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Assessment of Hydropower Potential of Selected Rivers in North Shoa Zone, Amhara Regional State, Ethiopia

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Abstract Energy generated by the force of water in hydropower can provide a more sustainable, non-polluting alternative to fossil fuels, along with other renewable sources of energy, such as wind, solar and tidal power, bio-energy and geothermal energy. Small-scalehydroelectricity in Ethiopia is well suited for “off-grid” rural electricity applications. Micro-hydropower which is hydro energy in a ‘small’ scale provides electricity to small communities by converting hydro energy into electrical energy. The purpose of this paper is to assess the micro-hydroelectric potential of different rivers in North Shoa Zone, Ethiopia, especially rural communities, 5Km far from main grid. From the 22 woreda towns found in north shoa zone only 9 of them with 11 rivers were assessed. Based on the head and flow rate measurements all the studied rivers have the potential to generate electric power, with the result ranges between 5.51 kW to 52.19 kW. These results were estimated for 80% hydropower generation, which are more than 5kW. Therefore, all of the assessed river sites are sufficient for micro-hydro power generation with through study on proper site location and socio-economic aspects.

Keywords: *micro-hydropower, hydropower potential, renewable energy, head, flow rate*

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1. Introduction

Energy is one of the most fundamental elements in the world and it is the critical factor for the economic development of one country. Micro Hydropower (from hydro meaning water and micro meaning small scale) refers to electrical energy that comes from the force of moving water used to power a household or small village [1]. One major driver of energy demand is population, its rapid increase coupled with industrialization in this century brought about a huge energy demand [2,3]. According to [2], the total world consumption of marketed energy is projected to increase by 57% for the period from 2004 to 2030; this means that much of the world’s energy is currently produced and consumed in such a way that the level of consumption cannot be sustained, if technology remains constant and overall quantities of energy do not increase substantially. For many centuries, water is a resource that has been exploited for various purposes. Hydropower is the leading source of renewable energy, providing more than 97% of all electricity generated by renewable sources [2].

The micro hydropower project can be developed economically by the simple design of turbines, generators and civil works. Micro-hydropower systems use the energy in flowing water to produce electricity or mechanical energy. Although there are several ways to harness the moving water to produce energy, run of the river systems, which do not require large storage reservoirs, are often used for micro-hydro, and sometimes for small-scale hydro, projects. For run-of-the-river hydro projects, a portion of a river’s water is diverted to a channel, pipeline, or pressurized pipeline (penstock) that delivers it to a waterwheel or turbine [4]. It is derived from the falling water, either from rivers and streams flowing downhill along the river course due to the force of gravity. Hydropower is a renewable energy source where power is derived from the energy of water moving from higher to lower elevations. It is a proven, mature, predictable and typically price competitive technology. Hydropower has among the best conversion efficiencies of all known energy sources (about 90% efficiency, water to the wire). It requires a relatively high initial investment but has a long lifespan with very low operation and maintenance costs [5]. According to World Energy Council (2004), “hydropower potential of a river is the theoretical possibility, capability, potential or tendency for power to be generated from that river”, it is regarded as the inherent ability of a river to generate electricity if favoured with the required factors [5].

Micro hydro systems can be regarded as a renewable energy source resulting from the natural hydrological cycle, it is by some considered sustainable due to the lack of impoundment of water and assumed negligible environmental impact [6]. The best geographical areas for micro-hydropower systems are those where there are steep rivers, streams, creeks or springs flowing year-round, such as in hilly areas with high year-round rainfall. To measure the water flow rate (discharge), several methods are available [7], of which include Container/bucket method, Weir method and Float/velocity area method [6]. The technology was initially used in Himalayan villages in the form of water wheels to provide motive power to run devices like grinders [8]. Hydropower has various degrees of 'smallness'. To date, there is still no internationally agreed definition of 'small' hydro [8,9,10]. Micro-hydro-turbines have gained a rapid growth in the power generation field, especially in rural areas, as their power is needed to feed both base load and peak demand requirements of grid supply [11]. Micro-hydro power generation efficiency is generally in the range of 60-80% [12].

Then micro hydropower plants are defined as having a generation capacity ranges from 5KW to 100KW [13]. Water heads of 2 meters can be suitable to generate power efficiently with proper implementation of advanced technology. The energy problems in remote and hilly areas exist due to the uneconomical planning of the grid network [13,14]. Micro-hydropower provides low-cost solution for these remote sites. It provides a good solution for energy problems in remote and hilly areas where the extension of grid system is comparatively uneconomical [15].

Table 1 shows the classification of the hydropower system based on the generated power output.

