportunity for micro hydropower generation for meeting the energy demand of the villages at least 5km far from the main grid.

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