Table 1. Classification of hydropower by size [16]

S/N	Classification	Rated Power	Consumer
1	Large- hydro	>100 MW	usually feeding into a large electricity grid
2	Medium-hydro	15 - 100 MW	usually feeding a grid
3	Small-hydro	1 - 15 MW	usually feeding into a grid
4	Mini-hydro	100 kW - 1MW	either stand-alone schemes or more often feeding into the grid
5	Micro-hydro	5kW -100 kW	usually provided power for a small community or rural industry in remote areas away from the grid
6	Pico-hydro	< 5kW	

Ethiopia has an abundance of water and its geographical situation is suitable to implement hydroelectric power plants. Micro Hydropower (MHP) was one of the earliest small-scale renewable energy technologies and is still an important source of energy today. Now a day, the Ethiopian government has been engaged to build many hydropower generations in different scales. Almost 85% of the population of Ethiopia lives in a rural area, where is no access to electricity. The power supply in the country is very low compared to its population growth. As a result of this, rural area populations are relying on kerosene and traditional fuelwood to meet their energy demand. In addition, Ethiopia has taken an interest in an increased distributed generation, either as a good method in places of lacking infrastructure (places with no power lines) or just as an addition to the existing power supply. The study was performed in North Shoa Zone, Amhara Regional State, Ethiopia. This region has many rivers for small hydropower development. In the region around this zone, the topographical conditions and the existence of permanent water springs provide the suitability to install small hydroelectric power plant on the rivers. At the present conditions, it is not economical to address the power supply to the rural areas. Thus, self-containing (off-grid) renewable energy or climate proof system types are preferable and micro hydropower was effective. Therefore, the aim of this research is to evaluate the hydropower potential of the Rivers based on the basic information of the river discharge (flow), head, and the cross-section for Micro Hydropower development for rural communities that are 5-kilometerfar from the main grid.

2. Methodology

2.1. Study Area and Its Design

The study area was in North Shoa Zone, Amhara Regional State of Ethiopia of different woredas. In this zone, there are 22 woredas and some of the woredas are near to the main grid and in some woredas, the rivers are not available. Therefore, from 22 woreda's9 woredas of 11 rivers were assessed. The research was carried out by taking input data collection using observation, interview, questionnaires, and measurements. By reviewing different kinds of literature, standards were identified to apply for this study.

2.2. Data Analysis

2.2.1. Technical Aspect Assessment and Analysis

The main aim of the study was to investigate micro-hydro power generation potentials of different rivers of this zone. One of the most important activities in potential identification is to measure water discharge and head that could be utilized for micro-hydropower generation. In addition, the catchment areas of these rivers were estimated. The estimated lengths of these rivers have more than 25 Km.

Table 2. Characteristics of investigated watercourses in the study areas

No	Woreda	Name of river	Catchment area [km^2]
1	Qawat	Biremesh	420
2	Basonawrna	Beresa river	1000
3	Angolena enatera	Chacha river	670
4	Efratanagidm	Jema	1250
5	Ankober	Ayrara	560
		Jema	800
		Meskiwuha (shemamatebia)	500
6	Hager Mariam	Jambere	630
7	Tarmaber	Setatie (Tikuriti)	350
		Teterwuha	250
8	Menz mama	Moferwuha river	650
9	Menzgera	Shayiwenz	880

2.2.2. Head, Flow Rate Measurement

Head is a water pressure which is created by the difference in elevation between the water intake and the turbine. Field measurements of gross head are usually carried out using surveying techniques. The precision required in the measurement will impose the methods to be employed. The heads were measured by using hand GPS at the lower and higher locations of the rivers.

From different methods [6] the float method (also known as the cross-sectional method) is used to measure the flow rate for larger streams and rivers. Therefore, measurement of river flow rate is done by floating methods and the potential of hydropower generated determined using the following equation.

For a larger stream, an initial estimate can be made by multiplying the speed of the water by the cross-sectional area. The speed is measured by timing a float along a measured distance of stream (preferably straight and free from obstacles) and multiplying by a factor taken as 0.8 (straight smooth channel).

The hydropower generation potential for a river flow at 80% efficiency is computed by;

$$P = \eta \rho g Q H \tag{1}$$

Where:
P = Power estimate (Watts)
ρ = Density of the water (1000 kg/m^3)
η =Efficiency, 0.8
Q = the water flow rate (m^3/s)
g = the gravitational constant (9.81 m/s^2)
H= head measured.

3. Discussion on Results

The data collected from the measurements were presented in tables and mathematically analysed. The characteristics and potentials were presented in Table 3 and Table 4.

Table 3. Characteristics of the proposed hydropower plant on the selected rivers in the North Shoa Zone

No	Woreda	Name of river or water mills	Head measurement (m)	Flow Rate measurement (m^3/sec)	Descriptions
1	Qawat	Biremesh	21	0.062	Very far from the main grid
2	Basonawrna	Beresa river	15-19	0.193	Around 7km far from main gird
3	Angolena enatera	Chacha river	4	0.384	10km far from chacha town and main grid
4	Efratanagidm	Jema	6-9	0.214	Now, the river is used for irrigation and very far from the main grid
5	Ankober	Ayrara	19	0.275	Very far from the main grid
		Jema	14-25	0.266	Very far from main grid
		Meskiwuha (shemamatebia)	11-14	0.2052	Very far from main grid
6	Hager Mariam	Jambere	13-21	0.27	Very far from the main grid and there is a mill that working
7	Tarmaber	Setatie (Tikuriti)	10-17	0.219	Very far from the main grid and it is taken recent mill site, not working
8	Menz mama	Moferwuha river	13-15	0.047	Very far from the main grid and there is a mill that working
9	Menzgera	Shayiwenz	17-26	0.20	Very far from the main grid and it is taken recent mill site, not working

Table 4. Estimations of hydropower potentials of the selected rivers

No.	Woreda	Name of river	Head measurement (m)	Flow Rate measurement (m^3/sec)	Hydraulic power generation (kW) (ρgQH)	Hydraulic power generation (kW) (at 80% efficiency)
1	Qawat	Biremesh	21	0.062	12.91	10.33
2	Basonawrna	Beresa river	15-19	0.193	28.39-35.50	22.71 – 28.4
3	Angolena enatera	Chacha river	4	0.384	14.13	11.30
4	Efratanagidm	Jema	6-9	0.214	13.11-18.36	10.49-14.69
5	Ankober	Ayrara	19	0.275	50.58	40.46
		Jema	14-25	0.266	35.88-65.24	28.70-52.19
		Meskiwuha (shemamatebia)	11-14	0.2052	22.65-27.68	18.12-22.14
6	Hager Mariam	Jambere	13-21	0.27	33.11-56.29	26.49 - 45.03
7	Tarmaber	Setatie (Tikuriti)	10-17	0.219	21.49-37.60	17.19 - 30.077
8	Menz mama	Moferwuha river	13-15	0.047	6.06-6.89	4.85 – 5.51
9	Menzgera	Shayiwenz	17-26	0.20	33.45-50.13	26.76 – 40.103

Table 3 above shows the measurement of the head, flow rate and their characteristics relative to main grid available near to communities. This study mainly focused on rivers continuously flowing throughout the year and measured at different time, where the averages were taken. The heads were measured at different locations and the minimum and maximum elevations were included in the ranges. There are also different options to increase the head by diversion work or by creating access for some of these rivers in mountainous parts.

In Table 4 shown at 80% efficiency the hydropower generation of the assessed rivers were estimated. All except Mofer Wuha River in Menz Mama woreda the hydropower potential estimated were more than 10 kW. The hydropower potentials were estimated using eq. (1) and according to this determination, the requirement fulfils [16]. In addition for more hydropower potential, the result will be increased by increasing the heads of these rivers.

4. Conclusion

In this study carried out a thorough investigation and analysis through different rivers in North Shoa Zone. Based on the head measurement, flow rate and with catchment area the hydropower generation potential has been identified on these rivers. It has also been concluded that the hydrological parameters of most of the identified locations for possible hydropower plants for these rivers allow power generation ranging from 5 kW to 48 KW at the maximum head measured. Amongst the rivers under analysis in this paper, the greatest potential for hydropower generation obtained at Jema, Jambere, Ayirara, and ShayiWenz Rivers they have 52.19 KW, 45.03 KW, 40.46 KW, and 40.10 KW respectively. The minimum hydropower potential was registered in Mofer Wuha River with 5.51 KW at maximum elevations.

Generally, all of the identified or assessed rivers are sufficient for micro-hydro power generation for rural areas. This assessment was done at the natural ground elevation, in order to increase the hydropower potential, it is possible to minor diversion to be applied.

Therefore, the main aim of the study was to assess the hydropower potential of different rivers in North Shoa Zone of rural communities especially far from 5 Km off-grid, which is Ethiopian policy and directives show this option and the results were met with minimum micro-hydropower potential which is 5KW power generation. But, in order to assess the exact hydropower parameters of all the rivers needs to carry out a thorough study on proper site location and socio-economic aspects investigations.

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